JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Tracing the Evaluation of Graph Theory and Cryptology: A Bibliometric and Network-Based Study

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Abstract : This study shows comprehensive bibliometric analysis of research trends, collaborations, networks, patterns, and developments in the intersecting areas of graph theory and cryptology. By examining publications published since 1991 and available on the web of science, key contributions, influential articles, collaborative networks, and emerging topics in these interdisciplinary areas shown. The analysis used the free and open-source software of Vos viewer software. The study finds the increasing importance of graph theoretical approach in cryptographic systems, especially security, cryptographic protocols, and blockchain technologies. Citation metrics, keyword co-occurrence, and authorship pattern used to reveal the intellectual structure and evaluation of the field. Our findings show valuable insight into current research directions and potential future developments and draw attention to the expanding use of graph-based cryptology by academics and practitioners.

***IndexTerms* - Graph theory, cryptology, bibliometric analysis, trends, Vos viewer.**

I. INTRODUCTION

With the use and application of graph theory, a sub-branch of discrete mathematics, in computer science, the areas of use of graph theory have diversified. On the other hand, graph theory and cryptology are two developing fields of computer science and mathematics. Graph theory, with its basic structures such as vertices and edges, provides powerful tools modeling complex relationships and networks. Cryptology, which includes both cryptography and cryptanalysis, focuses on securing information and communication through mathematical techniques. In recent years, the joint consideration of security issues in information and communication has increasingly increased the importance of cryptology and graph theory. Common topics of graph theory and cryptology are secure communication protocols, blockchain technologies, and applications such as post-quantum cryptography. Graphs used to be secure networks, model trust relationships, analyze cryptographic algorithms, and design secure topologies that are resistant to attacks. As Shinde, Kumar, and Patil (2024) and Talebi&Rashmanlou (2019) have said, these areas are network security, social media analysis, bio informatics, and optimization challenges. Bibliometric analysis gives valuable insights into the evolution and current state of this interdisciplinary research field (Dayap et al., 2025). Bibliometrics yields statistical analysis of scientific publications to reveal trends, influential works, collaboration networks, and thematic developments. With this method, we aim to find the most active researchers, institutions, and countries in this field, as well as key topics and emerging trends.

This study provides a data-driven overview of academic outputs related to graph theory and cryptology. By mapping the scientific landscape, we aim to inform future research directions and develop a deeper understanding of how these two fields interact and evolve over time. In this study, the developments of the research, collaborations, and citation networks were examined separately using the Web of Science database and the Vos viewer open-source software with bibliometric analysis. It focuses on dominance in graph theory between 1991 and 2025. By highlighting significant research, highly cited works, and prevailing thematic patterns, the goal is to show the development of this subfield.

The current study examines the development of graph theory and cryptology research from 1991 to 2025 using bibliometric techniques. The study employs co-authorship, co-citation, and keyword association techniques to show important contributors, often cited works, and thematic trends after analyzing Web of Science data using the keywords "graph theory" and "cryptology." This study aims to determine the direction in which research is directed, how research is clustered, and to provide an overview by visualizing collaborations between authors, organizations, and countries. The results could provide insightful information for researchers looking to investigate new developments in the multidisciplinary applications of dominance theory. Furthermore, the findings of this study will have a worldwide influence on the literature on graph theory and cryptology and could serve as baseline data for future researchers.

II METHODS

2. 1 Data Collections

The Web of Science (WoS) serves as an authoritative and trusted source for extracting peer-reviewed scientific literature, making it an ideal candidate for this bibliometric analysis. Using Boolean logic, we refined our search to the title, abstract, and keywords fields with ("graph theory") and "cryptology" to gather literature that intersects these two domains. The data collected limited to the period of 1991 to 2025 and only included English journal articles. The comprehensive search yielded 7,324 collected journal articles, which extracted as of May 8, 2025, ensuring that the analysis conducted was unspeaking research output until that date. The bibliographic information provided in the dataset was foundational to conduct citation analysis and trend evaluation and included, document title, authors, author keywords, year of publication, source title (journal name), author affiliations, citation count, and other relevant metadata. The dataset preprocessed and analyzed with bibliometric tools after exported in *.txt file* format. This first analysis of publication trends, collaboration networks, and thematic networks relies heavily on the structured data in the exported files.

2.2 Data Analysis

This study uses bibliometric analysis to find trends in research on graph theory and cryptology. A total of 351 studies related to graph theory and cryptology conducted on the Web of Science have reviewed. The main aims of this analysis are to check research output trends over the years, identify important contributing authors, and examine which countries the research is from.

Through the analysis, publication and citation trends, authors and their contributions to the field, global participation, countries where teamwork and collaborations made, and keywords used are determined to find how the research field has grown and how it has changed over time. VOS viewer 1.6.20 software used to analyze data, show networks, create and visualize bibliometric maps. The study also uses Web of Science tools to further examine trends and citation counts. These methods provide a complete look at research patterns, teamwork connections, and the intelligent structure of the field. It also provides directions on how the region is growing and where it can go next.

III RESULTS

3.1 Research Trends

Table 1 presents the distribution of the number of publications and citations from 1991 to 2015. The number of publications shows a steady increase until 2006, after which a significant upward trend is observed. This increase in the number of publications peaked around 2013-2014, followed by a slight decrease in 2015. Similarly, the number of citations follows a similar pattern, with a significant increase starting in 2006, reaching its peak in 2013–2014, and a slight decline in 2015. After 2010, the number of citations increased more significantly. A peak of approximately 340 citations seen in 2023.

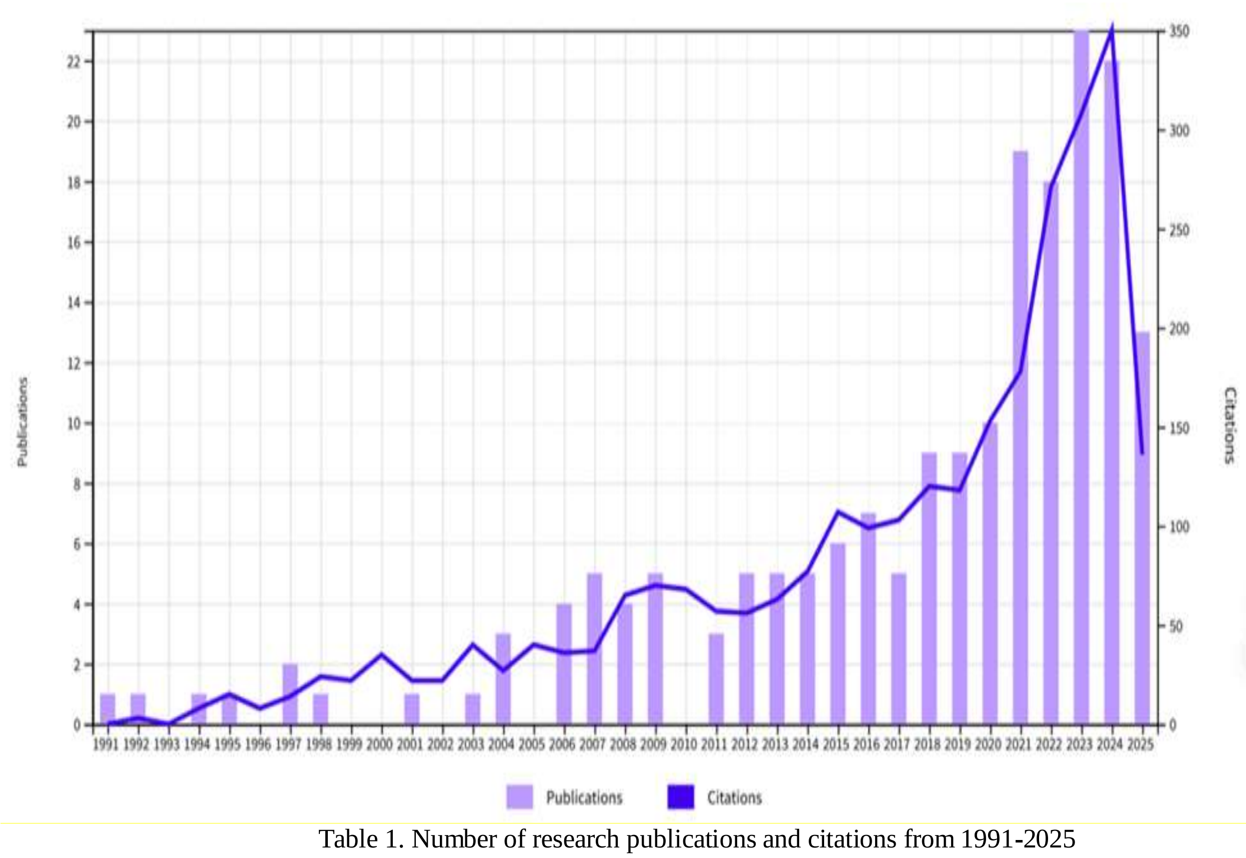

Table 1. Number of research publications and citations from 1991-2025

A sharp decline seen in 2025, again due to the incompleteness of the year. These data show that research activities and their impact have increased over the years, gaining momentum especially after 2006. It is observed that there have been significant increases in the number of publications and citations after 2020. As can be seen from the table, the number of publications peaked in 2022. Similarly, the number of citations follows this upward trend and reaches its peak around 2022. After this peak, there was a slight decrease seen in citations. It saw that as the number of publications increases; the citations tend to increase. Especially between 2019 and 2023, both metrics increase sharply, showing an increase in academic interest. 2020–2023 is a period of high activity and

impact in terms of both quantity (publications) and quality/recognition (citations). 2023 stands out as the most influential year so far, leading in both metrics. 2025 shows a sudden decrease, due to incomplete data collection or citation delay.
As a result, Table 1 shows an increase in academic interest in the subject. The reason for this may be the growth after 2015, technological advances or the increasing interest in the subject and global issues related to the importance of the field (e.g., climate change, artificial intelligence, pandemics). 351 studies on graph theory and cryptology were examined in Web of Science. (Table 2).

Table 2. Journals and number of publications in Web of Science that include studies on graph theory and cryptology

Mathematics Applied	66
Computer Science Theory Methods	61
Computer Science Information Systems	44
Mathematics	41
Engineering Electrical Electronic	37
Telecommunication	16
Computer Science Hardware Architecture	13
Computer Science Software Engineering	13
Physics Multidisciplinary	9
Computer Science Artificial Intelligence	8
Computer Science Interdisciplinary Applications	7
Mathematics Interdisciplinary Applications	7
Multidisciplinary Sciences	6
Automation Control Systems	3
Engineering Multidisciplinary	3
Operations Research Management Science	3
Optics	3
Physics Atomic Molecular Chemical	3
Engineering Mechanical	2
Astronomy Astrophysics	1
Computer Sciences Cybernetics	1
Criminology Penology	1
Education Educational Research	1

3.2.1 Publication Types

When the publications on the subjects of "graph theory" and "cryptology" at the Web of Science are examined, it is seen that there are publications including one hundred and forty-four articles, four review articles, two book chapters, forty-five conference proceedings, three early access publications, and two editorial articles. As a result, when this data are examined, the majority of the research in the field of graph theory and cryptology has been published in the form of articles and conference proceedings. While the high number of articles writes down that the research in these areas is comprehensive and detailed, the considerable number of conference proceedings shows that these studies are often presented and discussed at academic conferences. Other publication types such as review articles, book chapters, and editorial materials are less common but still exist and show a variety of publication formats in these research areas.

3.2 Leading Researchers

Table 3 illustrates the top researchers and numbers of articles in graph theory and cryptology, ranked of Web of Science index publications.

Table 3. Articles of Authors

Authors	**Articles**
Ustimenko, Vasyl	6
Ahmad, Ali	5
Mesnager, Sihem	4
Kristin Lauter	3
Ajeena, Ruma Kareem K.	3
Abdullah, Roslan Hasni	3
Wang, Hongyu	3
Yao, Bing	3
Cimato, Stelvio	2
Parker, Matthew	2
Priyadarsini, Ponnada	2
Cabello, Adan	2
Riera, Constanza	2

Tang, Yuansheng, …	2
Kim, Suhri;	1
Kushilevitz, Eyal	1
Krishnaa, Auparajita	1
Mrsic, Leo	1

3.3 Countries

The most cited authors' countries (Figure 1) are Spain 73 times, Norway 67 times, South Korea 61 times, Pakistan 60 times, India 43 times, Poland 41 times, Saudi Arabia 37 times, Malaysia27 times, England 20 times, Peoples R China 19 times, Iraq 16 times, Brazil 10 times, Slovakia 10 times, Albania 7 times,.

Figure 1**.** The most cited authors' countries

Cluster one include Check Republic, England, Iran, and Saudi Arabia. Cluster two includes India, Iraq, Pakistan, and South Korea. Third cluster include Albania, Brazil, Peoples R China, and Poland.

3.3.1 Leading Countries

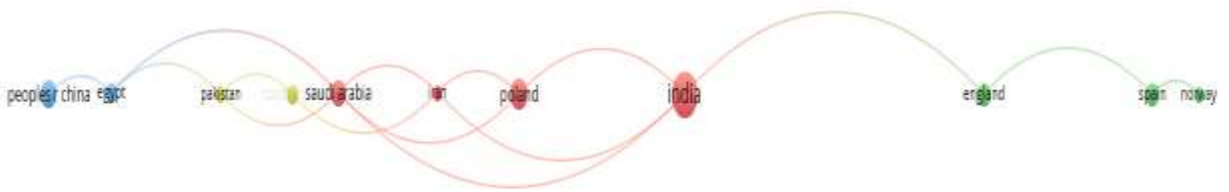

Figure 2. Leading Countries

Figure 2 shows the leading countries in "graph theory" and "cryptology" research by number of Web of Science publications. They were grouped into four groups. The first group includes India, Iran, Poland, Saudi Arabia. The second group includes England, Norway, and Spain. The third group includes Egypt, Peoples R China. The fourth group includes Pakistan and South Korea.

3.4 Leading Sources

Figure 3 shows the top publications and resources indexed in Web of Science.

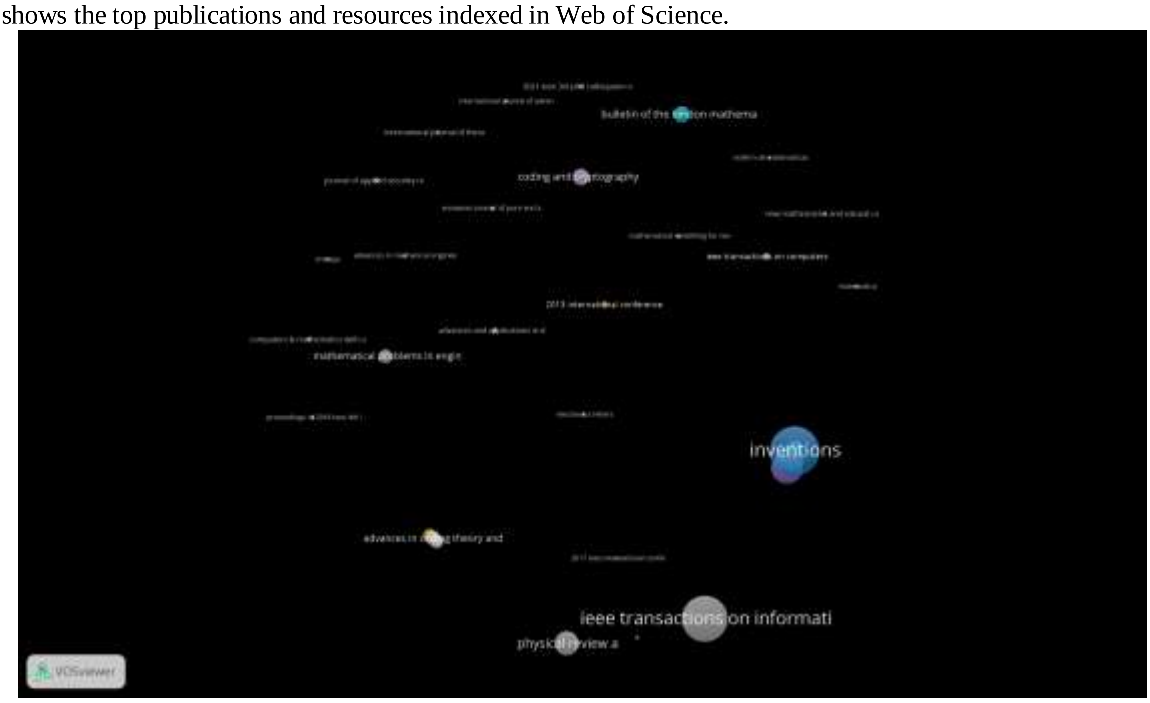

Figure 3. Leading citations of sources

Journal of Discrete Mathematics Science (8 documents and 25 citations), Algebra and Discrete Mathematics (2 documents and 10 citations), Journal of Mathematics (2 documents and 2 citations), Mathematics (2 documents and 32 citations), New Mathematics and Natural Computations (2 documents and 2 citations), Physical Review (2 documents and 22 citations), Advances in Coding

Theory and Cryptology (1 document and 11 citations), Acta Appleade Mathematica (1 document and 10 citations), Axioms (1document), Discreate Mathematics (1 document), Inventions (1 document and 60 citations).

3.5 Organizations

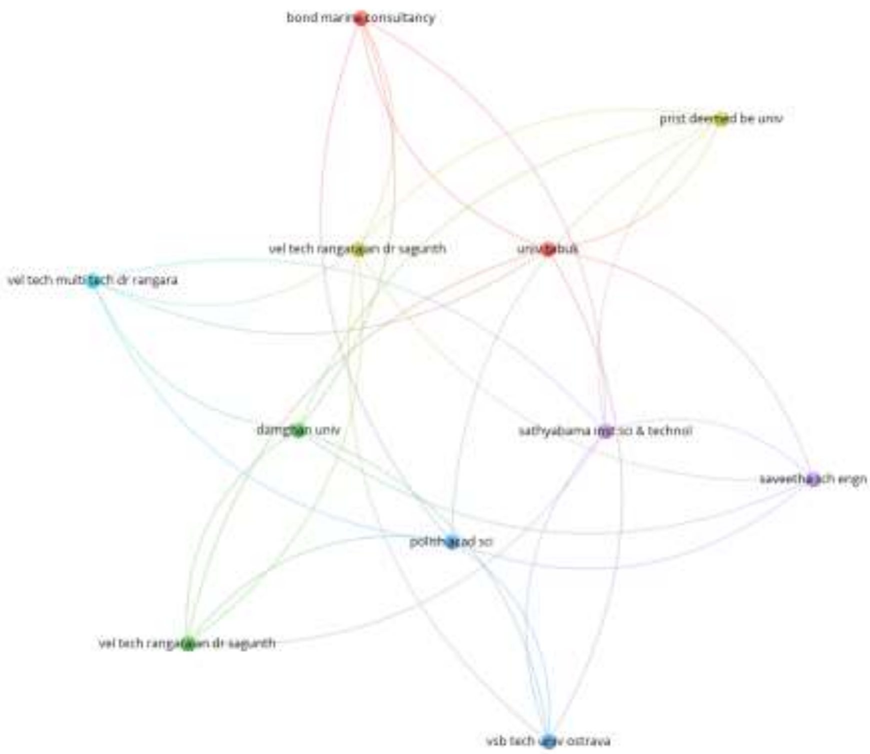

Figure 4. Connection of organizations

The institutional collaboration network shown in Figure 4 visualizes partnerships between universities and research institutions working on graph theory and cryptology. Each node represents an institution, and the connections (edges) indicate co-authorship or collaborative research. Vel Tech Rangarajan-Dr. Sagunthar College appears multiple times in different clusters, indicating a central and bridging role between different research communities. Bond Marine Consultancy and University of Tabuk are prominent nodes in the red cluster, indicating strong mutual collaboration and ties with other institutions. In Europe, the Polish Academy of Sciences and the VSB Technical University of Ostrava work together. On the other hand, academic communities in South Asia, the Middle East, and Europe cooperate through institutions such as "Damghan University", "Sathyabama Institute of Science and Technology" and "Saveetha School of Engineering". Overall, this network indicates a moderate level of international collaboration, with some institutions acting as hubs or bridges, which is important for promoting global scientific integration in graph theory and cryptology.

3.5 Co-authorship Network Analysis

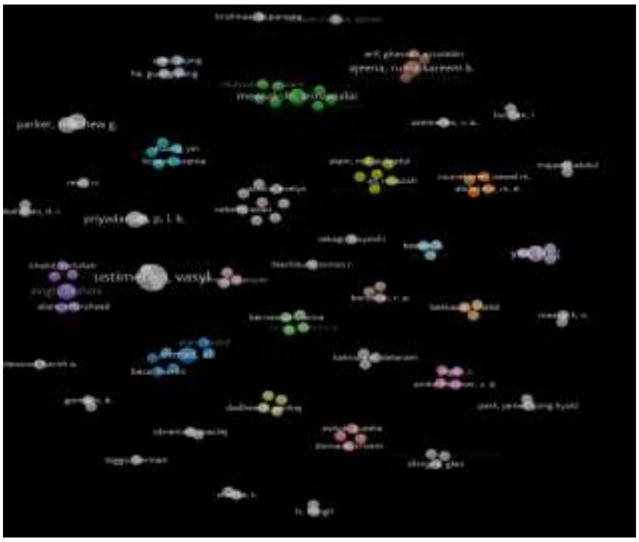

Figure 5a Authors

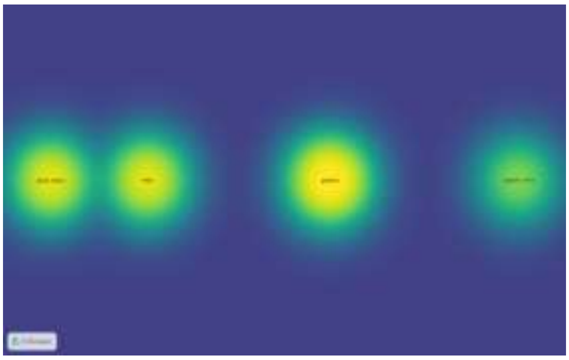

Figure 5b. Countries

Figure5c. Co-authors relationship

This is a network map where nodes (circles) represent institutions/universities and links (edges) represent collaboration/co-authorship relationships, whereby color and clustering groups as community of closely collaborating institutions (Figure 5a, 5b, 5c). Node size = volume of activity (e.g., number of documents, collaborations). There are strong connections between universities in Red Cluster: Central Node: Taibah University Benha University, Menoufia University, and Ain Shams University. This shows us, collaboration between Egyptian and Middle Eastern institutions. Universities in the Green Cluster are Northern Border University, Jahangirnagar University, and Fayoum University. Likewise, Taibah University seems to function as a central collaborator across regional boundaries (Middle East and South Asia/North Africa connectivity).

3.6 Keyword Co-Occurrence Analysis

Table 4 shows that the keyword Cryptography (18 times) is the most used keyword. This shows that the subject of cryptography is at the center of the study. The keyword Graph Theory (14 times) is the second most used keyword along with Cryptography. This shows that the mathematical foundations of cryptography discussed especially through graph theory.

Table 4. Keywords and occurrence of keywords

Keywords	Occurrence
Cryptography	18
Graph Theory	14
Encryption	7
Security	5
Graphs	4
Decryption	4
External graph theory	3
Multivariate cryptography	3
Information	2
Protocols	2
Post quantum cryptography	2
Boolean Functions	2
Key distribution protocol	2
Authentication	2
Cryptanalysis	2
Families	2
Schemes	2
Bipartite graph	2
Fuzzy graph	2

The keyword Encryption (7) is one of the basic components of cryptography. The keywords Security (5) and Graphs (4) indicate the emphasis on security and the widespread use of graphs. The keyword Decryption (4) emphasizes that the subject of decryption covered the keywords External graph theory, Multivariate cryptography, Post quantum cryptography indicates more specific and advanced topics. Boolean Functions, Key distribution protocol, Authentication, Cryptanalysis - Technical components and protocols in cryptography included here. On the other hand, the keywords Bipartite graph and Fuzzy graph are special subfields of Graph theory and show how these theoretical structures used in cryptography. This keyword analysis clearly shows that the study focuses on cryptography and graph theory. It seen that the topics extend to both basic and advanced techniques, proving a bridge between security and mathematical modeling.

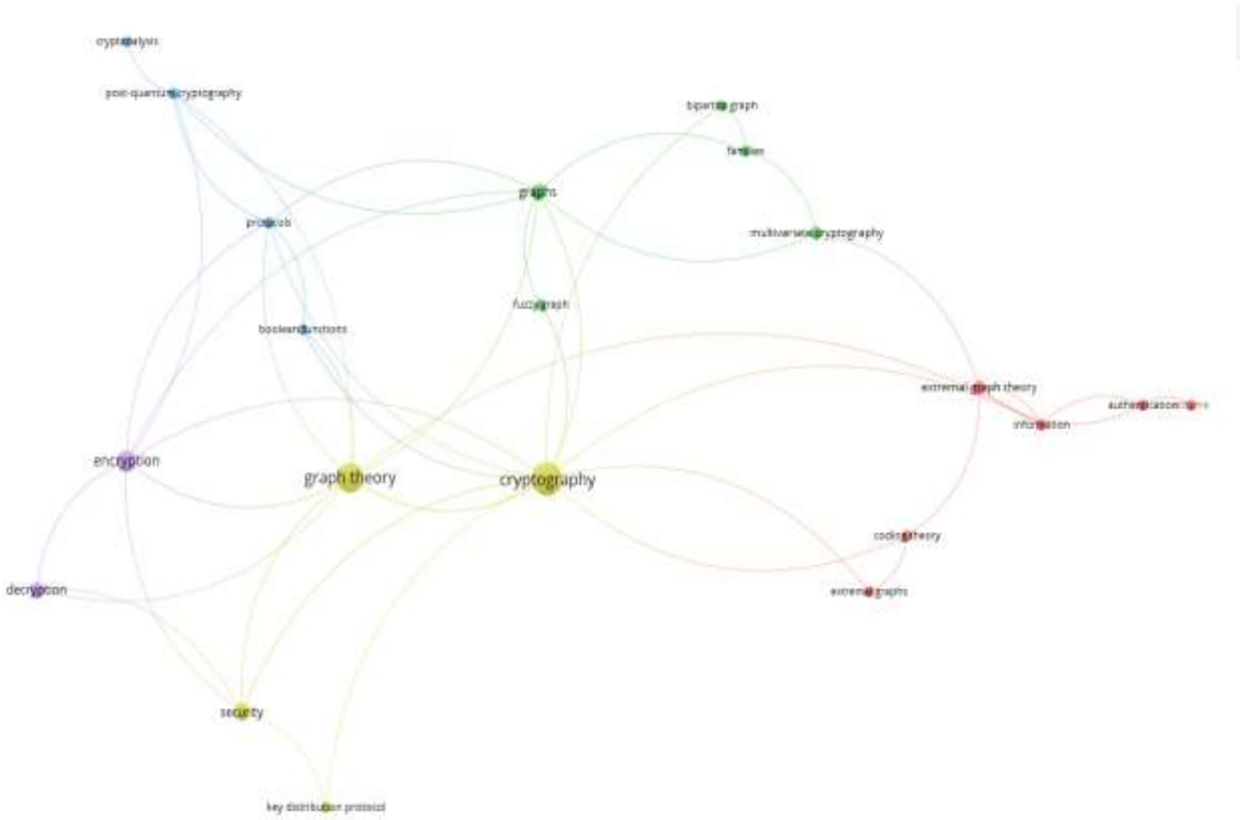

Figure 6a. Keywords

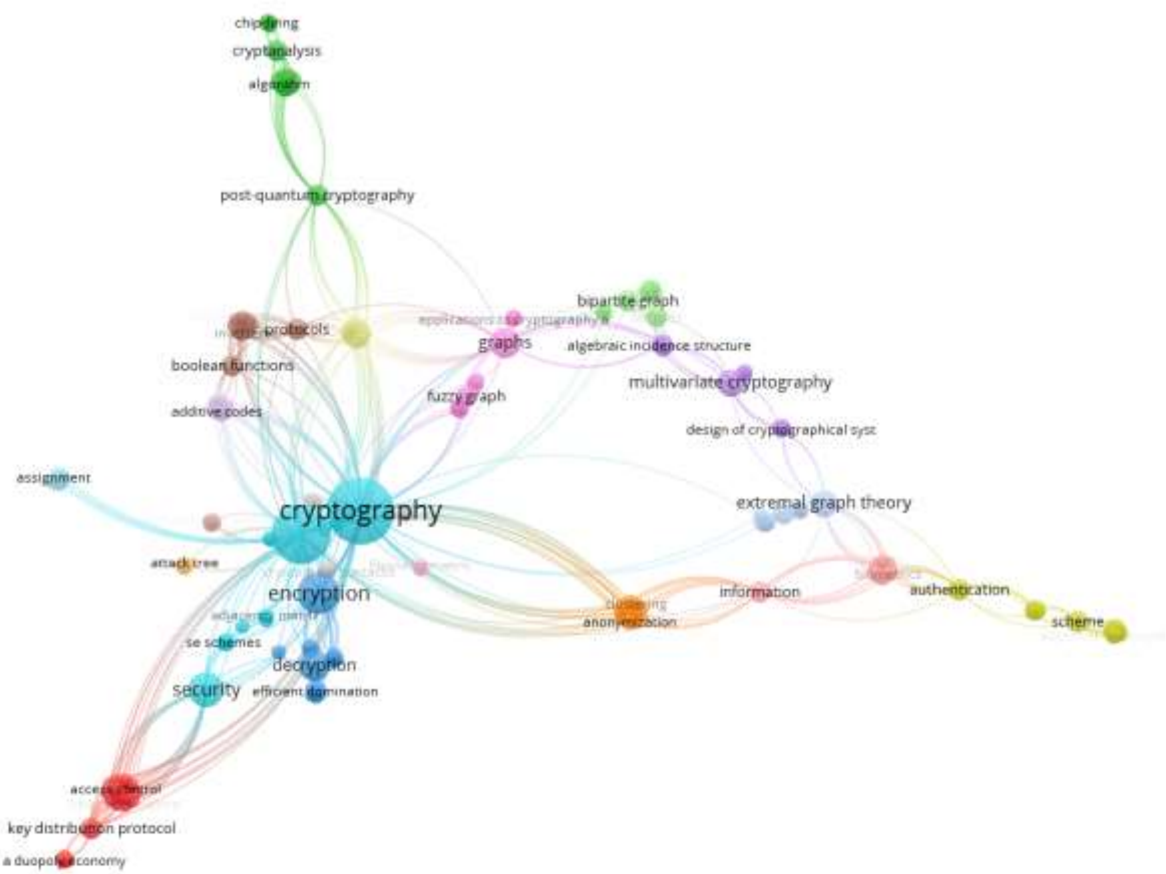

Figure 6b : Keywords

Similarly, the Vos viewer image (Figure 6a and Figure 6b) is a conceptual network graph that visually maps the core topics in cryptography and graph theory and how they interconnect. The size of the node and the thickness of the edges indicate its dominance and high connectivity in this network. Central Nodes: Cryptography and Graph Theory. These two are the core nodes, each connecting to various related topics and showing their significant role in this field of knowledge. The keywords in the "Yellow" cluster, which connected to the keyword Cryptography, are Security, Encryption/Decryption, Key Distribution Protocol, Graph Theory, Multivariate Cryptography, Post-Quantum Cryptography, Coding Theory, and Boolean Functions. The "Yellow Green" cluster, which connected to the keyword Graph Theory, is Fuzzy Graph, Binary Graph, Extreme Graph Theory, Graphs, Boolean Functions, and Protocols. The "Red" cluster, which connected to the keyword Extreme Graph Theory, is Information, Authentication Scheme, Coding Theory, and Extreme Graphs. In the Blue Set, which linked to the Post-Quantum Cryptography keyword, there are Cryptanalysis, Protocols, and Boolean Functions. In the Interdisciplinary Intersections keyword, there are Graph Theory ↔ Cryptography, which is the strongest conceptual bridge connecting the following topics: Security, Protocols, Boolean Functions, and Extreme Graph Theory. This figure suggests ongoing research themes in theoretical and applied cryptography that use graph-theoretic structures. For example: Extreme Graph Theory can support cryptographic structures with strict structural constraints. Boolean Functions and Protocols play a role in both cryptographic schemes and graph theory applications.

3.7. Citation Network Analysis

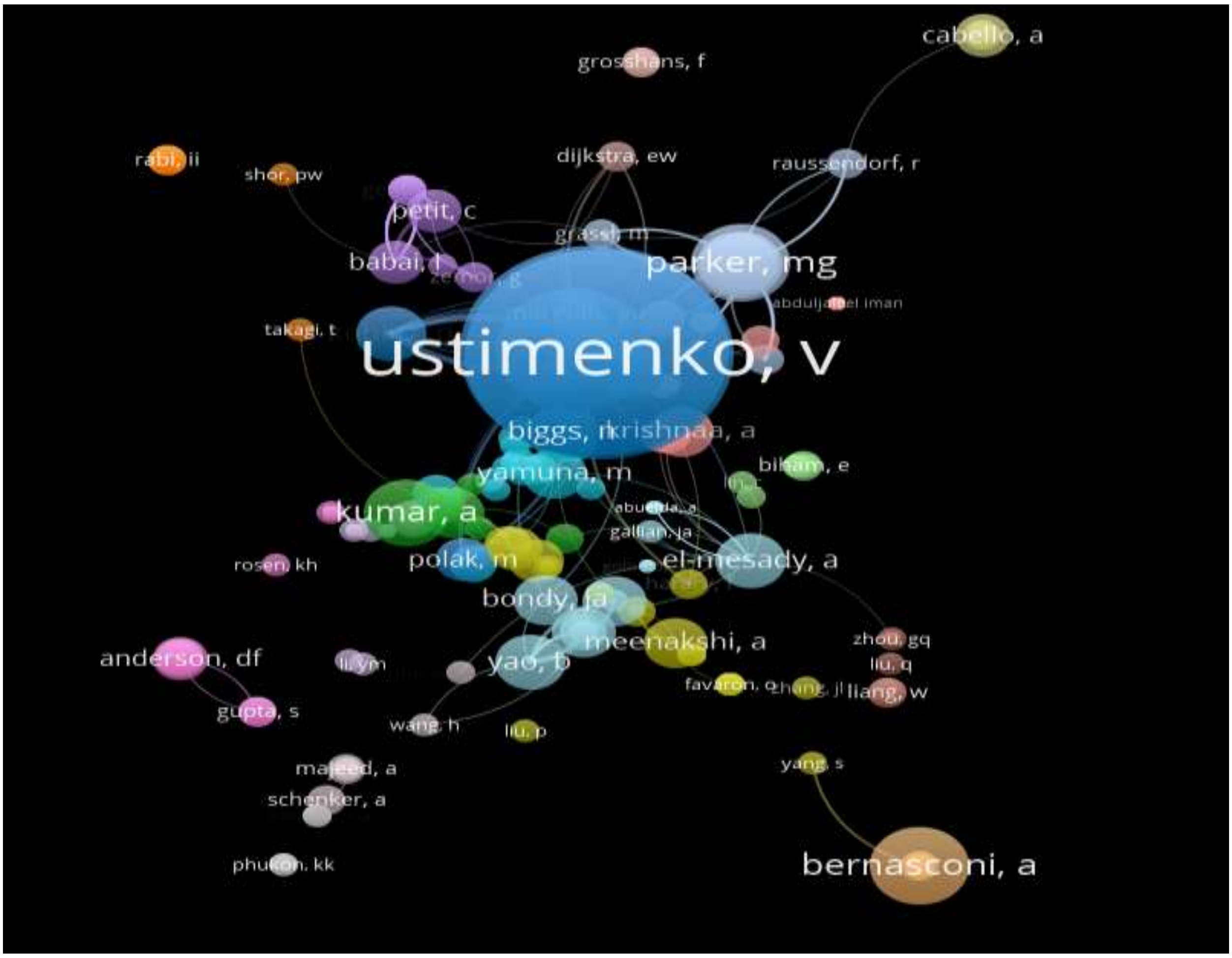

Figure 7. Citation network

The most cited authors given in Table 5.

Table 5. The most cited authors

Author	Citations
Usemenko, V.A.;	44
Usemenko, V	44
Lazebnik, F.	21
Parker, M.G.	11
Bernasconi, A.	11
Kumar, A.	9
Riera, C.	9
Danielsen, L.E.	8
Yao, B.	7
Arriatia, R.	7
Kobilts, N.	7
El-Mesady, A.	7
Biggs, N.	7
Yau, B.	7
Akram, M.	6
Bondy, J.A.	6
Meenakshi, A.	6

The Table 5shows that Usemenko, V.A. and Usemenko, V are the clear leaders of the list with a total of forty-four citations. Medium-level citation authors; Lazebnik, F. (21 citations). Parker, M.G. (11 citations) and Bernasconi, A. (11 citations) included in this group. These authors have a certain level of recognition and influence. Low-medium impact authors; Kumar, Riera, Danielsen, Yao, Arriatia, Kobilts, El-Mesady, Biggs, Yau and Akram, ... included in this group. This group shows that the authors are making contributions to their fields with their work but have not yet achieved widespread influence. The others: Bondy, J.A. and Meenakshi, A. and other authors are below this lower limit.

Figure 8 shows that ten authors of fist cluster: Agarwal, S., Dawood, H.A., Gupta, S., Li,Y.M., Liu, D., Liu, F.K., Liu, P., Madan, R., Pavan, M., Ren, X., Zeng, A. *Ten authors of second cluster*: El-Mesady, A., Zemor,G., Wang,Y.Y., Lempken, W., Kahrobaei, D., Takayasu, A., Singhi,N., Rabi, İ.İ., Moore, C. and Maglivears, S.S.

Figure 8. Cited authors.

Ten authors of third cluster: Kumar, A, Zadeh, L.A., Mordeson, J.N., Nobile, M.S., Takagi, T., Meenakshi, A., Khalid, S., Fuschs, C., Rashmanlou, H and Mathew, S. *The fourth cluster*: Koblitz, N., Biggs, N.L., Erdos, P., Lazebnik, F., Klisowski, M., Ustimenko, V., Ustimenko, V.A., Ustimenko, Vasyl. Romanczuk, U., and Bollabas, B. *The fith cluster*: Arristia, R., Bouchet, A., Danielsen, L.E., Grassl, M. Parker, M.G. and Riera,C. *The sixth cluster*: Yao, B and Yao, Bing.

IV. DISCUSSIONS

Graph theory, a fundamental field in discrete mathematics, has found significant application in computer science, especially in modeling complex systems and relationships. With its basic structures such as vertices and edges, graph theory offers versatile tools for networks and interactions in various domains. In parallel, cryptology, which encompasses both cryptography (the construction of secure systems) and cryptanalysis (the deconstruction of these systems), has appeared as a critical area for ensuring data privacy and secure communication in the digital age.

This study analyzes the bibliometric data analysis of the intersection between graph theory and cryptology using Web of Science data over the last twenty-five years. In total, 351 academic studies were analyzed in the study of the bibliometric analysis of the intersection between graph theory and cryptology. The findings reveal that the academic output in this field consists of indexed journal articles and conference proceedings, indicating that the field is both research intensive and actively discussed in academic forums. The smaller number of review articles, book chapters, and editorial materials suggests that while the field is growing, comprehensive syntheses and foundational texts are still relatively limited. Network analyses conducted to show patterns of collaboration across institutions. The co-authorship network indicates strong regional collaborations, particularly among Middle Eastern and South Asian institutions. “Taibah University”, “Benha University”, “Menoufia University”, “Ain Shams University”, and “Northern Border University” appear to be a central node facilitating cross-border collaborations, particularly among institutions. These insights suggest a growing regional interest and institutional investment in the intersection of graph theory and cryptology. Keyword analysis further reveals conceptual trends. The most frequent keywords are Cryptography (mentioned eighteen times) and Graph Theory (mentioned fourteen times), highlighting their centrality to the research landscape. Other significant terms include Encryption (7 times), Security, Key Distribution Protocol, Post-Quantum Cryptography, and Boolean Functions. These keywords, especially those in the yellow cluster of the Vos viewer conceptual map, highlight the ongoing integration of mathematical foundations with emerging security challenges, including those posed by quantum computing. The conceptual network diagrams (Figure a and Figure b) visually illustrate how the field is structured around these two core areas, cryptography, and graph theory—and each connects to subtopics. The density and connectivity of nodes suggests a highly interdisciplinary field with a stable but evolving core. In terms of academic impact, Usemenko, V.A. and Usemenko, V lead with the total highest number of citations (88), followed by medium-impact contributors such as Lazebnik (21), Parker (11), and Bernasconi (11). These authors are the key voices whose work shapes the discourse in the field. A larger group of authors, such as Kumar, Danielsen, Yao, and Akram, show modest citation counts, suggesting emerging or niche impact, while others, such as Bondy and Meenakshi, remain at the lower impact end, indicating recent contributions or limited reach.

V. CONCLUSION

Bibliometric findings suggest that the intersection of graph theory and cryptology is a vibrant, evolving field driven by both theoretical exploration and practical applications. The recurring presence of keywords such as encryption, key distribution, and security confirms the field’s importance in addressing modern cybersecurity challenges. Furthermore, the increasing focus on post-quantum cryptography reflects a forward-looking approach to emerging technological threats. This study provides a structured overview of research trends and institutional collaborations in this interdisciplinary field. Visualized co-authorship and keyword networks provide valuable insights for researchers looking to identify potential collaborators, emerging themes, and intellectual foundations. This research will serve as a reference point for future studies, stimulate global academic exchange, and contribute to the development of more secure and mathematically sound cryptographic systems.

Statement of Research and Publication Ethics

Research and publication ethics were observed in the study.

VI. ACKNOWLEDGEMENT

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