Application of Bradford\\\'s Law of Scattering to the Light Pollution Literature in India

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Abstract

The present study deals with the application of Bradford's law of scattering for the literature related to 'Light Pollution' research in India during the period of 2005 to 2024 as reflected in the Web of Science. A total of 1831 articles related to Light Pollution research published and are scattered in 526 journals during the study period. The study analysed the year wise publication productivity, ranking of most preferred journals and time series analysis is also used to predict the future growth of literature. It was observed that Environmental Science and Pollution Research ranked 1st with a total of 355 (19.39%) publications, followed by Environmental Pollution ranked 2nd with 66 (3.60%) publications and Journal of Environmental Chemical Engineering ranked 3rd with 35 (1.91%) publications. The result shows that verbal formulation 1: n: n^2 has fits well with the data on Light Pollution and verification of Bradford's law and it fits with 8:79:439 geometric series with 3.91% of error. The Bradford law is also verified through graphical formulation by drawing the graph and is found to approve all the three characteristics.

Keywords: Bradford's Law, Light Pollution, Time Series Analysis, India,

I. INTRODUCTION

Light is a vital resource for preserving visible atmospheres, dividing between day and night activities, amplifying some critical procedures like photosynthesis and assisting in the rehabilitation and restoration of organisms. It also provides information that Photoperiodism and circadian clocks assist in spatial orientation and visual perception.Light pollution is the excessive, inadequately directed or invasive artificial light from homes and towns, which interferes with wildlife, stargazing, sleep habits, and professional astronomy and wastes a vast amount of energy (Gallaway et al., 2010). It is particularly prominent when the night sky becomes more visible, which makes it challenging to see planets and stars. Excessive illumination, glare, light trespass, and skyglow are the four primary types of light pollution (Rodrigo-Comino et al., 2023).Light pollution is a major environmental issue that is difficult to control and continues to grow towards an increase exponentially. Consequently, the scientific community has focused on this particular issue over the last two decades.

Bradford's Law of Scattering is one of the bibliometric laws which is used in bibliometric/scientometric studies.This method assists to determine the highly-cited journals listed as nucleus journals of the subject. The Bradford's Law of scattering and the idea of core journals were identified by Samuel Clement Bradford in 1934.Bradford's law described how the research articles on any given subject field scattered or spread across different journals. According to a certain mathematical function so that a growth in articles on a subject requires a growth in the number of journals/information sources. The number of the groups of journals to produce nearly equal number of articles is roughly in proportion to 1: n: n^2 …, where n is called the Bradford multiplier (Bradford's 1934). The present study analyses the application of Bradford's law to the light pollution literature in India during the period of 2005 to 2024.

II. OBJECTIVES OF THE STUDY

The specific objectives of this study are:

1. To prepare the rank list of journals and study the phenomenon for the scattering of journals in India light pollution publications;
2. To test the appropriateness of verbal and graphical formulation of Bradford's Law of Scattering in the field of light pollutionresearch publications.

III. METHODOLOGY

For the present study focused on the verification of Bradford's law of scattering in the Light Pollution research in India. The data was retrieved from the Web of Science database. The database has been searched with the keyword as 'Light Pollution' in the 'Title' AND 'CU=India' during the period of 2005 to 2024. A total of 1831 articles published in 526 journals were taken for study. The following are the test Bradford's law and indicators used to analyse and evaluate data on Light Pollution.

IV. DATA ANALYSIS OF INTERPRETATION

4.1 Year Wise Distribution of Articles

Table 1 reveals the year-wise distribution of published articles. As per data, the highest publications i.e., 351 (19.71%) were published in the year 2024. Data reveals continuous growth in publications. The highest citations were received in 2021 with 13.63% of the total citations received by 8040 articles. The highest average citations per article in the year 2009 (108.50) and the average citation per year is 402.0. A total of 1831articles received 58993 citations.

Table 1: Year Wise Distribution of articles and Received Citations

Year	Articles	% of 1831	Cum. Art.	Cum. Art %	TCR	TCR %	ACPA	ACPY
2005	3	0.16	3	0.16	217	0.37	72.33	10.85
2006	4	0.22	7	0.38	50	0.08	12.50	2.5
2007	7	0.38	14	0.76	188	0.32	26.86	9.4
2008	12	0.66	26	1.42	484	0.82	40.33	24.2
2009	14	0.76	40	2.18	1519	2.57	108.50	75.95
2010	11	0.60	51	2.79	706	1.20	64.18	35.3
2011	25	1.37	76	4.15	842	1.43	33.68	42.1
2012	19	1.04	95	5.19	716	1.21	37.68	35.8
2013	23	1.26	118	6.44	1112	1.88	48.35	55.6
2014	32	1.75	150	8.19	1919	3.25	59.97	95.95
2015	43	2.35	193	10.54	2196	3.72	51.07	109.8
2016	49	2.68	242	13.22	2842	4.82	58.00	142.1
2017	54	2.95	296	16.17	2375	4.03	43.98	118.75
2018	83	4.53	379	20.70	5397	9.15	65.02	269.85
2019	107	5.84	486	26.54	5691	9.65	53.19	284.55
2020	144	7.86	630	34.41	6933	11.75	48.15	346.65
2021	211	11.52	841	45.93	8040	13.63	38.10	402.00
2022	302	16.49	1143	62.42	7890	13.37	26.13	394.5
2023	337	18.41	1480	80.83	5477	9.28	16.25	273.85
2024	351	19.17	1831	**100**	4399	7.46	12.53	219.95
Total	**1831**	**100**			**58993**	**100**	**32.22**	**2949.65**

Cum. Art.= Cumulative Articles, TCR-Total Citations Received; ACPA-Average Citations Per Article, ACPY= Average Citations Per Year

4.2 Time series analysis

Time series are analyzed in order to understand the underlying structure and function that produce the observations. Understanding the mechanisms of a time series allows a mathematical model to be developed that such a way that prediction, monitoring or control can occur. This analysis also includes prediction/forecasting, which is widely used in economics and business. Monitoring of ambient conditions or of an input is common in science and industry. It is assumed that a time series data ser has at least one systematic pattern. The most common patterns are trends and seasonality. Trends are generally linear or quadratic. To find trends, moving averages or regression analysis is often used. For the total

number of 1831 publications in the field of light pollution research during the period of 2005 to 2024. In this study, time series analysis is applied to forecast the growth of the light pollution literature in India.

Table 2:Time series analysis of Light Pollution Research

Sl. No.	Year	Publications (Y)	X	X^2	XY
1	2005	3	-10	100	-30
2	2006	4	-9	81	-36
3	2007	7	-8	64	-56
4	2008	12	-7	49	-84
5	2009	14	-6	36	-84
6	2010	11	-5	25	-55
7	2011	25	-4	16	-100
8	2012	19	-3	9	-57
9	2013	23	-2	4	-46
10	2014	32	-1	1	-32
11	2015	43	1	1	43
12	2016	49	2	4	98
13	2017	54	3	9	162
14	2018	83	4	16	332
15	2019	107	5	25	535
16	2020	144	6	36	864
17	2021	211	7	49	1477
18	2022	302	8	64	2416
19	2023	337	9	81	3033
20	2024	351	10	100	3510
		1831	**0**	**770**	**11890**

The Straight line equation is applied under the Time series analysis to enable the formulation of assessments for future growth.

Straight Line equation $Yc = a + bx$

Where,
Y = Trend value to be computed (dependent variable)
X=Unit of time (Independent variable)
a= Constant to be calculated
b= Constant to be calculated

Application of straight line equation to the Light Pollution

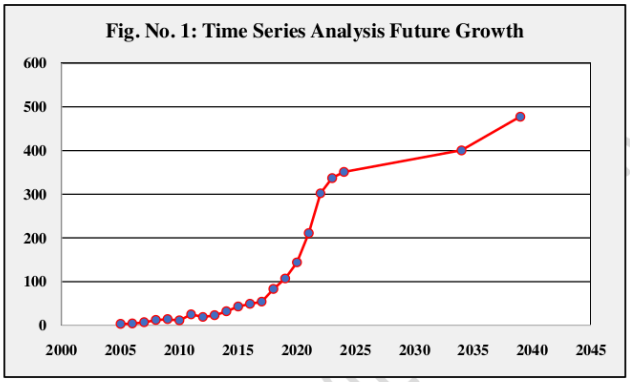
Since $\Sigma x = 0$

$a=\Sigma Y/N = 1831/20=91.55$ $b=\Sigma XY/\Sigma x^2 =11890/770=15.44$

Estimated literature in 2034 is, when X=2034-2014=20 years

=91.55+15.44*20=91.55+308.8**=400.35**
Estimated literature in 2039 is, when 2039-2014=25 years

=91.55+15.44*25=91.55+386 **=477.55**



From the above results, it is observed that the calculations the estimated future growth of Indian Light Pollution research will be increased from 91.55 in the year 2024 to 400.35 in the year 2034 and in the year 2039 to 477.55, the tableno.2 and Fig. no.1 reveal the same. The increasing trend continued up to the estimated year. So it can be assumed that the rate of growth is positive in relation by the year-wise publications.

4.3 Ranking of Journals

The table 3 reveals the top 20 ranking of journals which are preferred by scientists in the field of Light Pollution research. Environmental Science and Pollution Research ranked 1st with a total of 355 (19.39%) publications share, followed by Environmental Pollution ranked 2nd with 66 (3.60%) publications, Journal of Environmental Chemical Engineering ranked 3rd with 35 (1.91%) publications, Science of the Total Environment ranked 4th with 35 (1.91%) publications and Water Air and Soil Pollution ranked 5th with 35 (1.91%) publications. The highest citations received by the preferred journal is Environmental Science and Pollution Research with 9115 citations. The highest average citation per article received by the Journal of Environmental Management is 81.81.

Table 3 : Top 20 Most Preferred Journals in the field of Light Pollution research in India

Rank	Source Title	Articles	% of	TCR	% of	ACPA	IF	Country

			1831		**58993**			
1	Environmental Science and Pollution Research	355	19.39	9115	15.45	25.68	5.8	Germany .
2	Environmental Pollution	66	3.60	2070	3.51	31.36	7.3	Netherlands
3	Journal of Environmental Chemical Engineering	35	1.91	2193	3.72	62.66	7.2	United Kingdom
4	Science of the Total Environment	35	1.91	1186	2.01	33.89	8.0	Netherlands
5	Water Air and Soil Pollution	35	1.91	538	0.91	15.37	3.0	Germany
6	Chemosphere	32	1.75	1667	2.83	52.09	8.1	Netherlands
7	Atmospheric Pollution Research	31	1.69	460	0.78	14.84	3.5	Netherlands
8	Environmental Research	27	1.47	724	1.23	26.81	8.431	Netherlands
9	Environmental Monitoring and Assessment	22	1.20	447	0.76	20.32	3.0	Netherlands
10	Inorganic Chemistry Communications	22	1.20	245	0.42	11.14	5.4	Netherlands
11	Journal of Environmental Management	21	1.15	1718	2.91	81.81	8.910	Netherlands
12	Atmospheric Environment	20	1.09	767	1.30	38.35	4.012	United Kingdom
13	Marine Pollution Bulletin	19	1.04	344	0.58	18.11	7.001	United Kingdom
14	Chemistryselect	15	0.82	104	0.18	6.93	2	Germany
15	New Journal of Chemistry	15	0.82	185	0.31	12.33	3.3	France
16	Atmospheric Chemistry and Physics	14	0.76	785	1.33	56.07	6.133	Germany
17	International Journal of Environmental Science and Technology	14	0.76	175	0.30	12.5	2.860	Germany
18	Ceramics International	13	0.71	604	1.02	46.46	5.6	Netherlands
19	Colloids and Surfaces A Physicochemical and Engineering Aspects	13	0.71	235	0.40	18.08	5.41	Netherlands
20	Journal of Cleaner Production	12	0.66	778	1.32	64.83	10.1	Netherlands
Truncated								

TP-Total publications; TCR-Total Citations Received; ACPP-Average Citations per Paper; IF: Impact Factor

4.4 Bradford's Law of Scattering

Bradford's Law of Scattering is one of the bibliometric laws which is used in bibliometric/scientometric studies. This method assists to determine the highly-cited journals are listed as nucleus journals of the subject. Bibliometric Law of scattering was formulated by Samuel Clement Bradford (1934). He carryout a study in Applied geophysics research. He noticed that the scattered of scientific journal papers followed a common pattern. He describes a quantitative relationship between journals and published papers which the papers be found (Bradford, 1934).Application of Bradford's Law of Scattering shows the three productive zones so that each zone produces 1/3 of the total relevant papers. Bradford (1950) defined Bradford law as "If the scientific periodicals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nuclear of periodicals more particularly devoted to the subject and different groups or zones containing the same number of papers as the nucleus when the number of periodicals in the nucleus and succeeding zone will be as 1: n: n2. The first nucleus zone comprises a small number of highly productive journals say n1, the second zone has a larger number of temperately productive journals say n2, and the third zone has still larger number of journals of low productivity say n3.He enunciated his law 1: n: n^2, where 'n' is a multiplier

In the present study depicts the Bradford law has been tested for journal articles of Light Pollution research during 2005 to 2024. For testing the Bradford's law in the Light Pollution, 1831 publications dispersed in the 526 journals are divided into three zones and listed by rank order. The beginning core journals contributed the highest number of publications. It is defined that the journals structured in descending order of journal productivity and it exposes that most productive journal publications appeared first as well as low productive journal publications appeared last in the table 4.

Table 4: Parameter value for the Bradford's distribution in Light Pollution Journals

Rank	Number of Journals	Cumulative number of Journals	Number of Articles	Cumulative number of Articles	Log(n)
1	**1**	**1**	**355**	**355**	**0.00**
2	1	2	66	421	0.69
3	**3**	5	105	526	1.61
4	1	6	32	558	1.79
5	1	7	31	589	1.95
6	**1**	**8**	**27**	**616**	**2.08**

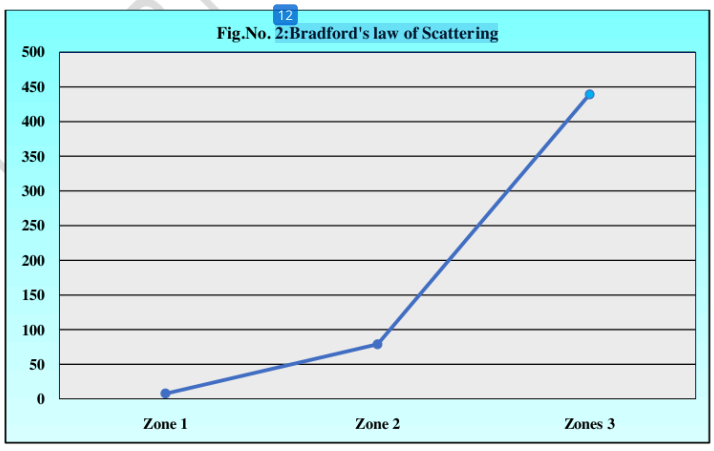
7	**2**	10	44	660	2.30
8	1	11	21	681	2.40
9	1	12	20	701	2.48
10	1	13	19	720	2.56
11	2	15	30	750	2.71
12	2	17	28	778	2.83
13	2	19	26	804	2.94
14	2	21	24	828	3.04
15	2	23	22	850	3.14
16	6	29	60	910	3.37
17	4	33	36	946	3.50
18	6	39	48	994	3.66
19	3	42	21	1015	3.74
20	8	50	48	1063	3.91
21	15	65	75	1138	4.17
22	**22**	**87**	**88**	**1226**	**4.47**
23	41	128	123	1349	4.85
24	84	212	168	1517	5.36
25	**314**	**526**	**314**	**1831**	**6.27**
	526		**1831**		

Table No 5: Scattering of Journals and Publicationsover Bradford's zones

Zones	Journals	Journals %	Publications	Publications %	Bradford Multiplier (k)
1	8	1.52	616	33.64	0
2	79	15.02	610	33.32	9.88
3	439	83.46	605	33.04	5.56
Total	526	100	1831	100	7.72*

*Mean value of Bradford multiplier **

Fig. No.2: Scattering of Journals and Publications over Bradford's zones



For testing of Bradford's law, the Light Pollution research articles, the 526 journals are divided into three zones. The distribution of journals and a corresponding number of articles in the three zones along with the value of Bradford multiplier are shown in table 5 & figure 2. In the present dataset, the first 8 journals covered 616 (33.64%) articles, followed by 79 journals covered 610 (33.32%) articles and the next 439 journals covered 605 (33.04%) articles. It can be noticed that the three zones are almost exactly the 1/3rd of the total articles as suggested by Bradford.

. According to Bradford's law, of scattering, zone wise distribution will form an approximately geometric series in the form 1: n: n^2. The relationship of each zone in the present study is 8:79:439. Here, The Bradford multiplier between the number of references in zone 1 and zone 2 is 9.88 while it is 5.56 between zone 2 and 3. The average multiplier value is 7.72.

Therefore, 1: n: n^2

=8: 8*7.72: 8*$(7.72)^2$

=8: 61.76: 476.7872

=546.5472

$$\text{Percentage error} = \frac{\text{Value of 1: n: } n^2 \text{ - Total no. of journals}}{\text{Total no. of journals}} \text{ X100}$$

Therefore,

Percentage error = [(546.5472-526)/526] *100

= 546.5472-526 =20.5472

= 20.5472/526 = 0.039063

= 0.039063*100= 3.91%

Percentage error = 3.91%

Since the percentage of error is negligible(3.91%) here, the data fits well Bradford's lawof scattering.

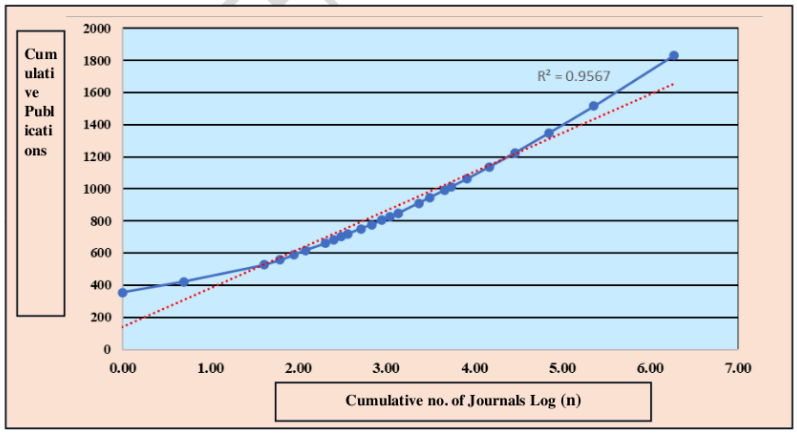
4.5 Graphical Formulation

The Graphical formulation is just the experimental verification of the verbal formulation which observes certain regularity in the distribution of scientific publications (Sudhier 2010). The graphical formulation approach was developed by Brookes which tries to verify the Verbal formulation of the Bradford's Law of scattering (Bookers, 1969). If the distribution confirms to Bradford's law, it will show the characteristics in the 3 distinct regions:

1. the graph may have sharp rise at beginning which shows the core journals;
2. a major portion of linear relation between two variables,
3. a 'droop' at the tail end of the distribution indicating the incompleteness of the bibliography.

In this study, Graphical formulation has been used as a visual formulation for the verbal formulation of the law of scattering

Figure 3: Bradfords Bibliograph for Journals Distribution



The graph in the Fig 3 shows the logarithmic plot of cumulative publications on the horizontal (X) axis and the log of cumulative number of journals on the vertical (Y) axis. In

this study Bradford curve with a Groos droop.The Bradford's curve with a Groos droop, where the journals are plotted against their productivity.

V. CONCLUSION

Bradford's Law of Scattering is one such bibliometric law, which is helpful in selecting core journals in a research field.In this study, theoretical aspects of Bradford's Law of Scattering are tested and found that the data fits well in the present data set in the field of Light Pollution research publications during the period of 2005 to 2024. The Journal distribution pattern of Light Pollution literature fits well with Bradford's distribution, i.e., 1: n: n^2. Bradford's law of scattering states that articles in each zone should be equal, as witnessed in the present study. The percentage of error is found to be the most negligible (3.91%) and therefore law finds valid to the data set.Bradford's Law has been valuable for understanding the framework of scientific literature and has implications for research evaluation, information retrieval and science policy.

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