J Data Sci. Info. Citation Studies., 2025; 4(1):107-114.
https://www.jcitation.org

Short Communication

Application of Bradford's Law and Leimkuhler Model: A Bibliometric Analysis of Bharathidasan University Research Publications (1989-2021)

S. Gunaseelan[1,*], M. Sumathi[2], C. Ranganathan[3]

[1]Department of Library, AJK College of Arts and Science (Autonomous), Affiliated to Bharathiar University, Coimbatore, Tamil Nadu, INDIA.
[2]Department of Library, Central Library, Shrimati Indira Gandhi College, Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, INDIA.
[3]Department of Library and Information Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu, INDIA.

ABSTRACT

This study examines the application of Bradford's Law of Scattering and the Leimkuhler model to the research publications of Bharathidasan University, Tiruchirappalli, Tamil Nadu, spanning the years 1989-2021. Bibliographic data for the analysis was sourced from the Web of Science database. A total of 5,658 research documents published across 1,171 journals were analyzed. The findings reveal an average annual growth rate of 400.53 publications. Core journals contributing significantly to the university's research output were identified, with Acta Crystallographica Section E-Crystallographic Communications ranked first, followed by Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscopy. Additionally, Bradford's Law of Scattering and the Leimkuhler model were employed to validate the dataset and assess its consistency with bibliometric distributions.

Keywords: Bibliometrics, Bradford's Scattering Law, Leimkuhler Model, Time series analysis, Bharathidasan University, India.

Correspondence:
Dr. S. Gunaseelan
Department of Library, AJK College of Arts and Science (Autonomous), Affiliated to Bharathiar University, Coimbatore-641105, Tamil Nadu, INDIA.
Email: gunaseelan2703@gmail.com

Received: 24-11-2024;
Revised: 16-01-2025;
Accepted: 02-04-2025.

INTRODUCTION

This research focuses on the scholarly output of Bharathidasan University, located in Tiruchirappalli, Tamil Nadu, India. Established in February 1982, the university was named after the revolutionary Tamil poet Bharathidasan (1891-1964), whose poetic vision inspired the institution's motto: "We will create a brave new world." Over the years, Bharathidasan University has grown into a prominent hub for higher education and research, comprising 16 schools, 37 departments, and 29 specialized centres. The university has 263 faculty members supporting 2,564 students and scholars across 151 academic programs. These include 40 postgraduate degrees such as M.A., M.Sc., and M. Tech., along with 31 M.Phil., 33 Ph.D., 19 postgraduate diploma, 11 diploma, and 10 certificate programs. The curriculum follows the Choice-Based Credit System (CBCS). Additionally, 457 support staff members contribute to the university's operations. Beyond regular programs, 15 undergraduate and 26 postgraduate courses are offered through distance education. The university affiliates 308 colleges across seven districts, including Tiruchirappalli, Thanjavur, and Pudukkottai.

Bradford's Law of Scattering, introduced by S. C. Bradford in 1934, provides insights into the distribution of journal articles within specific fields. This concept, elaborated in his 1948 book, Documentation, describes the pattern of journal distribution through the formula 1: n: n^2, where n represents a multiplier. This paper explores the applications of Bradford's Law of Scattering and the Leimkuhler model in Bharathidasan University's research publications from 1989 to 2021, highlighting the characteristics of its scholarly contributions.

LITERATURE REVIEW

Thamaraiselvi and Lakshmi (2022) examine the applications of Bradford's law of scattering and Leimkuhler's model on the research publications of Manonmaniam Sundaranar University, Tirunelveli, Tamil Nadu, from 1992 to 2020, after discovering that Bradford's distribution did not fit the dataset. They concluded that the Manonmaniam Sundaranar University research publication fit to the Leimkuhler model. Revathi and Ranganathan (2021) investigate the application of Bradford's law and the Leimkuhler model of neurochemistry research output during the 1989-2020 study periods. During the study period,

OPEN ACCESS
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DOI: 10.5530/jcitation.20250153

Publishing Partner : Manuscript Technomedia. [www.mstechnomedia.com]

a total of 3232 publications were published. Both Bradford's law and Leimkuhler's model were found to be incompatible with the data set. Satish Kumar and Senthilkumar (2018) investigated the application of Bradford's law of scattering on Astronomy and Astrophysics research publications in India from 1988 to 2017 and concluded that Bradford's distribution does not fit the data set. They then used the Leimkuhler model to test the data set, but were unable to prove it. Amsaveni (2016) analyzes the application of Bradford's Law of Scattering to the neural network literature published in India during 2001-2015. The data for this study has been taken from the Web of Science for a period of 15 years (2001-2015), and it yielded 5209 articles and 58249 citations. As far as the implication of Bradford's law is concerned, in a theoretical aspect, this law does not fit, but the alternatives, such as the Leimkuhler model, hold good for neural network literature.

OBJECTIVES

- The present study was undertaken with the following objectives:
- To identify the Annual Growth Rate.
- To assess the Time series analysis.
- To find the core journals of Bharathidasan University research output.
- To test the applicability of Bradford's Law of Scattering.
- To verify the Leimkuhler model.

METHODOLOGY

This study examined the applications of Bradford's law of scattering and the Leimkuhler model based on the research publications of Bharathidasan University, Tiruchirappalli, Tamil Nadu. The data was collected from the Web of Science database from 1989 to 2021. In total, 5658 publications were published during the study period. The data has been analyzed and classified in the Histcite software. Then the bibliographical details are converted to MS Excel format using tabulation and visualization.

Time Series analysis

The multivariate analysis technique namely multiple regression has been used by the researcher. The purpose of using this technique is to predict the number of publications for the near future.

The regression equation is:

$$y=a+bx$$

Where y is the dependent variable (number of publications),

X is an independent variable (the reference year),

a and b are constants.

Bradford's Law

Bradford's law scattering has been adopted to examine all the journal title contributing to a bibliography that focused on Bharathidasan University research by the scientists.

The journals are arranged on the order of decreasing productivity on a given subject. They are divided into nucleus of journals/ periodicals more particularly divided to the Bharathidasan University research and several groups or zones containing the same number of articles as the nucleus, where the number of periodicals in the nucleus and the succeeding zones will be as 1: n: $n^{2.}$ For describing the scattering phenomena, the following mathematical formula expressed as:

$$F(x)=a+b \log X$$

Where, F(x) is the cumulative number of references as contained in first 'x' most productive journals. 'a' and 'b' are constants.

Leimkuhler Model

Leimkuhler (1967) derived another mathematical formula for Bradford's law of distribution. Leimkuhler mathematical model shown as below:

$$k=(ey*Ym)1/p \text{ where } ey=1.781$$

k=Multiplier value,

P=Number of zones i.e. =3,

Ym=Number of publications in the first rank core journal,

T=Total number of journals.

r_o is calculated by using the below given formula:

Hence,

$$ro=T\ (k-1)/(kp-1)$$

DATA ANALYSIS AND INTERPRETATION

Annual Growth Rate

Table 1 shows the annual growth rate of publication on "Bharathidasan University" during the period (1989-2021). The maximum 50.00 AGR was recorded in the year of 1992 and the minimum -0.91 AGR recorded in 2019. The Annual Growth Rate (AGR) are calculated on the formula given by (Kumar and Kaliyaperumal, 2015) and mentioned as follows:

$$AGR = \frac{\mathbf{EndValue - FirstValue}}{\mathbf{FirstValue}} X\ 100$$

Time series analysis of Bharathidasan University Research Output

Table 2 indicates that the application of the formula of time series analysis and subsequently, from the results obtained separately for the years 2030, 2035 and 2040, it is found that the future trend

of growth in research literature output may take an increasing trend straight line equation is applied to arrive at estimates for future growth under the Time Series analysis during the years to come. The inference is that there is a positive growth level in research literature output in Bharathidasan University research output.

Straight Line equation

$$Yc=a+bX$$

X is the median of the year,

X^2 is the multiplication of X,

Where $XY=X^2-X$

Table 1: Annual Growth Rate of Bharathidasan University Research Output.

Sl. No.	Publication Year	Number of Publication	Cumulative No. of Publication	AGR
1	1989	22	22	
2	1990	22	44	0.00
3	1991	24	68	9.09
4	1992	36	104	50.00
5	1993	31	135	-13.89
6	1994	46	181	48.39
7	1995	42	223	-8.70
8	1996	57	280	35.71
9	1997	65	345	14.04
10	1998	63	408	-3.08
11	1999	56	464	-11.11
12	2000	55	519	-1.79
13	2001	65	584	18.18
14	2002	91	675	40.00
15	2003	123	798	35.16
16	2004	117	915	-4.88
17	2005	135	1050	15.38
18	2006	143	1193	5.93
19	2007	137	1330	-4.20
20	2008	135	1465	-1.46
21	2009	188	1653	39.26
22	2010	198	1851	5.32
23	2011	291	2142	46.97
24	2012	267	2409	-8.25
25	2013	280	2689	4.87
26	2014	320	3009	14.29
27	2015	317	3326	-0.94
28	2016	317	3643	0.00
29	2017	297	3940	-6.31
30	2018	330	4270	11.11
31	2019	327	4597	-0.91
32	2020	455	5052	39.14
33	2021	606	5658	33.19
				400.53

Table 2: Time series analysis of Bharathidasan University Research Output.

Sl. No.	Publication Year	Publications	X	X2	XY
1	1989	22	-16	256	-352
2	1990	22	-15	225	-330
3	1991	24	-14	196	-336
4	1992	36	-13	169	-468
5	1993	31	-12	144	-372
6	1994	46	-11	121	-506
7	1995	42	-10	100	-420
8	1996	57	-9	81	-513
9	1997	65	-8	64	-520
10	1998	63	-7	49	-441
11	1999	56	-6	36	-336
12	2000	55	-5	25	-275
13	2001	65	-4	16	-260
14	2002	91	-3	9	-273
15	2003	123	-2	4	-246
16	2004	117	-1	1	-117
17	2005	135	0	0	0
18	2006	143	1	1	143
19	2007	137	2	4	274
20	2008	135	3	9	405
21	2009	188	4	16	752
22	2010	198	5	25	990
23	2011	291	6	36	1746
24	2012	267	7	49	1869
25	2013	280	8	64	2240
26	2014	320	9	81	2880
27	2015	317	10	100	3170
28	2016	317	11	121	3487
29	2017	297	12	144	3564
30	2018	330	13	169	4290
31	2019	327	14	196	4578
32	2020	455	15	225	6825
33	2021	606	16	256	9696
Total		5658		2992	52674

Since ∑X=0

a=∑Y/N=5658/33=171.45; ∑XY/∑X2=52674/2992=17.61

Estimated literature in 2030 is when X=2030-2005=25

=171.45+(17.61*25)

=171.45+440.25

=611.7

Estimated literature in 2035 is when X=2035-2005=30

=171.45+(17.61*30)

=171.45+528.3

=699.75

Estimated literature in 2040 is when X=2040-2005=35

=171.45+(17.61*35)

=171.45+616.35

=787.8

Scattering of Articles in Different Journals

Table 3 lists the top twenty journals in different disciplines at Bharathidasan University's research publication. The cumulated publications for the study period revealed that the journal Acta Crystallographica, Section E-Crystallographic Communications, had the highest number of publications with 219 papers, which have received the highest cited reference (3330) with *h*-Index 15; followed by Spectrochimica Acta, Part A-Molecular and Biomolecular Spectroscopy, which had the next highest number of publications (107) and also received the next highest cited reference (3663) with 132 *h*-index. The highest *h*-index was 307 in Physical Review E. In the above analysis, Research Policy journal got the highest impact factor (8.025) with 43 publications and 144 *h*-index.

Application of Bradford's Law

Table 4 shows that the first 43 journals covered more than one-third of the articles published. The next 166 journals covered the next one-third of the published articles. The last 962 journals covered the last one-third of the articles. It is evident from the above ratio that the number of journals in each zone is not increasing geometrically. According to Bradford's distribution, the relationship between the zones is 1: n: n2, while the relationship in each zone in the present study is 43: 166: 962, which does not fit into Bradford's distribution.

Table 3: Journal wise Distribution of Bharathidasan University Research Output.

Name of the Journal	NP	NA	CR	*h*-Index	Impact Factor	Country of Origin
Acta Crystallographica Section E-Crystallographic Communications	219	961	3330	15	0.347	UK
Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscopy	107	392	3663	132	4.831	Netherlands
Current Science	100	261	1621	124	1.169	India
Acta Crystallographica Section C-Structural Chemistry	99	410	1837	19	1.184	UK
RSC Advances	90	440	4781	167	4.036	UK
Journal of Materials Science-Materials in Electronics	75	372	3367	80	2.779	USA
Physical Review E	74	243	3160	307	2.707	USA
Physics Letters A	58	157	1795	177	2.707	Netherlands
Journal of Molecular Structure	54	266	2592	110	3.841	Netherlands
International Journal of Bifurcation and Chaos	45	138	1480	107	2.450	Singapore
International Journal of Biological Macromolecules	43	206	2423	144	8.025	Netherlands
Tetrahedron Letters	42	123	1836	173	2.032	UK
Dalton Transactions	40	179	3447	193	4.569	UK
Marine Pollution Bulletin	39	228	2022	193	7.001	UK
Journal of Mathematical Physics	36	119	984	112	1.478	USA
Chaos	34	121	1512	115	3.741	USA
Environmental Science and Pollution Research	34	193	2085	132	5.190	Germany
Indian Journal of Chemistry Section B-Organic Chemistry Including Medicinal Chemistry	34	113	703	48	0.456	India
Microbial Pathogenesis	33	191	1710	80	3.848	USA
Scientific Reports	33	225	1788	242	4.996	UK

NP=Number of Publication, A=Number of Authors, CR=Citied Reference.

Table 4: Bradford's law Distribution.

Sl. No.	No. of Journals	No. of Articles	Total No. of Articles	Cumulative No. of Articles
1	1	218	218	218
2	1	104	104	322
3	1	98	98	420
4	1	87	87	507
5	2	73	146	653
6	1	58	58	711
7	1	56	56	767
8	1	54	54	821
9	1	46	46	867
10	1	42	42	909
11	1	41	41	950
12	1	39	39	989
13	1	38	38	1027
14	1	37	37	1064
15	2	33	66	1130
16	4	32	128	1258
17	1	31	31	1289
18	4	30	120	1409
19	1	28	28	1437
20	1	27	27	1464
21	1	25	25	1489
22	6	24	144	1633
23	2	23	46	1679
24	1	22	22	1701
25	5(43)	21	105	1806 (1728.33)
26	6	20	120	1926
27	3	19	57	1983
28	7	18	126	2109
29	6	17	102	2211
30	2	16	32	2243
31	4	15	60	2303
32	6	14	84	2387
33	11	13	143	2530
34	6	12	72	2602
35	11	11	121	2723
36	9	10	90	2813
37	17	9	153	2966
38	15	8	120	3086
39	29	7	203	3289
40	34(166)	6	204	3493 (3456.66)
41	39	5	195	3688
42	58	4	232	3920

Sl. No.	No. of Journals	No. of Articles	Total No. of Articles	Cumulative No. of Articles
43	109	3	327	4247
44	182	2	364	4611
45	574(962)	1	574	5185
Total	1171		5185	

Table 5: Bradford's Distribution of Journals in Various Zone Analysis.

Zone	No. of Journals	No. of Articles	Multiplier Factor
Z1	43	1806	
Z2	166	1687	3.86
Z3	962	1692	5.8
Total	1171	5185	4.83

Bradford's Distribution of Journals in various zone analysis

Bradford's law of verbal formulation calculated the multiplier by dividing the number of journals in a zone by the preceding zone's number of journals. The three zones contain one-third of the articles in each zone, which reduces the percentage of errors during the distribution of articles. There are 1806 publications that have been published in 43 journals; 1687 publications in 166 journals; and 1692 publications in 962 journals. According to Bradford's law formula of 1: n: n2, the current study is 43: 166: 962. Hence, 43 journals represent the nucleus zone, and the mean value of the multiplier is 4.83.

Application of Leimkuhler Model

According to this law there are small numbers of a journal which produce maximum number of publications constitute of core journals.

A=5185 (Total number of articles)

Y_m=218 (Number of items in most productive source)

T=1171 (Total Number of Journals)

P=3 (Number of Zone in which the data has to be divided)

Y_0=A/P =5185/3=1728.33=1728 (approx.)

K=$(1.781 \text{ X } 5185)^{1/3}$=$(9234.48)^{1/3}$=20.97=21 (approx.)

$r_{0=}$T (K-1) / (K^P-1)=1171(21-1)/ (21^3-1)=2.52

a=Y_0/logK=1728/log 20.97=1728/1.32=1309.09

b=K-1/$r_{0=}$20.97-1/2.52=6.84

$r_{1=}$2.52*20.97=52.84

$r_{2=}$2.52*$(20.97)^2$=1108.15

Hence, 2.52: 2.52*20.97: 2.52*$(20.97)^2$ =1163.5

Percentage error=1163.5-1171/1171*100=-0.6404%

Hence, it can be found that the above calculation that the percentage error is in negative value (-0.6404%), the present data set fits to the Leimkuhler model.

MAJOR FINDINGS

The major findings of the study are as follows:

The maximum 50.00 Annual growth rate was recorded in the year of 1992 and the minimum -0.91 Annual growth rate recorded in 2019.

Time series analysis estimated literature year 2030=611.7, followed by the year 2035= 699.75 and the year 2040=787.8.

The Journal Acta Crystallographica, Section E-Crystallographic Communications, had the highest number of publications with 219 papers, which have received the highest cited reference (3330) with *h*-Index 15; the highest *h*-index was 307 in Physical Review E. In the above analysis, Research Policy got the highest impact factor (8.025) with 43 publications and 144 *h*-index points.

According to Bradford's distribution, the relationship between the zones is 1: n: n^2, while the relationship in each zone in the present study is 43: 166: 962, which does not fit into Bradford's distribution.

Leimkuhler's model was applied to verify Bradford's law of scattering. It can be found that the Leimkuhler model is fit for the present data.

CONCLUSION

The study provides the result of the annual growth rate and time series analysis for the research publications of Bharathidasan University, Tiruchirappalli, Tamil Nadu. It also revealed that the application of Bradford's law, the Leimkuhler model, concluded that Bradford's law does not fit the data set, whereas the Leimkuhler model verified that Bradford's law fits the data set. The inference is that there is a positive growth level in research literature output in Bharathidasan University research output.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

NP: Number of Publication; **NA:** Number of Authors; **CR:** Citied Reference; **AGR:** Annul Growth Rate.

REFERENCES

Amsaveni, N. (2016). Assessment of Bradford law's of scattering to Neural Network literature through bibliometric study. International Journal of Next Generation Library and Technologies, 2(3), 1-15.

BM Gupta, G., M Surulinathi, S., Nabeesab Mamdapur, G. M., Bansal, J., & Bansal, M. (2021). Impact of COVID-19 on children and adults: A bibliometric assessment of global publications. International Journal of Medicine and Public Health, 11(3), 139-145. https://doi.org/10.5530/ijmedph.2021.3.25

Borgohain, D. J., Verma, M. K., Nazim, M., & Sarkar, M. (2021). Application of Bradford's law of scattering and Leimkuhler model to information science literature. COLLNET Journal of Scientometrics and Information Management, 15(1), 197-212. https://doi.org/10.1080/09737766.2021.1943041

Bradford, S. C. (1934). Sources of information on specific subjects. Engineering, 137, 85-86.

Brookes, B. C. (1969). Bradford's law and the bibliography of science. Nature, 224(5223), 953-956. https://doi.org/10.1038/224953a0

Das, A. K., Das, G., & Dutta, B. (2022). A selective review of bibliometric studies on Indian physics and astronomy research output. Annals of Library and Information Studies, 68(2), 152-169. https://doi.org/10.56042/alis.v68i2.41198

Gayan, M. A., & Singh, S. (2019). Citation analysis of doctoral theses of physics: A bibliometrics study. Library Philosophy and Practice (e-Journal). https://digitalcommons.unl.edu/libphilprac/2903.

Kappi, M. (2019). Bibliometric analysis of the research output of Kuvempu University's publication in ISI Web of Science during 1990-2019. Library Philosophy and Practice (e-Journal). https://digitalcommons.unl.edu/libphilprac/3632.

Leimkuhler, F. F. (1967). The Bradford distribution. Journal of Documentation, 23(3), 197-207. https://doi.org/10.1108/eb026430

M, V., & Kolle, S. R. (2017). Indian Contribution in Information Science and Library Science Research during 1991-2015: A Bibliometric Analysis. DESIDOC Journal of Library and Information Technology, 37(6), 387. https://doi.org/10.14429/djlit.37.11005

Official Website of Bharathidasan University, Tiruchirappalli, Tamil Nadu, India. (n.d.). https://www.bdu.ac.in/

Ram, S. (2017). Indian Contribution to breast cancer research: A bibliometric analysis. Annals of Library and Information Studies, 64, 99-105.

Revathi, R., & Ranganathan, R. (2021). Applications of Bradford's law of scattering and Leimkuhler model to neurochemistry research output at global level. Webology, 18(1), 1034-1041.

Santha kumar, R., & Kaliyaperumal, K. (2015). A scientometric analysis of mobile technology publications. Scientometrics, 105(2), 921-939. https://doi.org/10.1007/s11192-015-1710-7

Sathishkumar, R., & Senthilkumar, R. (2018). Application of Bradford's law of scattering on research publication in Astronomy & Astrophysics of India. Library Philosophy and Practice (e-Journal). https://digitalcommons.unl.edu/libphilprac/2037.

Savanur, K. P. (2019). Application of Bradford's law of scattering to the economics literature of India and China: A comparative study. Asian Journal of Information Science and Technology, 9(1), 1-7. https://doi.org/10.51983/ajist-2019.9.1.2610

Sudhier, K. G. (2010). Bradford's law of Scattering revisited: A study based on the references in doctoral theses in the area of Physics. COLLNET Journal of Scientometrics and Information Management, 4(2), 35-47. https://doi.org/10.1080/09737766.2010.10700891

Sudhier, k. G. (2020). Application of Bradford's law of scattering to the physics literature: A study of doctoral theses citations at the Indian Institute of Science. DESIDOC Journal of Library and Information Technology, 30(2), 3-14.

Thamaraiselvi, M., & Lakshmi, S. (2022). Application of Bradford's law and Leimkuhler model on the research publications of Manonmaniam Sundaranar University during 1992-2020. Kelpro Bulletin, 26(1), 92-102.

Verma, M. K., & Shukla, R. (2019). Mapping the research trends on information literacy of selected countries during 2008-2017: A Scientometric analysis. DESIDOC Journal of Library and Information Technology, 39(3), 125-130. https://doi.org/10.14429/djlit.39.3.14007

Vickery, B. C. (1948). Bradford's law of scattering. Journal of Documentation, 4(3), 198-203. https://doi.org/10.1108/eb026133

Goffman, W., & Warren, K. S. (1969). Dispersion of papers among journals based on a mathematical analysis of two diverse medical literatures. Nature, 221(5187), 1205-1207. https://doi.org/10.1038/2211205a0

Wardikar, V. (2013). Application of Bradford's law of scattering to the literature of library and information science: A study of doctoral theses citations submitted to the universities of Maharashtra, India. Library Philosophy and Practice. https://digitalcommons.unl.edu/libphilprac/1054.

Cite this article: Gunaseelan S, Sumathi M, Ranganathan C. Application of Bradford's Law and Leimkuhler Model: A Bibliometric Analysis of Bharathidasan University Research Publications (1989-2021). Journal of Data Science, Informetrics, and Citation Studies. 2025;4(1):107-14.