

Application of Bradford's Law of Scattering to the Scientific Publications of Energy and Environment Research

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ABSTRACT

This study has been made an attempt to describe the one of the most essential bibliographic laws i.e. Bradford law of scattering to test the scholarly publications of energy and environment in Australia. A total of 2802 papers published, out which 83.4% were journal articles and 99.7% were in the English language. According to Australian research, the output of Environmental Sciences Ecology (13.807%) account for the largest increase and it is occupied in the first place and Energy Fuels (6.208%) is in the 6th place during the present study. The three most productive journals with high citations were 'Ecological Applications' (= 4, 2721 citations), 'Astrophysical Journal' (= 44, 1614 citations), and 'Monthly notes of the Royal Astronomical Society' (= 38, 1389 citations) and the maximum number of citations contributed by 'BAZZAZ FA' from Harvard University, USA. In this study, based on the speculative aspects of Bradford's Law of Scattering is tested and identified that the ratio depicts that it does not fit into the Bradford's law of distribution.

Key words

Scientometrics, Bradford's Law, scholarly publications, energy and environment, Australian research, India, Australia

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INTRODUCTION

To meet the energy requirements of supportable economic growth, policy makers, analysts, and corporate leaders have progressively referred to the role that energy and environment would perform. For that reason, this paper has taken into attention to find out the publications growth trends and development in the field of energy and environment research in Australia as indexed in the web of science. Some of the related works have already done in the field of

energy and solar energy by various scientists (Tijssen 1992; Gupta 1980; Lawson, Kostrewski & Oppenheim 1980; Pouris & Pouris 1987; ASSAF 2006). A numerous reviews of the research outputs on scientometrics as well as bibliometrics have already done including Bradford distribution. Here, we have identified some notable reviews of eminent scholars and researchers in different areas for the current study such as Bradford, 1934; Lawani, 1973; Brookes, 1977; Avramescu, 1980; Drott, 1981; Asai, 1981; Egghe, 1986, 1990; Tyagi, 1986; Qui, 1990; Gupta, 1991; Bandyopadhyay, 1999; Nicolaisen & Hjørland, 2007. To enrich strength of this paper, researchers have taken into account a few from authors' previous study under different domain as well as solo journals of scientometric analysis for the present analysis such as research analysis on Biotechnology by Velmurugan and Radhakrishnan (2015), Journal of Information Literacy (2015), Quantitative Analysis of Scientific Publications Output on Engineering Journal (2015), Supply Chain Management (2015), Library Herald (2015), Pharmacognosy (2015), Scientometric observations on DESIDOC Journal of Library and Information Technology by Velmurugan and Radhakrishnan (2015), Journal of Intellectual Property rights by Velmurugan (2013, 2014), Annals of Library and Information Studies for the year 2007-2012 by Velmurugan (2013) Indian Journal of Pure and Applied Physics for the Year 2009 – 2012 by Velmurugan (2014), Technical Review Journal by Velmurugan (2014).

OBJECTIVES OF THE STUDY

This study demarcates the research with computing the energy and environment publication trends for the period between January 1989 and November 2015 indexed at Web of science database. The study involves a total of 2803 scientific literature output from 1199 journals with 64994 citations and 14546 authors by 85 various countries. The present study has been designed with the below purposes.

- To identify the growth analysis of energy and environment research output,
- To compare the Indian versus Australian literature outputs,
- To compare the Australia publications share and World literature outputs,
- To depict the highly cited authors of energy and environment research,
- To find out the core journals of energy and environment in Australia and
- To test the Bradford Law of Scattering

METHODOLOGY AND LIMITATIONS

To meet the objectives of the study, the web of science core collection database has been used with the keyword as 'energy and environment' has given in the topic and the period 1989 – 2015 and 2802 scientific papers published in 1199 journals in the English language were retrieved till November 2015 for further analysis. To evaluate the research outputs, tested using the Bradford's Law of Scattering for better results during the period of study. The present study is limited for the period of 26 years beginning from 1989 to 2015 (till November 2015) but the data have been retrieved as it is available in the database (started 2016). Hence, the whole data have taken into account and made specific observations based on the study in the Australia scenario with comparison of India and world output.

ANALYSIS AND RESULTS

Growth rate of literature in Energy and Environment in India and Australia

Table 1 represents that the research outputs of Energy and Environment in India and Australia during the period of study between 1989 and 2015. As far as the Indian literature concerns, the huge numbers of 353 (12.7%) papers are produced in the 2015 on the other

hand, the small numbers of papers are produced in the year 1989. It is found that the growth rate has been gradually increased in the year 1991 onwards. According to Australian outputs, the growth rate ratio is 21 papers in 1991 and 308 papers in 2015 with 1466% increase. The maximum numbers of outputs are published in the year 2015 whereas the least number of research papers are published in 1991 and the average numbers of papers are 112.08 in Australia and the average numbers of papers are 102.89 in Indian literatures.

Table 1: Growth of publication

S. No	PY	India		Australia	
		TR	TR%	TR	TR%
1	1989	1	0.0	-	-
2	1990	3	0.1	-	-
3	1991	17	0.6	21	0.7
4	1992	24	0.9	28	1.0
5	1993	26	0.9	33	1.2
6	1994	25	0.9	33	1.2
7	1995	24	0.9	37	1.3
8	1996	30	1.1	50	1.8
9	1997	30	1.1	49	1.7
10	1998	40	1.4	56	2.0
11	1999	38	1.4	45	1.6
12	2000	42	1.5	55	2.0
13	2001	51	1.8	59	2.1
14	2002	59	2.1	66	2.4
15	2003	50	1.8	91	3.2
16	2004	79	2.8	82	2.9
17	2005	90	3.2	80	2.9
18	2006	113	4.1	126	4.5
19	2007	139	5.0	119	4.2
20	2008	116	4.2	108	3.9
21	2009	148	5.3	162	5.8
22	2010	180	6.5	170	6.1
23	2011	196	7.0	227	8.1
24	2012	253	9.1	238	8.5
25	2013	316	11.4	279	10.0
26	2014	335	12.0	280	10.0
27	2015	353	12.7	308	11.0
Total		2781	100	2802	100

Note: PY- Publication year, TR- Total records, TRP- Total records percentage

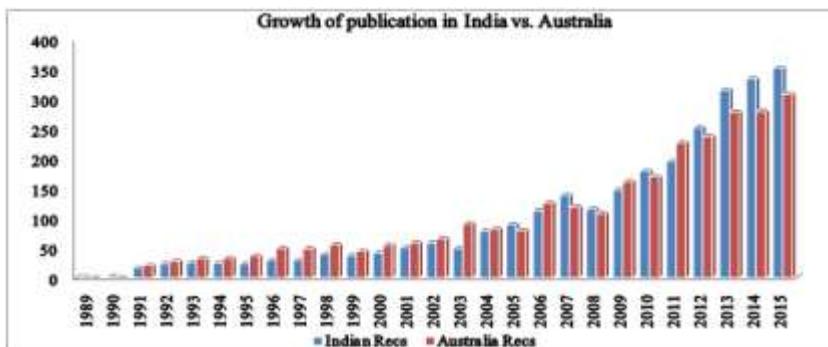


Figure 1: Growth of publication in India vs. Australia

Australia's publication share in world literature outputs

Table 2 represents that the global publications share of Australia during 1991-2015 was 3.828183 which has gradually increased from 2.277657 in 1991 to 4.756022 in 2015. This growth pattern could also be counted based on the journals increase via web of science database over the years. The maximum growth share is 4.75% in the year 2015 and followed 4.462355 % in 2011, 4.336338 % in 2013, 4.223936 % in 2006, 4.132607 % in 2003, and 4.035266 % in 2012, whereas the least growth share in 1994 is 2.930728 % and in the year 1991 is 2.27 percent. The results illustrate that the growth share of Australia and compare with world outputs during the period and indicates that the growth level is fluctuation trend.

Table 2: Australia's publication share in world literature outputs

S. No	PY	ALO	WLO	Australia's Share%
1	1989	-	43	-
2	1990	-	126	-
3	1991	21	922	2.28
4	1992	28	911	3.07
5	1993	33	998	3.31
6	1994	33	1126	2.93
7	1995	37	1149	3.22
8	1996	50	1321	3.79
9	1997	49	1335	3.67
10	1998	56	1562	3.59
11	1999	45	1583	2.84
12	2000	55	1701	3.23
13	2001	59	1752	3.37
14	2002	66	1933	3.41
15	2003	91	2202	4.13
16	2004	82	2351	3.49
17	2005	80	2604	3.07
18	2006	126	2983	4.23
19	2007	119	3322	3.58
20	2008	108	3592	3.01
21	2009	162	4163	3.89
22	2010	170	4532	3.75
23	2011	227	5087	4.46
24	2012	238	5898	4.04
25	2013	279	6434	4.34
26	2014	280	7088	3.95
27	2015	308	6476	4.76
1989-2015		2802	73194	3.83

Note: PY- Publication year, ALO- Australia Literature Output, WLO- World Literature Output

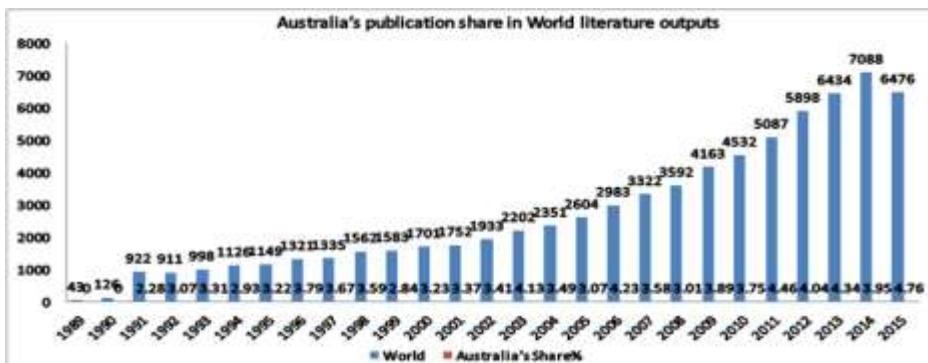


Figure 2: Australia's publication share in world literature outputs

Chronological distribution of publication in Australia

Literature outputs are essential in every academic as well as research and development institutions. Here, Table 3 and figure 4 indicate we have evaluated the publication growth trend in the field of Energy and Environment Research, and the below table picture the total citations and annual citation per paper (ACPP) are measured during the study. Based on the outputs, the growth ratio range is from 0.80 to 1.58 and followed by the annual growth rate range is from 0.36 to 57.5. The citation range is from 263 in 2015 to 5674 in 2000 (figure 3). The most number of 308 (11.0%) articles are published in 2015 and the small numbers of papers (21 papers) are produced in the begging year. the greatest number of annual average citation per paper is 53.05 in the year 2005.

Table 3: Chronological distribution of publication

S. No	PY	Recs	Percent	TC	ACPP
1	1991	21	0.7	974	46.38
2	1992	28	1.0	936	33.43
3	1993	33	1.2	1383	41.91
4	1994	33	1.2	601	18.21
5	1995	37	1.3	1145	30.95
6	1996	50	1.8	1959	39.18
7	1997	49	1.7	2460	50.20
8	1998	56	2.0	1710	30.54
9	1999	45	1.6	1708	37.96
10	2000	55	2.0	5674	10.32
11	2001	59	2.1	1807	30.63
12	2002	66	2.4	2919	44.23
13	2003	91	3.2	3608	39.65
14	2004	82	2.9	3100	37.81
15	2005	80	2.9	4244	53.05
16	2006	126	4.5	3866	30.68
17	2007	119	4.2	3830	32.18
18	2008	108	3.9	3925	36.34
19	2009	162	5.8	3870	23.89
20	2010	170	6.1	3929	23.11
21	2011	227	8.1	4581	20.19
22	2012	238	8.5	3442	14.46
23	2013	279	10.0	2134	7.65
24	2014	280	10.0	926	3.31
25	2015	308	11.0	263	0.85
Total		2802	100	64994	23.20

PY – Publication year, TC – Total citations, ACPP- Average citation per paper

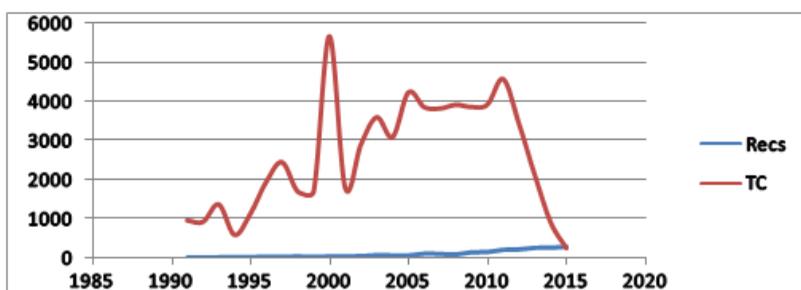


Figure 3: Chronological wise papers and citations

Ranking of highly cited authors

It can be observed from the Table 4 shows that the highly cited authors in the field of Energy and Environment Research in Australia during the period of study. The results reveal that a total of 64994 citations had contributed entire research outputs in the period of study. Out of that, more than 700 times cited papers of authors have collected for the present study. The maximum number of citations contributed by 'BAZZAZ FA' from Harvard University, USA, 'CLOUT M' from University of Auckland, New Zealand, 'EVANS H' from England, 'LONSDALE WM' from CRC Weed Management System, Australia, 'MACK RN' from University of Tennessee, USA, 'SIMBERLOFF D' from CSIRO Entomology, Australia with 2667 citations with one paper who have occupied in the first rank respectively, and the lowest citations (=1, 708 citations) is received by 'REKAS M' from University of New South Wales, Australia.

Table 4: Highly cited authors in Energy and Environment Research

Rank	Author	Affiliation	TR	TC
1	Bazzaz FA	Harvard University, Biological Labs, Cambridge, USA	1	2667
1	Clout M	University of Auckland, Scheme of Biological Science, New Zealand	1	2667
1	Evans H	CABI Bioscience, England.	1	2667
1	Lonsdale WM	CRC Weed Management System, Canberra, Australia	1	2667
1	Mack RN	University of Tennessee, Dept Ecology & Evolution Biology, USA	1	2667
1	Simberloff D	CSIRO Entomology, Canberra, ACT 2601, Australia	1	2667
2	Swinburn BA	Deakin University, Scheme of Health Science, Melbourne, Australia	6	1074
3	Lu GQ	University of Queensland, Scheme of Chemical Engineering, Brisbane, Australia	4	914
4	Buyya R	University of Melbourne, Dept Computer Science & Software Engineering, Australia	8	795
5	Nowotny J	Univ New S Wales, Scheme of Material Science & Engineering, Sydney, Australia	7	770
6	Nanson GC	University of Wollongong, Dept Geology, Wollongong, Australia	5	753
7	Dopita MA	Australian National University, Institute of Advanced Studies, Australia	7	744
8	Hiller RG	Macquarie Univ, Dept Biological Science, Australia	11	731
9	Bak T	University of New South Wales, Scheme of Material Science & Engineering, Australia	4	729
10	Salmon J	Deakin University, Centre for Physics Act & Nutrition Research, Australia	8	726
11	Sorrell CC	University of New South Wales, Scheme of Material Science & Engineering, Australia	2	721
12	Rekas M	University of New South Wales, Scheme of Material Science & Engineering, Australia	1	708

Note: TR- Total records, TC- Total citations

Identification of core Journals in Energy and Environment Research

Table 5 shows the counting ranking based core journals in energy and environment totally covered 1199 journals but, for analysis, we have selected only top 22 highly productive journals with more than 13 scientific papers. The results reveal that based on the literature outputs, PLOS One is in the top ranked with 11 h-index and 46 records and the citations are 384, and followed by Astrophysical Journal is the next position with 44 articles with 1614 citations and h-index is 21, Monthly Notices of the Royal Astronomical Society is occupied in the third rank with 38 articles (=1389 citations, 11 h-index), Journal of Coastal Research (=28, 350 citations, 11 h-index), Renewable Energy (=28, 180 citations, 8 h-index), Astronomy & Astrophysics (=25, 730 citations, 13 h-index), Journal of Experimental Biology (=23, 563 citations, 13 h-index), Physical Review B (=23, 616 citations, 13 h-index), Energy Policy (=19, 242 citations, 7 h-index) and Energy and Buildings (=17, 184 citations, 6 h-index). It finds out from the analysis that more citations among the journals occupied by Monthly Notices of the Royal Astronomical Society (=1389 citations) and followed by Astrophysical Journal (=1614 citations).

Table 5: Ranking of Journals on Energy and Environment Research in Australia

Sl. no	Journal	TP	TC	R
1	PLOS One	46	384	1
2	Astrophysical Journal	44	1614	2
3	Monthly Notices of the Royal Astronomical Society	38	1389	3
4	Journal of Coastal Research	28	350	4
5	Renewable Energy	28	180	4
6	Astronomy & Astrophysics	25	730	5
7	Journal of Experimental Biology	23	563	6
8	Physical Review B	23	616	6
9	Energy Policy	19	242	7
10	Energy and Buildings	17	184	8
11	Journal of Physical Chemistry B	17	761	8
12	Marine Geology	17	441	8
13	Minerals Engineering	17	238	8
14	Renewable & Sustainable Energy Reviews	17	237	8
15	Australian Journal of Experimental Agriculture	15	231	9
16	Building and Environment	15	178	9
17	International Journal of Hydrogen Energy	15	841	9
18	Australian Journal of Agricultural Research	14	209	10
19	Australian Journal of Earth Sciences	14	164	10
20	Journal of Zoology	14	185	10
21	Proceedings of the National Academy of Sciences	14	902	10
22	Sedimentary Geology	14	267	10

Note: TP- Total publications, TC- Total citations, R-Rank

Bradford law of scattering

In 1934, Samuel Clement Bradford introduced the Bradford's law of scattering to test the journals outputs whether they are fit or not fit as per the production. The Bradford's law is to explain that a group of journals could be arranged in an order of decreasing productivity and revealed that journals which yield the most productive articles are coming first and the most unproductive in the last. According to this law, the journals are to be grouped into a number of zones each producing a similar number of articles.

However, the number of journals in each zone will be increasing speedily. Then the relationship between the zones is 1: n: n². For describing the scattering phenomena, the following formula has been adopted by the researchers.

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

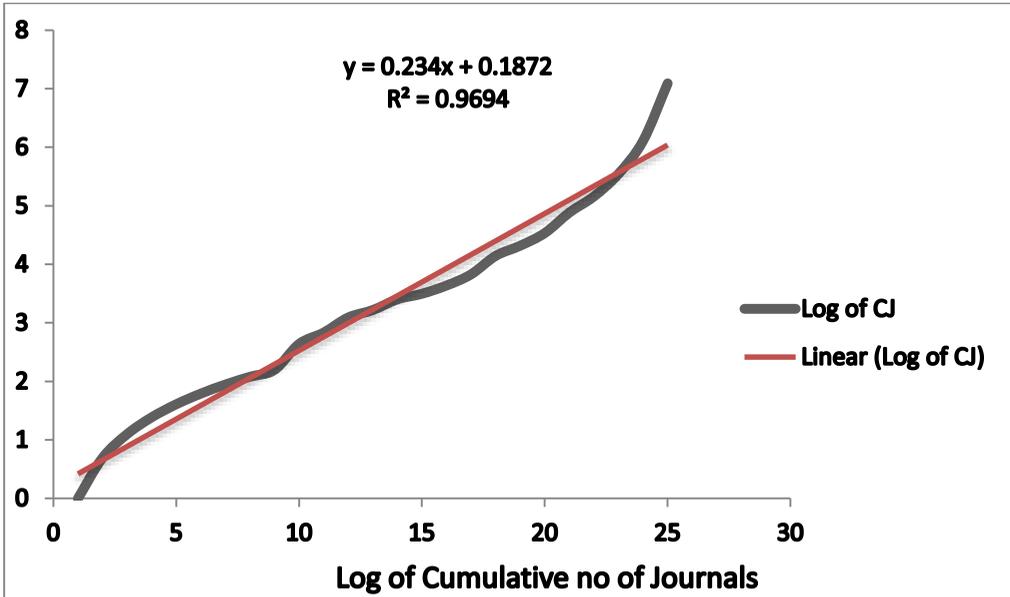
Where F(X) – is the cumulative number of references as contained in the first-x most productive journal and 'a' and 'b' are constants. Total number of journals for this present study is 1199.

Table 6: Bradford law of scattering in journals of energy and environment

Sl. no	NJ	CJ	NA	TA	CA	Log of CJ	PCA	PCJ
1	1	1	46	46	46	0	1.64	0.08
2	1	2	44	44	90	0.693	3.21	0.16
3	1	3	38	38	128	1.098	4.57	0.25
4	1	4	28	28	156	1.386	5.57	0.33
5	1	5	28	28	184	1.609	6.56	0.42
6	1	6	25	25	209	1.791	7.46	0.50
7	1	7	23	23	232	1.946	8.28	0.58
8	1	8	23	23	255	2.079	9.10	0.66
9	1	9	19	19	274	2.197	9.78	0.75
10	5	14	17	85	359	2.639	12.81	1.16
11	3	17	15	45	404	2.833	14.42	1.41
12	5	22	14	70	474	3.091	16.92	1.83
13	3	25	13	39	513	3.218	18.31	2.08
14	5	30	12	60	573	3.401	20.45	2.50
15	3	33	11	33	606	3.496	21.63	2.74
16	5	38	10	50	656	3.637	23.41	3.16
17	8	46	9	72	728	3.828	25.98	3.83
18	17	63	8	136	864	4.143	30.84	5.24
19	12	75	7	84	948	4.317	33.83	6.24
20	18	93	6	108	1056	4.533	37.69	7.75
21	39	132	5	195	1251	4.883	44.65	11.0
22	42	174	4	168	1419	5.159	50.64	14.50
23	82	256	3	246	1665	5.545	59.42	21.34
24	194	450	2	388	2053	6.109	73.26	37.53
25	749	1199	1	749	2802	7.089	100	100

NJ- No of journals, CJ- Cumulative journal, NA- No of articles, TA-Total article, CA- Cumulative articles, PCA-Percentage of Cumulative articles, PCJ-Percentage of Cumulative journals

Table 6 indicates the journal distribution of research in the field of energy and environment in Australia. The Bradford's law of scattering was introduced by Samuel Clement Bradford (1934) and pointed out that if scientific journals are arranged in order to decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particular devoted to the subject and several groups and zones contain the same number of articles as the nucleus when the number of periodicals in the nucleus and succeeding zones will be 1: n: n².



Graph 1: Log value of cumulative scientific journals

Based on the above table graph has been plotted with value of R2 = 0.9694 and also identified the Log value equation $y = 0.234x + 0.1872$ to estimate the cumulative value of scholarly publications in energy and environment research.

Table 7: Zone wise distribution

Zone	TJ	TJ %	TA	TA %	Multiplier
1	63	5.25	864	30.83	-
2	193	16.10	801	28.59	3.06
3	943	78.65	1137	40.58	4.89
Total	1199	100	2802	100	3.975 (mv)*

TJ-Total Journals, TJ- percentage, TA- Total articles, TA – percentage,*Mean value

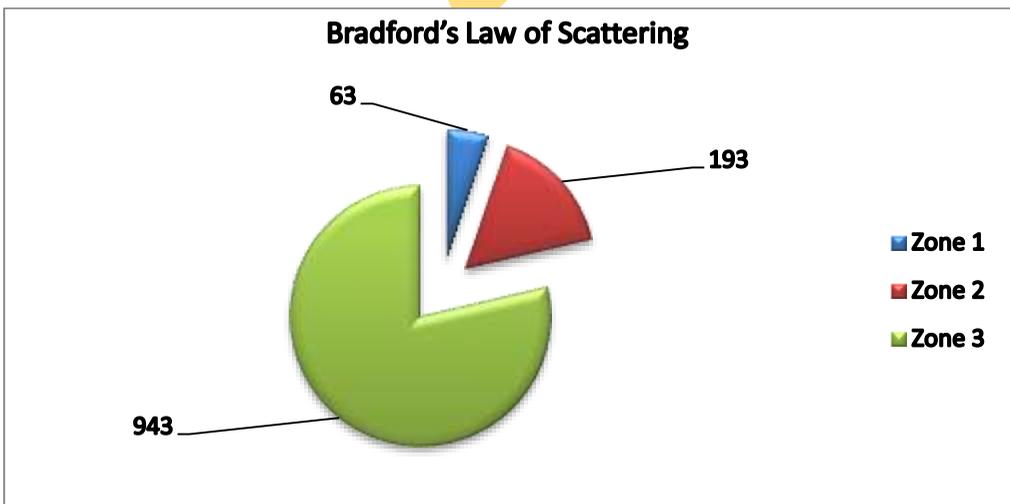


Figure 4: Bradford's Law of Scattering

Table 7 and Figure 4 represents that the distribution of scholarly journals and contribution of articles have classified into three zones. According to Bradford, the zones, indicated will form an approximately geometric series in the form 1: n: n². But, it is identified that the relationship of each zone in the present study is 63:193:943. The ratio depicts that it does not fit into the Bradford's law of distribution. The results show that the distributions of core journals were published by a few numbers of journals. It finds here from the analysis, 63 refer to the number of journals in the Nucleus and the mean Bradford multiplier is 3.975.

Hence, expression can be given as:

$$63:63 \times (3.975):63 \times (3.975)^2::1:n:n^2$$

$$63:250.425:995.439375 > 1308.864$$

$$\% \text{ error} = \frac{1308.864 - 1199}{1199} \times 100 = 9.163$$

It is therefore, very clear that the percentage of error is so high and therefore, the data does not fit in Bradford's law.

CONCLUSION

The Bradford of scattering is one of the best test tools for scholarly publications in the field of Library and Information Science. In this present study, authors have applied to test the Law whether it is fit or not as per data output during the period of study. Therefore, we can conclude from the study in the field of energy and environment in Australia and the findings show that the global publications the share of Australia during 1991-2015 was 3.828183 which have gradually increased from 2.277657 in 1991 to 4.756022 in 2015. Based on the study, the results reveal that the distributions of core journals were published by a few numbers of journals. It finds from the analysis, 63 refer to the number of journals in the Nucleus and the mean Bradford multiplier is 3.975. It identifies the relationship of each zone in the present study is 63:193:943. The ratio depicts that it does not fit into the Bradford's law of distribution. Moreover, the percentage of error is so high that the data does not fit in Bradford's law. Some number of scientometric studies have previously done in various fields by researches and scientists, this scientometric analysis on energy and environment research of Australia, authors hope this study may generate more scientometric studies for the resolution of evaluating energy and environment research in the country.

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