Research Trend in the Field of Metagenomics: A Scientometric Analysis

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ABSTRACT: *The study analyzed the scientific productivity of research output on metagenomics. The data for the study was retrieved from the Web of Science database from 2003 to 2024, using the keyword 'metagenomics'. The study results reveal that the average RGR of publications increased gradually from 0.82 to 1.77. Meanwhile, the publication's Doubling time (Dt) was 0.95, almost decreasing during the study period. The polynomial growth model fits well with the metagenomics research literature. Zhang Y (China) has the highest number (125) of research publications, followed by Delwart E with 122 (0.762%) publications and Wang Y with 119 (0.746%) publications. The National Natural Science Foundation (China) funded 1760 (10.99%) publications, followed by the United States Department of Health and Human Services, Washington, dedicated to enhancing the health and well-being of America has funded 1355(8.46%) publications.*

Keywords: Metagenomics, Scientometric, Relative Growth Rate, Doubling Time, Document Forms

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1. Introduction

Metagenomics pertains to investigating microorganisms within their indigenous habitat, encompassing the intricate microbial assemblages in which they commonly thrive. The scope of metagenomics research delves into the diversity of microorganisms, the composition of communities, genetic and evolutionary connections, functional behaviours, and interactions and associations with the surrounding milieu. Sequencing methodologies have progressed from conventional shotgun sequencing to the more sophisticated high-throughput, next-generation sequencing (NGS), and third-generation sequencing (TGS). NGS and TGS have demonstrated the efficacy of promptly identifying pathogenic microorganisms. Functional metagenomics plays a pivotal role in the exploration of novel bioactive compounds and functional genes derived from microorganisms and microbial byproducts (Zhang et al., 2021).

The current manuscript endeavors to explore the research trends in metagenomics utilizing scientometric analysis. Bibliometrics, Scientometrics, Webometrics, and Informatics in Library and Information Science can comprehend pertinent concepts from diverse knowledge domains. The primary objective of scientometric inquiry is to assess and quantify different attributes of scientific publications and the scientific domain. Scientometric analysis establishes standardized methodologies for comprehending authors' productivity patterns. (Rao & Neelameghan, 2014).

2. Need for the Study

The study of research trends in metagenomics through a scientometric analysis is pivotal due to the expeditious growth and unfolding nature of this interdisciplinary field, which combines biology, computational science, and environmental studies. With the escalation in next-generation sequencing technologies and bioinformatics tools, metagenomics has become an important approach to understanding complex microbial communities in various environments. However, the immensity of literature and the multidisciplinary nature of this field make it rigorous to track advancements, research gaps, and collaboration patterns. A scientometric analysis provides valuable insights into publication trends, prominent research, emerging areas, and global collaboration networks. Such a study is required to guide researchers, funding agencies, and policymakers to identify vital areas for investment, nurture creativity, and address gaps in the current body of knowledge.

Research Issues

The key issue of the study is to map the global landscape of metagenomics research by scientometrics comprehensively. The trend analysis and growth pattern in the metagenomics field provide insights into its development over time and the effect of metagenomics in the other fields of science, technology, and management. Explores the geographical distribution of contributions, highlighting the role of different countries in advancing metagenomics research, major academic and research institutions, prolific authors and institutions, and the most preferred source titles in metagenomics publications. Explores authorship patterns and their impact on citation metrics, providing a deeper understanding of the influence and collaboration dynamics within the metagenomics research community. It helps researchers, academics, and industries understand the impact of metagenomics research, make informed decisions, and adopt technologies in metagenomics research.

3. Data and Methods

The Web of Science database was searched for the research literature on ‘Metagenomics’. The keyword used for downloading the data was ‘metagenomics’, in the topic for the period 2003 to 2024. Eventually, retrieved 16,006 records. These records were downloaded on 3rd May 2024. The retrieved records were analyzed using an MS Excel sheet.

4. Results and Discussion

4.1. Growth of publications

Table 1. Year-wise distribution of publications

Publication Years	Record Count	% of 16,006
2003	1	0.006
2004	10	0.062
2005	40	0.25
2006	45	0.281
2007	78	0.487
2008	129	0.806
2009	153	0.956
2010	191	1.193
2011	255	1.593
2012	330	2.061
2013	435	2.717
2014	517	3.229
2015	683	4.266
2016	801	5.003
2017	971	6.065

2018	1203	7.515
2019	1383	8.639
2020	1615	10.088
2021	2085	13.024
2022	2267	14.161
2023	2184	13.642
2024	630	3.935

Growth refers to (Castellano & Ho, n.d.) an increase, expansion, or change over time indicates the performance over two or more time points. Table 1 shows the year-wise distribution of publications on metagenomics. The highest number (2267) of publications was found in 2022 because metagenomics has enabled a significant increase in discoveries related to the microbial world. The last number (01) of publications was found in 2003. The reason may be that the term 'metagenomics' was coined by Handlesman & others in 1998, and the publication was indexed in Web of Science in 2003. It reveals that the growth of literature has an exponential trend (as Illustrated in Figure 1 below).

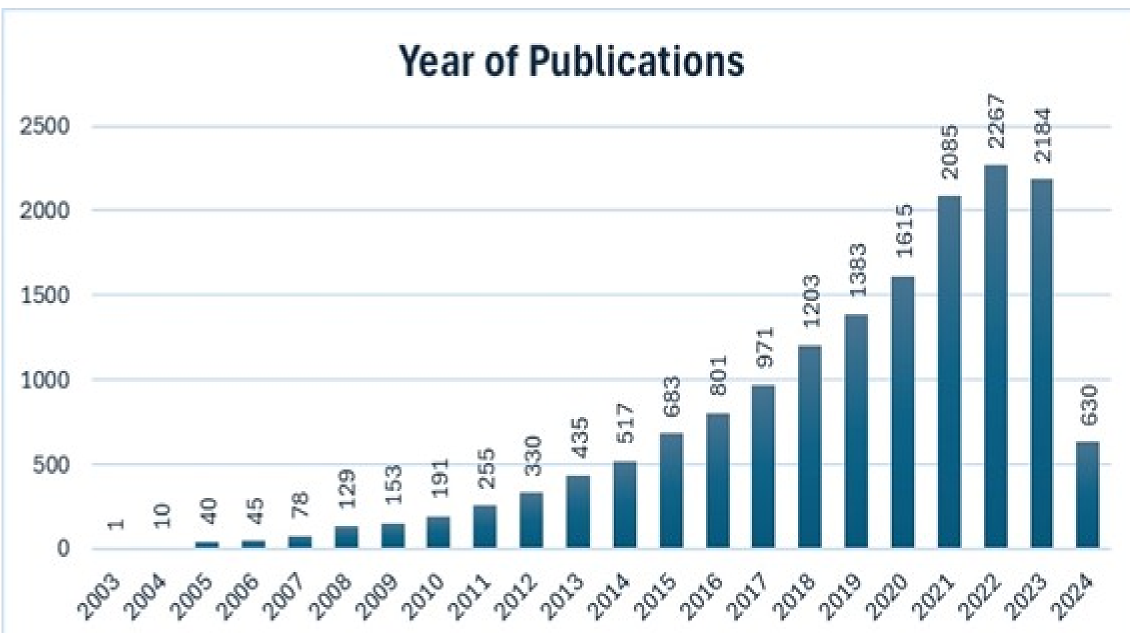

Figure 1. Year-wise distribution of publications

One of the most obvious features of science in recent years has been its rate of growth (Thirumagal & Sethukumari, 2013). Relative Growth Rate (RGR) means the increase in the number of publications per unit of time. Doubling time (Dt) is directly related to RGR and is defined as the time required for the publications to become two-fold of the existing amount. Table 2 depicts that the value of an average RGR of publications increased gradually from 0.82 to 1.77. The reason may be that metagenomic technologies complement or replace culture-based approaches and bypass some of their inherent limitations. So, a huge amount of research is undertaken, and hence, literature grows. Meanwhile, the value of the Doubling time (Dt) of the publications is 0.95, which almost decreased from the year 2004 to 2024; the reason may be many research literature may not appear in reputed journals and other communication channels and, therefore, not indexed in the database.

Table 2. Relative Growth Rate (RGR) and Doubling time (Dt)

S. No	Year	No. of Publications	% of Publications	Cumulative No. of Publications	% of Cumulative Publications	Log (p)1	Log (p)2	RGR(p)	Mean RGR	Dt(p)	Mean Dt(p)
1	2003	1	0.006	1	0.006		0.00	0.00			
2	2004	10	0.062	11	0.069	2.30	2.40	0.10		7.27	
3	2005	40	0.250	51	0.319	3.69	3.93	0.24		2.85	
4	2006	45	0.281	96	0.600	3.81	4.56	0.76		0.91	
5	2007	78	0.487	174	1.087	4.36	5.16	0.80		0.86	
6	2008	129	0.806	303	1.893	4.86	5.71	0.85	0.82	0.81	
7	2009	153	0.956	456	2.849	5.03	6.12	1.09		0.63	
8	2010	191	1.193	647	4.042	5.25	6.47	1.22		0.57	
9	2011	255	1.593	902	5.635	5.54	6.80	1.26		0.55	
10	2012	330	2.062	1232	7.697	5.80	7.12	1.32		0.53	
11	2013	435	2.718	1667	10.415	6.08	7.42	1.34		0.52	0.95
12	2014	517	3.230	2184	13.645	6.25	7.69	1.44		0.48	
13	2015	683	4.267	2867	17.912	6.53	7.96	1.43		0.48	
14	2016	801	5.004	3668	22.916	6.69	8.21	1.52		0.46	
15	2017	971	6.066	4639	28.983	6.88	8.44	1.56		0.44	
16	2018	1203	7.516	5842	36.499	7.09	8.67	1.58		0.44	
17	2019	1383	8.641	7225	45.139	7.23	8.89	1.65	1.77	0.42	
18	2020	1615	10.090	8840	55.229	7.39	9.09	1.70		0.41	
19	2021	2085	13.026	10925	68.256	7.64	9.30	1.66		0.42	
20	2022	2267	14.163	13192	82.419	7.73	9.49	1.76		0.39	
21	2023	2184	13.645	15376	96.064	7.69	9.64	1.95		0.36	
22	2024	630	3.936	16006	100.000	6.45	9.68	3.23		0.21	
Total		16006	100.000								

6.1.1. Growth Models

According to Gupta & Karisiddappa (2000), in the present age of information, the intense growth of scientific knowledge in the current science is one of the most apparent features, and it has instigated an unprecedented growth of information. Hence, there is a need to study the growth of scientific knowledge and its dynamics by applying different growth models as the best growth model elucidates the growth of knowledge with different scientific specialties. The present study applies the different growth models to determine the model that fits well with the growth of literature.

1. Linear model

Used only if the curve gives a linear tendency over the investigation or study period.

$$Y=a+bx$$

where *a = constant; b=constant and x=unit of time*

2. Exponential model

It begins slowly and then increases quickly over time.

$$Y = K + abx$$

where *a=constant; b=constant; K= Asymptote or the Upper limit and x=unit of time*

3. Polynomial model

Determines the relationship between an independent and dependent variable.

$$Y = ax2 + bx + c$$

where, a=constant; b=constant; c=constant and x=unit of time.

4. Logarithmic model

Used with data that extend more than decades but cannot be used to proper adverse data or data equal to zero

$$Y = c \ln x = b$$

where, *c = constant; b = constant; ln = natural logarithm function and x = unit of time.*

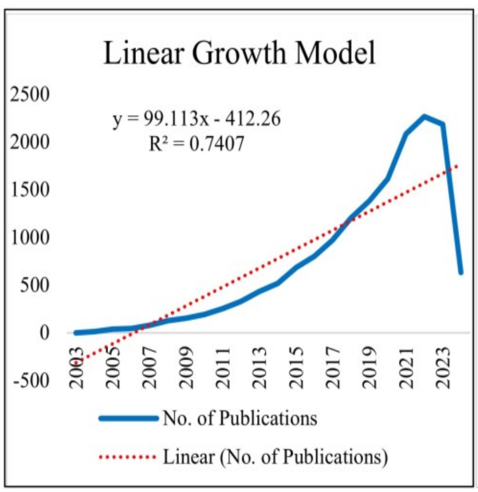

Figure 2. Linear model

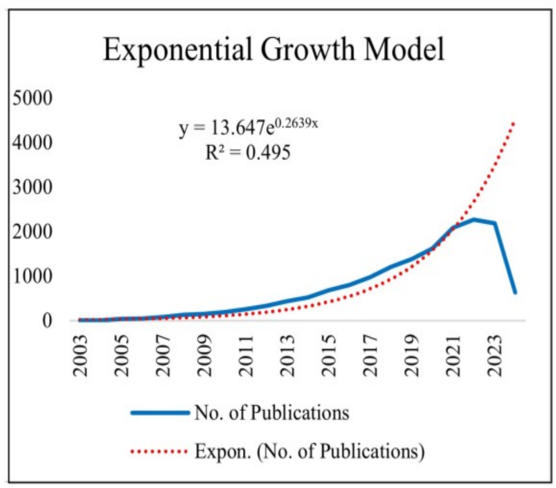

Figure 3. Exponential model

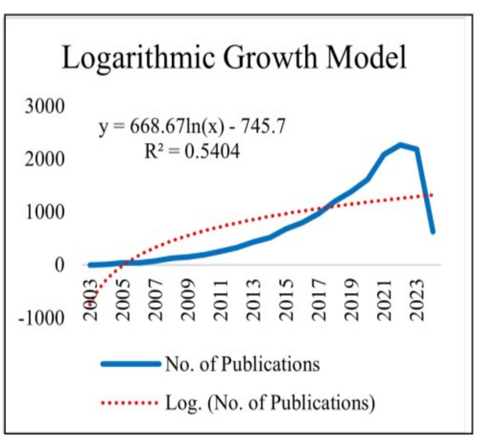

Figure 4. Logarithmic model

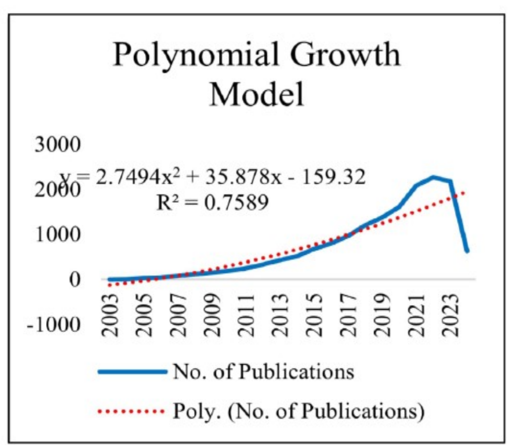

Figure 5. Polynomial model

Table 3. Level of growth models and their fitness

Growth models	R^2
Exponential	0.4950
Polynomial	0.7589
Linear	0.7407
Logarithmic	0.5404

Polynomial is one of the mathematical aspects that contain the number of terms, each term comprising a variable otherwise, variable elevated to power, and the same terms multiplied by a coefficient (Anandhalli, 2020). It is an empirical model frequently used in science, engineering, and social science for data analysis. It examines the association between the variables simply via well-known and understood assets.

The above table reveals that the polynomial growth model is the most appropriate growth model that is likely to fit. The result of the comparison between the growth curves shows that 'there is a steady growth of literature' because of the relationship between the dependent and independent variables.

6.2. Most Prolific Author(s)

Table 4. Top 10 Prolific authors in terms of research productivity

Sl No	Authors	Record Count	% of 16,009	No. of Citations	h-Index
1	Zhang Y China	125	0.781	742	12
2	Delwart ESan Francisco	122	0.762	33155	93
3	Wang Y (China)	119	0.743	7342	36
4	Wang JCalifornia	117	0.731	168083	205
5	Zhang W	95	0.593	5257	36
6	Li YEngland	88	0.55	3099	26
7	Li JCanada	86	0.537	835	13
8	Knight REngland	82	0.512	112	3
9	Zhang LHong Kong	82	0.512	103136	145
10	Banfield JFBerkley	81	0.506	92083	153
11	Liu Y	79	0.493	38287	94
12	Wang HCalifornia	77	0.481	30171	84
13	Deng XTChina	75	0.468	13583	55
14	Zhang TIllinosis	73	0.456	59432	117
15	Bork PGermany	71	0.444	379282	242
16	Chen YMichigan	69	0.431	8266	40
17	Ventura MItaly	67	0.419	35762	98
18	Yang YSAustralia	65	0.406	1487	21
19	Raoult DSenegal	62	0.387	235321	215
20	Milani CItaly	60	0.375	16742	64

Table 4 reveals the top 20 prolific authors in terms of scientific productivity. Zhang Y (Gansu Key Laboratory of Animal Generational Physiology and Reproductive Regulation, Lanzhou, China) has the highest number (125) of research publications followed by Delwart E with 122 (0.762%) publications and Wang Y with 119 (0.746%) publications. Milani C (University of Parma, Italy) secured the 20th position with 60(0.375%) publications. The University of Parma is ranked 596 in the best global universities. About several citations received, Peer Bork, Director of EMBL Heidelberg, (Germany) has ranked first with 379282 citations. EMBL is Europe's Life Sciences Laboratory, an intergovernmental organization with more than 110 independent research groups followed by Didier Roault of Senegal received 235321 citations. Didier Raoult was a French physician and microbiologist specializing in infectious diseases. Wang J of California positioned third with 168083 citations.

6.3. Institutional Affiliations

Table 5. Publication affiliations with top 20 institutions

Affiliations	Record Count	% of 16,006
University of California System, USA	929	5.803
Chinese Academy of Sciences,China	613	3.829
United States Department of Energy [DOE], USA	579	3.617
Centre National De La Recherche Scientifique [CNRS],France	530	3.311
INRAE (Research for Agriculture, Food and Environment, Paris)	352	2.199
Consejo Superior De Investigaciones Cientificas CSIC, France	331	2.068
Helmholtz Association, Germany	304	1.899
Harvard University, Massachusetts, USA	297	1.855
Universite Paris Cite, Paris	281	1.755
Institut National De La Sante Et De La Recherche Medicale [INSERM, France]	247	1.543
State University System of Florida, USA	246	1.537
University of Chinese Academy of Sciences [UCAS], China	235	1.468
University of California, San Diego, USA	231	1.443
Universite Paris-Saclay, Paris	224	1.399
University of Copenhagen, Denmark	222	1.387
Max Planck Society, Germany	217	1.355
University of California, San Francisco, USA	217	1.355
University of California, Berkeley, USA	214	1.337
Lawrence Berkeley National Laboratory, Berkeley, USA	212	1.324
United States Department of Agriculture [USDA], USA	200	1.249

(**Note:** the University of California System consists of campuses at Berkeley, San Diego, San Francisco)

Table 5 reveals that out of 16006 publications, 929 publications were from the University of California System, USA. The researchers at the University of California System built a futuristic computational resource and developed software tools to decipher the genetic code of communities of microbial life in the world's oceans. A total of 613 (3.82%) publications were affiliated with the Chinese Academy of Sciences (CAS). The Chinese Academy of Sciences is the linchpin of Chin's drive to explore and harness high technology and the natural sciences for the benefit of China and the world. Chinese Academy of Sciences brings together scientists and engineers from China and around the world to address both theoretical and applied problems. The United States Department of Energy is an executive department of the U.S. federal government that oversees U.S. national energy policy and energy production has affiliated with 579 (3.61%) publications and secured third position. The last position on the above table is occupied by the United States Department of Agriculture with 200 (1.24%) publications to its credit.

6.4. Financial Support for Research

Table 6. Top 10 Funding agencies across the globe

Name of the funding Agencies	Record Count	% of 16,006
National Natural Science Foundation of China [NSFC]	1760	10.994
United States Department of Health and Human Services, Washington	1355	8.464
National Institutes of Health [NIH, USA]	1318	8.233
National Science Foundation [NSF, USA]	1073	6.702
European Union [EU], Netherlands	762	4.76
Spanish Government, Spain	554	3.461
UK Research Innovation [UKRI], UK	551	3.442
United States Department of Energy [DOE], USA	525	3.279
European Research Council [ERC], Brussels	313	1.955
Conselho Nacional De Desenvolvimento Cientifico E Tecnologico CNPQ, Brazil	280	1.749
NSF Directorate for Biological Sciences Bio, Alexandria	280	1.749
Natural Sciences and Engineering Research Council of Canada [NSERC], Canada	271	1.693
Biotechnology And Biological Sciences Research Council [BBSRC], Swindon, UK	268	1.674
German Research Foundation [DFG], Bonn, Germany	258	1.612
Agence Nationale De La Recherche [ANR], France	254	1.587
National Key Research and Development Program of China, China	248	1.549
Ministry of Education Culture Sports Science and Technology Japan	247	1.543
Coordenacao De Aperfeicoamento De Pessoal De Nivel Superior Capes, Brazil	239	1.493
Japan Society for The Promotion of Science, Japan	228	1.424
United States Department of Agriculture [USDA], USA	220	1.374

The data in Table 6 reveals that the National Natural Science Foundation of China is an organization directly affiliated with China's State Council for the management of the National Natural Science Fund for promoting and financing basic research and applied research, funded for 1760 (10.99%)publications followed by United States Department of Health Human Services, Washington, dedicated to enhancing the health and well-being of America has funded for 1355(8.46%) publications secured second position followed by The National Institutes of Health, USA the primary agency of the United States government responsible for biomedical and public health research has financed for 1318 (8.23%) publications.

6.5. Preferred Publication Sources

Table 7. Top 20 preferred channels for research communication

Sl No	Publication Titles	IF	Cite Score	Record Count	% of 16,006
1	Frontiers In Microbiology, Switzerland	4.0	7.7	1064	6.65
2	Microbiome, Cambridge University Press, England	13.8	24.8	378	2.36
3	PLOS One, California, USA	4.4	5.6	355	2.22
4	M-Systems, American Society for Microbiology, USA	5.10	7.8	314	1.96
5	Scientific Reports, Nature Portfolio	3.8	6.9	308	1.92

6	Science of the Total Environment, Elsevier, Netherlands	10.753	8.2	296	1.85
7	Microorganisms, MDPI, Switzerland	4.1	6.4	250	1.56
8	Applied And Environmental Microbiology, American Society for Microbiology, USA	3.9	7.8	247	1.54
9	ISME Journal, Nature Portfolio, Canda	10.8	20.4	235	1.47
10	Viruses Basel, MDPI, Switzerland	4.7	6.6	199	1.24
11	BMC Bioinformatics, Biomed Centre, UK	3.169	4.2	164	1.02
12	Environmental Microbiology, Wiley, USA	4.3	8.2	160	0.10
13	Water Research, Elsevier, Netherlands	13.400	18	158	0.99
14	BMC Genomics, UK	4.547	7.1	150	0.94
15	Bioinformatics, USA	4.4	5.7	149	0.93
16	PEERJ, UK	3.8	4.2	148	0.92
17	International Journal of Molecular Sciences, Switzerland	4.9	7.8	133	0.83
18	Microbiology Spectrum, USA	3.7	3.2	131	0.82
19	Frontiers In Cellular and Infection Microbiology, Switzerland	4.6	7.9	129	0.81
20	FEMS Microbiology Ecology, UK	3.5	7.5	126	0.79

Journals are a major carrier of research productivity. The data depicted in Table 7 shows the journals chosen by the scientists to publish research findings. Frontiers In Microbiology, (Switzerland) is the most preferred journal that advances microbes play in solving problems such as healthcare, food security, and environmental issues such as climate change. The journal produced 1054 publications followed by Microbiome (Cambridge University Press, England) produced 378 publications. PLOS One, California, (USA) ranked third with 355 publications. PLOS ONE is one of the journals, which advance science for the benefit of society. FEMS Microbiology Ecology is one of the seven FEMS, peer-reviewed scientific journals, which cover every aspect of microbial ecology produced 125 publications.

6.6. Cross-national Analysis of Publications

Table 8. Geographical distribution of publications

Position	Countries/Regions	Record Count	% of 16,006
1	USA	5260	32.86
2	Peoples R China	3446	21.52
3	Germany	1289	8.05
4	France	1133	7.08
5	England	1069	6.68
6	Spain	882	5.51
7	Canada	845	5.28
8	Italy	838	5.23
9	India	833	5.20

10	Australia	774	4.83
11	Netherlands	586	3.66
12	Brazil	575	3.59
13	Japan	478	2.99
14	Denmark	475	2.97
15	Sweden	410	2.56
16	Switzerland	389	2.43
17	South Korea	384	2.40

Table 8 reveals that the USA has the highest number (5260) of publications with a share of 32.58% of publications. This may be because of a well-established funding system for scientific research like the financial support received from NIH, NSF, and various other organizations. Further, the USA established world-class research institutions, universities, and research laboratories equipped with the latest technology and facilities which is required to conduct metagenomics research by scientists. Moreover, the USA has a strong tradition of collaboration with other countries of the world and a rich diversity of ecosystems. Peoples R. China is in second place with 3446 (21.52%) publications. This may be because of significantly increased investment in research and development over the past decades led to the development of research infrastructure and the establishment of research institutions in different disciplines including metagenomics. Moreover, China has prioritized biotechnology and genomics as key areas of research and its scientists frequently collaborate with international scientists which led to high-quality publications. Germany also produced a good number (1289) of publications positioned third. The reason may be, that Germany is known for its well-established research universities and institutions that provide excellent facilities to scientists for research on metagenomics. It supports research by providing substantial funds and also Germany has a strong collaborative network, leading to high-quality research productivity that contributes significantly to the existing knowledge. 833 (5.20%) of publications have originated from India, which stands in the 9th position. The attributed factors are, that metagenomics is a niche field, where funding and infrastructure available is not extensive. Metagenomics is a relatively new field, so India's focus may still be growing. In developing countries like India, priorities often align with immediate societal and economic needs, not nascent fields of research like metagenomics.

6.7. Key Areas of Research

Table 9. Sub-fields of research

Research Areas	Record Count	% of 16,009
Microbiology	5216	32.58
Biotechnology -Applied Microbiology	2250	14.05
Environmental Sciences -Ecology	2164	13.52
Biochemistry- Molecular Biology	1874	11.71
Science Technology Other Topics	1447	9.04
Genetics Heredity	934	5.83
Virology	680	4.23
Engineering	622	3.88
Agriculture	570	3.56
Mathematical Computational-Biology	538	3.36
Infectious Diseases	503	3.142
Food Science Technology	494	3.09

Immunology	443	2.77
Chemistry	393	2.45
Life Sciences Biomedicine Other Topics	384	2.40
Marine Freshwater -Biology	383	2.39
Plant Sciences	332	2.07
Gastroenterology Hepatology	314	1.96
Pharmacology Pharmacy	308	1.92

Microbiology is the basis for all microbial studies and hence complements metagenomics because it provides a culture-independent approach to studying genetic and functional heterogeneity microorganisms in their natural habitats. As data depicted in the Tavle-9, microbiology is the main field of study with 5216 publications followed by biotechnology with 2250 publications. More than sixty percent (60.15%) of the publications belong to microbiology, biotechnology, and environmental sciences since they tend to be the basis for microbial studies.

Metagenomics has a comprehensive relationship with numerous scientific subfields. Microbiology and Applied Microbiology play a pivotal role, as metagenomics helps reveal the variety of microbial communities in environments, contributing to advancements in biotechnology and microbial applications. Environmental Sciences and Ecology use metagenomics to study ecosystems, pursuing microbial interactions and their impact on ecological health. In Biochemistry and Molecular Biology, metagenomics imparts apprehension into the functional roles of genes within microbial populations. Genetics and Heredity are also firmly associated, as metagenomics sorts out genetic diversity and evolutionary processes in microbial communities. Virology benefits from metagenomics for identifying novel viruses, while fields like Infectious Diseases, Immunology, and Gastroenterology leverage it to explore pathogen-host dynamics. Further. disciplines like Agriculture, Food Science, and Marine Biology utilize metagenomics for analyzing microbiomes in soils, food products, and aquatic ecosystems, respectively, demonstrating its interdisciplinary reach across life sciences

6.8. Document Types

Periodical Articles are often the main form of publication in academic and research fields because of the easy and effective

Table 10. Forms of Literature

Document Types	Record Count	% of 16,006
Periodical Articles	13239	82.71
Review Article	2059	12.86
Editorials	299	1.87
Meeting Abstract	275	1.72
Conference Papers	172	1.07
Early Access	157	0.98
Book Chapters	119	0.74
Correction	62	0.39
Letters	42	0.26
Data Paper	28	0.17
News Item	22	0.14
Retracted Publications	15	0.09
Software Review	4	0.02
Expression of Concern	6	0.04
Reprint	1	0.01

dissemination of research findings compared to other forms. Further articles are likely to focus on particular aspects of a topic. Generally, scientists prefer to communicate their research findings in article format, which provides avenues for discussion. Table 10 shows that 82.70% of the publications are in the form of periodical articles, followed by Review Articles (12.86%) and Editorials (1.87%).

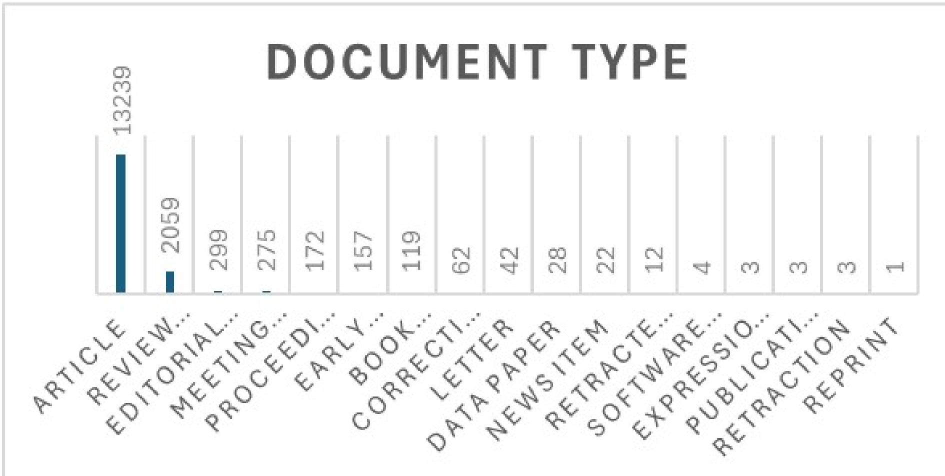

Figure 6. Document type

7. Conclusion

By analyzing the research publications on 'metagenomics', one can determine the pattern and trends and also the research output, which will assist the policymakers and stakeholders, especially information professionals and scientists to gauge the scientific knowledge and chalk out research and funding programs. The study also determined the Relative Growth Rate and Doubling time of the publications, which need of the hour to know how rapidly new field 'metagenomics' is emerging. About, the most preferred channels of communication by the scientists to disseminate the research findings, will assist in identifying core journals to consult and refer to when inquiries are made on the study subject It will be a regular feature to inform the scientists who are working on metagenomics in specific and other areas of research in general about the funding agencies that would support to conduct research in the areas of significance to the society in general and the country in particular.

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