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APPLICATION OF BRADFORD'S AND LOTKA'S DISTRIBUTION TO BIO-ENERGY LITERATURE : A STUDY BASED ON TEN ABSTRACTING SERVICES

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Attempts to apply Bradford's Law of scattering and Lotka's Law of productivity to bio-energy literature and to verify if the law holds good for ten abstracting services (eight international and two Indian).

It has been verified that literature related to bio-energy conforms to Bradford's law of scattering and that grouping of services (all services together) also yields a Bradford distribution. The new model developed in this study fits the data very satisfactorily - r value ranged from 0.952 to 0.998 (for papers from journal titles) and 0.989 to 0.998 (for papers from conference proceedings). The value of p (multiplication factor) for bio-energy literature ranged from 2.19 to 4.09 (except for IEA and ISA) for articles from journal titles and from 2.02 to 4.59 for papers from conference titles.

Results of linear regression showed that Lotka's distribution holds good for bio-energy literature and the value of n ranged between 2.5 and 4.5. The K-S test confirmed these findings.

INTRODUCTION

Bradford's Law of scattering describes how the literature on a particular subject is scattered or distributed in the journals. The law is based on an investigation performed in 1933 by L Jones in the Science Museum Library, London. It was first reported in 1934 in the journal *Engineering* by Bradford and, subsequently, in a book titled *Documentation* by the same author in 1948 [1]. Bradford formulated his law as follows:

"If scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus, when the number of periodicals in the nucleus and succeeding zones will be as $1:n:n^2 ...$".

The paper involves application of Bradford's Law of scattering and Lotka's Law of productivity to bio-energy literature. The study is based on ten abstracting services of which eight are international and two Indian. These abstracting services are *Biomass Abstracts* (BA), *Chemical Abstracts* (CA), *Energy Abstracts* (EA), *Energy Abstracts for Policy Analysis* (EAPA), *Energy Research Abstracts* (ERA), *Foresty Abstracts* (FA), *Forestry Products Abstracts* (FPA), *Fuel and Energy Abstract* (FEA), *Indian Energy Abstracts* (IEA, now TERI Information Digest on Energy), and *Indian Science Abstracts* (ISA).

LITERATURE REVIEW

Bradford's Law

Several reviews of the literature of bibliometrics have included the Bradford distribution but the treatment has not been comprehensive [2]. Some of the important review papers examined by Lockett were Broadus [3], White [4], Narin and Moll [5], Hjerppe [6], Fiarthorne [7], Drott [8], Wilkinson [9], Hubert [10], and Asai [11]. Lockett examined critically the growth of research associated with the Bradford distribution through

a detailed discussion on the significant papers published between 1934-1987. The review addresses three major concerns of the literature: (a) appropriate formulation of Bradford's Law, (b) parameters of the Bradford distribution, and (c) relationship of the Bradford distribution to other distributions.

There are numerous studies that have applied Bradford's Law to various collection management problems which include tests of collection adequacy, journal acquisition, retention policies, evaluation of indexing and abstracting services, and cost-benefit considerations of additional coverage. Some important studies are: Brookes [12], Goffman and Morris [13], Worthen [14], Pope [15], Cline [16], Shukla [17], Peritz [18], and Nordstrom [19].

Lotka's Law

Commonly referred to as Lotka's inverse power law was presented by Bookstein [20] as a = C/n where b and C are constants to be estimated; from a given set of data, and n = 1,2,3,. Lotka asserted that this equation applies to a variety of fields. By considering two data sets from two different areas, physics and chemistry, he formulated the rule [21]. The value of exponent or (alpha) was found to be 2 for physicists and 1.89 for chemists. Lotka's equation suggests that the proportion of single-paper authors is a function of the exponent. This indicates that increase in exponent is accompanied by the increase of low productivity scientists. This implies that for a given N and for a large value of the exponent, the proportion of highly productive scientists will decrease. So larger the exponent, the greater is the gap between the productivity of individual group of scientists [22].

The methodology (including sampling) for studying author productivity has been standardized by Pao [23, 24], Nicholls [25,26], Griffith [27], and Dierick [28]. On the other hand, Fang & Fang [29] have proposed a modification of the Lotka's function. It appears from the review of literature [30] that there are several studies covering many disciplines that have investigated the applicability of Lotka's inverse square law. The law holds true in some cases but not in others. Wagner-Dobler and Berg [31] have shown that the Lotka distribution is highly dependent on the selection of the period of investigation.

OBJECTIVES

There were two objectives of this study:

(i) to apply Bradford's law of scattering to bio-energy literature and verify if the law holds good, and

(ii) to examine the applicability of Lotka's distribution to the research productivity of bio-energy researchers.

METHODOLOGY

A total of 9206 records were selected as a sample, which forms 16.4% of the total output (56240) abstracts) covering the period from 1982 to 1986 of the ten databases under examination. Stratified random sampling was employed in the case of BA, FA, and FPA. In the remaining seven services [CA, EA, EAPA, ERA, FEA, IEA (merged with TERI Information Digest on Energy in 1991), and ISA], all the abstracts were taken for further analysis (Table 1).

Table 1

Sample selected for the study

Name of the service	Year of publication 1982	1983	1984	1985	1986	Total
Samples of abstracts published						
BA	296	308	328	275	262	1469
FA	333	314	324	328	281	1580
FPA	168	143	152	144	111	718
						3767(41%)
All the abstracts published						
CA	181	204	190	175	140	890
EA	118	91	163	137	72	581
EAPA	60	80	140	102	148	530
ERA	431	409	277	387	374	1878
FEA	159	110	86	94	99	548
IEA	60	71	139	150	48	468
ISA	65	40	25	290	124	544
						5439(59%)
Total						9206

For each of the 9206 records the following items of information were noted:

(1) name of the service in an abbreviated form (e.g. BA for *Biomass Abstracts*, CA for *Chemical Abstracts*) followed by year of publication and the abstract number;

(2) name of only the first author, followed by year of publication;

(3) title of the document;

(4) source;

(5) language of the text;

(6) affiliation of the first author (on the back of the card);

(7) document type (e.g. J for journal article, B for book); and

(8) country of the source document.

Each of the 9206 records from the sample was assigned a bibliographic tag: B for book, J for journal article, and so on; there were 13 such bibliographic categories (Table 2). Table 2 shows that over 71% research papers were contributed by journals and conference titles. For each abstracting service, a consolidated list of journal titles was prepared by arranging the 4228 catalogue cards (which carried the tag J) according to the name of journal. These cards were distributed as follows: BA-611, CA-372, EA-470, EAPA-134, ERA-64, FA-1031, FEA-243, FPA-461, IEA-321, and ISA-521. Naturally, many cards under any given service featured the same journal title. Therefore, for each service, the number of separate journal titles were counted, e.g. 611 papers abstracted in BA were contributed by 341 journal titles. The list thus provided data on the number of papers abstracted from each journal title monitored by a particular service.

As a first step, separate slips were prepared for each journal title appearing in the consolidated list of journals monitored by *Biomass Abstracts*. Each slip contained information regarding; (a) title of the journal, (b) country of publication, (c) total number of articles abstracted, and (d) the abstracting services monitoring the journal (Figure 1).

Table 2

Distribution of records according to bibliographic forms

Service	B	BL	C	P	R	RN	S	T	J	I	M	D	L	Total
BA	39	02	451	103	218	20	-	25	611	-	-	-	-	1469
CA	37	01	238	132	95	02	-	13	372	-	-	-	-	890
EA	05	-	096	-	06	04	-	-	470	-	-	-	-	581
EAPA	38	03	205	-	131	06	-	12	134	-	-	01	-	530
ERA	25	06	837	08	907	23	01	02	64	01	-	04	-	1878
FA	23	-	154	-	177	168	-	23	1031	-	02	-	02	1580
FEA	32	-	163	22	86	01	-	-	243	-	-	01	-	548
FPA	16	01	060	-	128	38	05	07	461	-	-	-	02	718
IEA	05	-	132	-	10	-	-	-	321	-	-	-	-	468
ISA	-	-	014	-	07	-	01	01	521	-	-	-	-	544
TOTAL	220	13	2350	265	1765	262	07	83	4228	01	02	06	04	9206

Note : B = book, BL = bibliography, C = conference proceedings, P= patents, R= reports, RN = research note, S = standard, T = theses, J = journal article, I = index, M = map, D = directory, L = leaflet.

Figure 1

Specimen entry for document category J (Format D)

Name of the J/C	BA	CA	EA	EAPA	ERA	FA	FEA	FPA	IEA	ISA	Total
Agriculture						√					
Bruxelles						1					1
(Belgium)											

Explanation : This journal is published from Belgium. It has been monitored by FA only and one research paper was abstracted from this journal during 1982 to 1986.

The second step involved checking the slips against the consolidated list of each service. While collecting these data, it was noticed that some journal titles were common; these journal titles were marked accordingly. However, many journal titles were unique to each consolidated list. For all such titles, slips were prepared and merged in the main alphabetical sequence. In other words, there was only one slip for each journal title, no matter how many services monitored it. To obtain data on the core journals for each service, the slips were arranged in the decreasing order of contribution. In other words, a journal title from which maximum research papers were abstracted was put first in the ranked list of core journal titles. The data on core journals was used to plot Bradford's bibliograph, which describes the scatter pattern of bio-energy literature. For each abstracting service, a consolidated list of conference titles was also prepared by arranging the 2350 catalogue cards (which carried the tag C), according to the name of the conference. These cards were distributed as follows: BA-451, CA-238, EA-96, EAPA-205, ERA-837, FA-154, FEA-163, FPA-60, IEA-132, and ISA-14. Eliminating the duplicates, the number of conference titles for BA amounted to 240, contributing 451 abstracts. The list thus provided data on the number of papers abstracted from each conference title monitored by a particular service. The method followed to obtain data on core conference titles was same as for journal titles as explained above.

RESULTS AND DISCUSSION

Core periodicals

Scrutiny of the consolidated list of journal titles for each service showed that a total of 1571 titles had been monitored by these ten services during 1982-86. For each service, the following table gives the break-up of journal titles and number of papers abstracted from these journals.

It is clear from Table 3 that BA, FA, CA, and FPA together monitored over 67% journal titles, which contributed over 58% of the bio-energy literature. It is interesting to note that only 172 journal titles contributed 52.6% of the literature (Table 4). The remaining 47.4% literature is scattered over 1399 (89%) journal titles. It was further noticed that only 18 journal titles (1.1%) were monitored by more than one service and contributed over 24% literature (Table 5). Six titles from this table were monitored by more than two services.

Table 3

Break-up of journal titles and abstracts

Service	Journal titles		Papers abstracted	
	Number	%	Number	%
BA	341	21.7	611	14.4
CA	213	13.5	372	8.8
EA	144	9.2	470	11.1
EAPA	78	4.9	134	3.2
ERA	38	2.4	64	1.5
FA	325	20.7	1031	24.4
FEA	118	7.5	243	5.7
FPA	187	11.9	461	10.9
IEA	51	3.6	321	7.6
ISA	76	4.8	521	12.3
Total	1571	100.0	4228	100.0

Table 4

Break-up of journals contributing more than 5 and fewer than 5 articles

Service	Journal titles monitored	Number of journal titles contributing 5 or more papers		Number of papers abstracted		Number of journal titles contributing 4		Number of papers abstracted or fewer papers	
		No.	%	No.	%	No.	%	No.	%
BA	341	19	5.6	188	30.8	322	94.4	423	69.2
CA	213	10	4.7	85	22.8	203	95.3	287	77.2
EA	144	24	16.7	295	62.8	120	83.3	175	37.2
EAPA	78	3	3.8	22	16.4	75	96.2	112	83.6
ERA	38	1	2.6	18	28.1	37	97.2	46	71.9
FA	325	59	18.1	635	61.6	266	81.9	896	38.4
FEA	118	9	7.6	85	35.0	109	92.4	158	65.0
FPA	187	21	11.2	211	45.8	166	88.8	250	54.2
IEA	51	11	21.6	253	78.8	40	78.4	68	21.2
ISA	76	15	19.7	431	82.7	61	80.3)	90	17.3
Total	1571	172	11.0	2223	52.6	1399	89.0	2005	47.4

Table 5

Journal coverage pattern

No. of services monitoring the Journal	Number of journals*		Number of papers abstracted	Cumulative Percentage
6	1	Biomass	150	3.5
5	1	Indian Forester	384	12.6
4	2	Biotechnology & Bioengineering Agriculture Wastes	131	15.7
3	2	Biotechnology & Bioengineering Symposium, Transactions of American Society of Agricultural Engineers	68	17.3
2	12		290	24.2
1	118		1220	52.6
Total	136		2223	100.0

* some of these journal titles are no longer published/or merged with other titles

A core list based on all the services yielded 26 journal titles each of which had contributed a minimum of 15 abstracts. These 26 journals, if their contribution in terms of number of articles abstracted is considered, can be designated as the core journals in the field of bio-energy. However, this would be a quantitative and not a qualitative measure. It is clear from the core list that *Indian Forester* contributed the highest number of articles. A total of 388 (9.2%) papers were abstracted from *Indian Forester* by these services and it was monitored by seven services (EAPA and ERA abstracted less than 5 papers). It was further observed that out of 388 papers, ISA abstracted more than 54% and IEA 34% (both Indian). Similar trend was seen for all the top ranked journals, as seen below:

Journal	Total Papers	Percentage/Service
Biomass	152	60.5 (EA)
Biotechnology	70	44.3 (BA)
Allgemeine Forstzeitschrift	48	72.9 (FA)

This indicates that for each service there are a few unique journals from which relatively more papers are abstracted. Language and subject coverage of each service also determines which paper (s) are to be abstracted.

BIBLIOGRAPH

The analysis of the core periodicals showed that bio-energy literature was concentrated among a few major journals, the rest being dispersed among many journals. In the present study, Bradford's bibliograph was plotted for each service by arranging the journals in decreasing order of their contribution on a semilog scale (Figures 2-5).

The purpose of this exercise was to apply Bradford's law of scattering to literature related to bio-energy. The specific tasks were: (1) to verify, for each service, that references follow the Bradford distribution; and to determine the parameters of the distribution; and (2) to verify whether by grouping the services (global) the distribution remains the same.

Before applying Bradford's law to any data it is necessary to ascertain that the data satisfies certain conditions. Brookes [12] suggested that these conditions be; (a) the subject of the bibliography must be well defined; (b) the bibliography must be complete, that is, all relevant papers and periodicals must be listed; and (c) the bibliography must be of limited time-span so that all contributing periodicals have the same opportunity of contributing papers. The data collected as a part of this work satisfied these conditions to a large extent. Brookes [32] suggests an acceptable time-span of three years. This data has a time-span of five years, which is also acceptable. He also suggested that the productivity of the sources considered be at least one reference per annum. In this case it implies that only those sources be considered that have contributed five or more references over the five-year period. However, in this work sources with even lesser contributions have been considered. Yet, it was observed that the nature of the distribution was unaffected.

The precise mathematical formulation to be used would depend on the shape of the distribution, and the information required. It was observed that when the cumulative number of articles was plotted against the logarithm of the cumulative number of journals (ranked in descending order of productivity) the distribution was a smooth curve throughout the range, for the services BA, CA, and EAPA. In the case of EA, ERA, FA, FEA, and FPA the distribution is initially curved and linear later. For IEA and ISA the distribution is uniformly linear, perhaps because of scarce data or that the services are not devoted entirely to bio-energy literature.

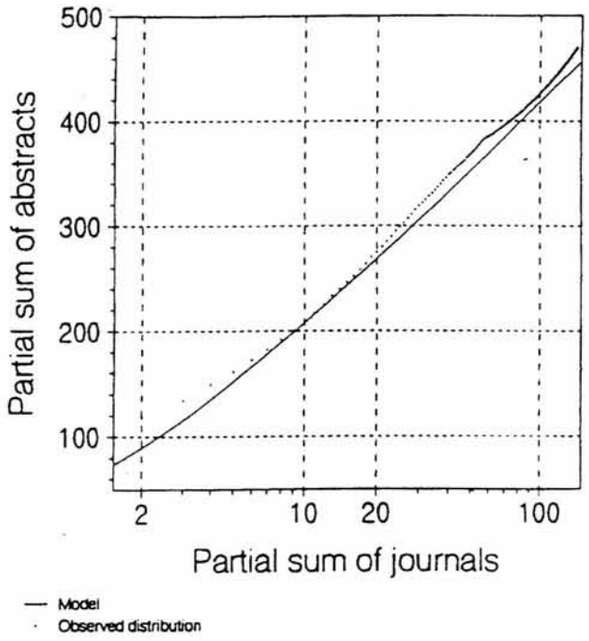

Figure 2 Bradford's bibliograph in the field of biomass (data from EA)

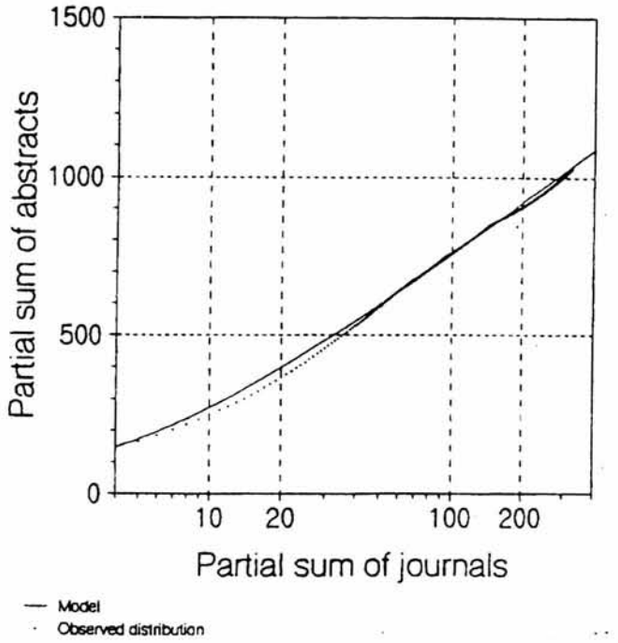

Figure 3 Bradford's bibliograph in the field of biomass (data from FA)

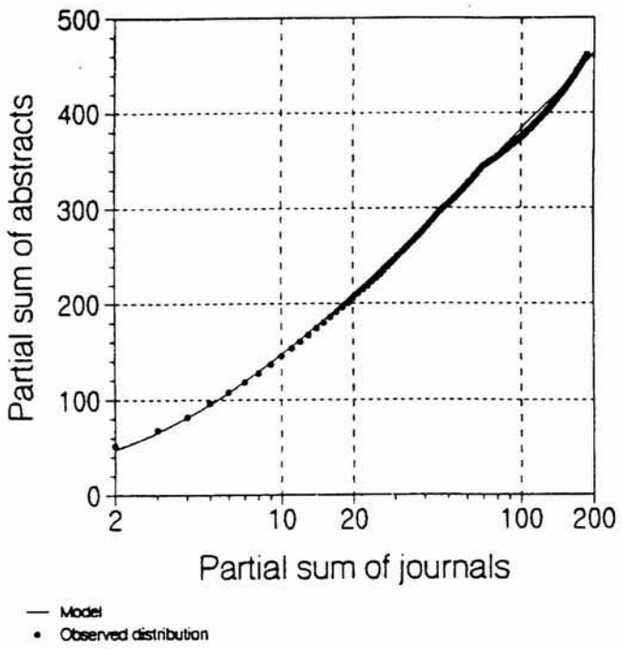

Figure 4 Bradford's bibliograph in the field of biomass (data from FPA)

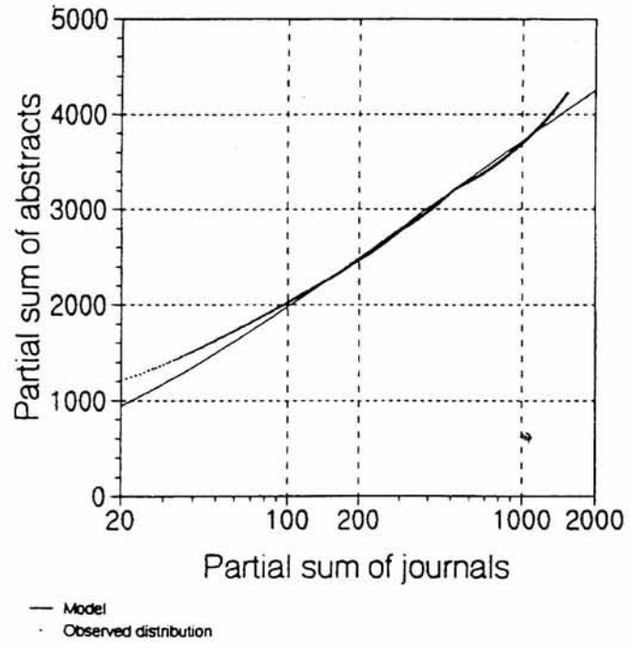

Figure 5 Bradford's bibliograph in the field of biomass (data from all services)

For conference proceedings BA, ERA and FPA exhibit an initial curve followed by a linear portion. Only FA has a uniformly curved distribution, whereas CA, EA, EAPA and FEA are uniformly linear. Again, the distributions for IEA and ISA are anomalous.

Because the distribution of some of the services is initially curved, there is need to use formula that can predict this feature. It is important to mention that in none of the distributions, Groos droop [33] which is supposed to occur at the fag end of the range, was observed. Also, from the point of view of information needs, the formula should be able to predict the number of journals in the nucleus (first or core zone), the number of reference in the nucleus and the multiplication factor.

While the graphical technique proposed by Brookes [32] is simple, the method to predict the size of the nucleus is ambiguous. The formula that has been used here predicts the shape of the distribution and the associated parameters exactly. The major disadvantage with this approach is that computation is complex and therefore requires sophisticated softwares. The formula has the following form:

$R(n) = (c/\log_e p) \times \log_e (1 + (p - 1)n/f)$

where:

- R(n) = cumulated number of papers contributed by the first n ranked journals
- c = cumulated number of papers contributed by the journals in the nucleus
- f = cumulated number of journals in the nucleus
- p = multiplication factor
- n = cumulated number (partial sum) of the first n ranked journals

In deriving this, it has neither been assumed that the bibliography is complete, nor that the total number of journals can be divided into any integral number of zones.

For each service the unknown parameters c, f, and p were determined through non-linear regression analysis, This technique requires initial rough estimates of the parameters. By trial-and -error and from experience it had been discovered that p lies between 2 and 4. Initial values of c and f were obtained by examining the graph of eah distribution. The point where the curve meets the straight line $R(n) = a + b.\log_e (n)$ provided clues to the values of c and f.

The formula yielded excellent results, as evidenced by the fact that r^2 ranges from 0.952 to 0.998 for journals; and from 0.989 to 0.998 for conference procedings.

The value of p ranged from 2.19 to 4.09 (for all services other than IEA and ISA) for journal articles; and from 2.02 to 4.59 for conference proceedings. It was observed that 2-12% of journals contributed one-fifth to one-third of the papers and 3-13% of the conference proceedings contributed one-fourth to one-third of the papers. The extremely high value of p for journals articles in IEA and ISA is perhaps because these services monitored few titles from the field of bio-energy.

In conclusion, it was verified that literature related to bio-energy conforms to Bradford's law of scattering and that grouping of services (global) also yields a Bradford distribution.

Table 6 gives comparative data on partial sum of references (c) and journals (f) in the first zone and multiplication factor (p). Multiplication factor in the present study ranged between 2 and 4, except in case of IEA and ISA, where it was higher, because there were only a few productive journals. In other words, fewer journal titles in the first zone means that the respective service (s) abstracts relatively more papers from these journals. When all the services were considered, for a constant number of articles, in this case 996, the number of journals increased by a multiple of 3.6.

Table 6

Comparative data on the Bradford's Law as applicable in the field of biomass

	No. of journal titles in the 1st zone (c)	f as% of total journal titles	No.of papers in the first zone (f)	c as % of total papers	Multiplication factor (p)	r^2
BA	26	8	191	31	3.03	0.980
CA	16	75	98	26	2.19	0.991
EA	4	3	135	29	4.09	0.996
EAPA	9	12	43	32	2.38	0.995
ERA	4	11	22	34	3.56	0.952
FA	6	2	196	19	2.21	0.997
FEA	6	5	60	25	2.38	0.995
FPA	5	3	95	21	2.24	0.998
IEA	2	4	169	53	37.80	0.995
ISA	1	1	253	49	50.71	0.984
Global	22	1	996	24	3.60	0.988

Table 7 gives a list of journals appearing in the first zone of all services. It is clear from this table that 32 titles were monitored by only one service, 14 titles by two services, and one title each by three, four, five and six services. The last four titles - *Biomass, Indian Forester, Biotechnology and Bioengineering, Biotechnology and Bioengineering* Symposium - do feature in the list of journals in the first zone based on all the services (Table 8).

Table 7

Journals appearing in the first zone (all services)

	No. of papers abstracted	BA	CA	EA	EAPA	ERA	FA	FEA	FPA	IEA	ISA	sTotal
1	Acqua Aria, Italy 4	–	√	–	–	–	–	–	–	–	–	1
2	Adv Biochem Eng, USA 5	–	√	–	–	–	–	–	–	–	–	1
3	Agricultural Wastes, UK 29	√	–	–	–	–	√	–	–	–	–	2
4	Alt Energy Sources, USA 11	√	√	–	–	–	–	–	–	–	–	2
5	Allgemeine Forstzeitschrift, Ger 39	√	–	–	–	–	√	–	–	–	–	2
6	Applied Biochem Biotechnol, USA 6	√	–	–	–	–	–	–	–	–	–	1
7	Applied & Environ Microbiol, USA 14	√	√	–	–	–	–	–	–	–	–	2
8	Biomass, UK 147	√	√	√	√	√	–	√	–	–	–	6

contd.

(contn.) table 7

No. of papers abstracted	BA	CA	EA	EAPA	ERA	FA	FEA	FPA	IEA	ISA	Total
9 Biotech Bioeng, USA 70	√	√	√	–	–	–	√	–	–	–	4
10 Biotechnol Bioeng Symp, USA 27	√	√	–	–	√	–	–	–	–	–	3
11 Biotechnol Lett, UK 13	√	√	–	–	–	–	–	–	–	–	2
12 Can J Chem Eng, Canada 6	–	√	–	–	–	–	–	–	–	–	1
13 Can J Forestry Res, Canada 43	√	–	–	√	–	–	–	–	–	–	2
14 Changing Villages, India 41	√	–	–	–	–	–	√	–	–	–	2
15 Chem Age India, India 8	–	√	–	–	–	–	–	–	–	–	1
16 Chem Engineering, UK 3	–	–	–	√	–	–	–	–	–	–	1
17 Chem Eng Pro, USA 4	–	√	–	–	–	–	–	–	–	–	1
18 Ecology, USA 7	–	–	–	–	√	–	–	–	–	–	1
19 Energy, UK 30	–	–	√	√	–	–	–	–	–	–	2
20 Energy in Agril, Neth 12	√	–	–	√	–	–	–	–	–	–	2
21 .Energy Exploration & Exploitation, UK 4	–	–	–	√	–	–	–	–	–	–	1
22 Energy Environ & Dev in Africa 7	–	–	–	√	–	–	–	–	–	–	1
23 Energy Policy, UK 4	–	–	–	√	–	–	–	–	–	–	1
24 Enzyme Microbiol Technol, UK 6	√	–	–	–	–	–	–	–	–	–	1
25 Forest Products J, USA 21	√	–	–	–	–	–	–	√	–	–	2
26 Forest Science, USA 25	–	–	–	–	√	√	–	–	–	–	2
27 Fuel, UK 4	–	√	–	–	–	–	–	–	–	–	1
28 Holz als Roh und Werkstoff, Ger 14	–	–	–	–	–	–	–	√	–	–	1
29 Holzforschung, Ger 5	√	–	–	–	–	–	–	–	–	–	1
30 Holz–zentralblatt, Ger 20	–	–	–	–	–	–	–	√	–	–	1
31 Gas Wasser Abwasser, Ger 8	–	–	–	–	–	–	√	–	–	–	1
32 Indian Forester, India 383	√	–	–	√	–	√	–	–	√	√	5
33 J Am Oil Chem Soc, USA 6	√	–	–	–	–	–	–	–	–	–	1
34 J Analytical & Applied Pyrolysis, USA 9	–	√	–	–	–	–	–	–	–	–	1
35 J Chem Technol Biotechnol, UK 9	√	–	–	–	–	–	–	–	–	–	1
36 J Ferment Technol, Japan 13	√	–	–	–	–	–	–	–	–	–	1
37 J of the Japan Wood Res Soc, Japan 16	–	–	–	–	–	–	–	√	–	–	1
38 J Water Pollution Control Fed, USA 11	√	√	–	–	–	–	–	–	–	–	2
39 Khim Drev, USSR 4	√	–	–	–	–	–	–	–	–	–	1
40 Lesnoe Khozyaistvo, USSR 46	–	–	–	–	–	√	–	–	–	–	1
41 Lesnoi Zhurnal, USSR 32	–	–	–	–	–	–	–	√	–	–	1
42 Lesovedenie 20	–	–	–	–	–	√	–	–	–	–	1
43 Prepr Pap Am Chem Soc Div Fuel Chem, USA 8	√	–	–	–	–	–	–	–	–	–	1
44 Process Biochem, UK 5	√	–	–	–	–	–	–	–	–	–	1
45 Resour Conserv, Neth 16	√	–	–	–	√	–	–	–	–	–	2
46 Science, USA 4	√	–	–	–	–	–	–	–	–	–	1
47 Starch 4	√	–	–	–	–	–	–	–	–	–	1
48 Trans of the ASAE, USA 6	√	–	–	–	√	–	–	–	–	–	2
49 Water Res, UK 5	√	–	–	–	–	–	–	–	–	–	1
50 World Development, UK 4	–	√	–	–	–	–	–	–	–	–	1
Total	26	16	3	9	4	6	6	5	2	1	78

Table 8

List of journals appearing in the first zone (all services): some key data

Journal	No. of papers abstracted	%	Impact factor	Annual subscription ($) in 1991-92
Indian Forester	388	9.2	-	150
Biomass	152	3.6	0.434	734
Biotechnology and Bioengineering	70	1.6	1.376	1225
Agricultural Wastes	61	1.4	0.264	1017
Allegemeine Forstzeitschrift	48	1.1	-	178
Lesnoe Khozyaistvo	46	1	-	-
Biotechnology and Bioengineering Symposium	45	1	-	635
Lesnoi Zhurnal	44	1	-	-
Canadian Journal of Forestry Research	43	1	0.644	71
Changing Villages	41	0.96	-	30
Energy	35	0.82	0.204	664
Holz-zentralblatt	29	0.68	-	172
Forest Science	25	0.6	0.552	80
Transactions of American Society of Agricultural Engineers	25	0.6	-	-
Forest Products Journal	21	0.5	0.370	155
Resources and Conservation	21	0.5	0.259	157
Lesovedenie	20	0.47	-	-
Holzforschung	17	0.4	0.996	514
Journal of Analytical & Applied Pyrolysis	17	0.4	0.816	379
Journal of Japanese Wood Research Society	16	0.37	-	-
Alternative Energy Sources	14	0.33	-	102
Applied & Environmental Microbiology	14	0.33	2.356	220

If the costs of acquiring the first four journals are considered, then 16% coverage of journal literature would cost $3126, 50% would cost $9769 and 75% would cost $14653 (actual costs of first four journals, estimated for others; personnel and other costs excluded). The costs of monitoring and available percentage/share of journal coverage would change if one were to opt for only one or two services. For example, in case of IEA and ISA, 40-50% journal coverage would cost only $150-180 whereas in case of FPA, 20% coverage costs $1034, Table 9, [34].

Table 9

Coverage pattern and estimated costs

Service	Number of journals in the 1st zone	Number of papers abstracted	Journal coverage %	Estimated subscription costs ($) in 1991-92
BA	26	214	35.0	8175
CA	16	109	29.3	9729
EA	3	134	28.5	2623
EAPA	9	45	33.6	4110
ERA	4	26	40.6	691
FA	6	185	17.9	725
FEA	6	68	28.0	4099
FPA	5	96	20.0	1034
IEA	2	170	52.9	150
ISA	1	210	40.3	180

Thus, the users of these services and libraries/ information centres working in the area of bio-energy/renewable energy, will have to adopt combined strategy to achieve maximum journal coverage - perhaps only 20-30% coverage of journal literature. The additional or more coverage could only be obtained by use of *Current Contents* and scanning most appropriate abstracting service(s).

CORE PERIODICALS AND JCR IMPACT FACTOR

Journal Citation Reports (JCR) extends the use of citation analysis to examine the relationship among journals. Bibliometric rankings reported in JCR include impact factor, immediacy index, citing half-life, and self citation rate. Impact factor is a measure of the frequency with which the average article in a journal has been cited in a particular year [35]. The impact factor is basically a ratio of cited item to citable source item published. The impact factor, in the opinion of Garfield, permits some refinement of quantitative data to evaluate relative standing of journals. The qualification is algorithmic and objective, "but nonetheless useful" in journal evaluation [36]. Out of the 50 core journals in the first zone, 24 (48%) were found to be covered by *Science Citation Index*. These 24 journals contributed over 14% of the bioenergy energy literature. *Science* had the highest impact factor, but the journal ranked 46th in the present study. When impact factor for journals contributing 20 or more papers was checked, it was found that most of the bio-energy journals (except *Biotechnology and Bioengineering*) had an impact factor of less than one (Table 10). *Indian Forester*, which occupied first position in this study, was not covered by *Science Citation Index*.

Table 10

Impact factor for core journals

Journal	No. of papers abstracted	Impact factor
Biomass	152	0.434
Biotechnology and Bioengineering	70	1.376
Agricultural Wastes	61	0.264
Canadian Journal of Forestry	43	0.644
Enegry	35	0.204
Forest Science	25	0.552
Forest Products Journal	21	0.370
Resources and Conservation	21	0.259
Holzforschung	17	0.996
Journal of Analytical & Applied & Pyrolysis	17	0.816
Applied & Environmental Microbiology	14	2.356
Holz alas Roh und Werkstoff	14	0.048
Biotechnology Letters	13	1.117
Journals of Fermentation Technology	13	0.737
Energy in Agriculture	12	0.041
Fuel	11	1.040
Journal of Water Pollution Control Federation	11	0.776
Journal of Chemical Technology Biotechnology	9	0.435
Science	9	16.458
Ecology	7	2.550
Applied Biochemistry & Biotechnology	6	1.162
Canadian Journal of Chemical Engineering	6	0.535
Journal of American Oil Chemical Society	6	0.880
Water Research	5	1.308

CORE CONFERENCE TITLES

Examining the consolidated lists of conference titles covered by each service revealed that a total of 889 titles were monitored by these ten services (Table 11). It was further noticed that only 114 conference titles (12.9%) contributed 5 or more papers (Table 12). These 114 conference titles contributed over 50% papers, and the remaining literature was scattered in over 775 conference titles (87.2%). Out of 114 conference titles, 80 were unique to the respective service; they were covered by only one service (Table 13).

Table 11

Break-up of conference titles and number of abstracts

Service	Conference titles		Papers abstracted	
	Number	%	Number	%
BA	246	27.7	451	19.2
CA	79	8.9	238	10.1
EA	45	5.0	96	4.0
EAPA	67	7.5	205	8.7
ERA	232	26.0	837	35.6
FA	98	11.0	154	6.5
FEA	57	6.4	163	6.9
FPA	39	4.4	60	2.5
IEA	22	2.5	132	5.6
ISA	4	0.4	14	0.6
Total	889	100.0	2350	100.0

Table 12

Break-up of conference titles contributing more than 5 and fewer than 5 articles

Service	Conference titles monitored	Conference titles contributing 5 or more papers		Papers abstracted		Conference titles contributing 4 or fewer papers		Papers abstracted	
		No.	%	No.	%	No.	%	No.	%
BA	246	16	6.5	0113	25.0	230	93.5	0338	75.0
CA	79	13	16.4	0131	55.0	066	83.6	0107	45.0
EA	45	5	11.1	0046	47.9	040	88.9	0050	52.1
EAPA	67	9	13.4	0120	58.5	058	86.6	0085	41.5
ERA	232	48	20.7	0545	65.1	184	79.3	0292	34.9
FA	98	2	2.0	0014	9.0	096	98.0	0140	91.0
FEA	57	11	19.3	0099	60.7	046	80.7	0064	39.3
FPA	39	1	2.6	0006	10.0	038	97.4	0054	90.0
IEA	22	8	36.4	0113	85.6	014	63.6	0019	14.4
ISA	4	1	25.0	0007	50.0	003	75.0	0007	50.0
Total	889	114	12.8	1194	50.8	775	87.2	1156	49.2

Table 13

Conference title coverage pattern

Number of services monitoring the conference title	Number of conferences abstracted	Number of papers	Cumulative papers %	Cumulative
5	01[a]	0042	-	01.8
4	03[b]	0158	0200	08.5
2	10[c]	0245	0445	19.9
1	80	0749	1194	50.8
94	1194			

a Bioenergy 84, 1984, Sweden

b Energy from Biomass, 1985. Italy
Energy from Biomass, 1981, UK
Fuels from Biomass and Wastes, 1981, USA

c Biomass Thermochemical Conservation 13, 1981 USA
Biomass Thermochemical Conservation 16, 1984 USA
Ecology and Management of Forest Biomass 1984, USA
Energy from Biomass, 1981, Denmark (Procd. of EC contractor's meet)
Energy from Biomass & Wastes 4, 1980, USA
Energy from Biomass & Wastes 8, 1984, USA
Energy from Biomass & Wastes 9, 1985, USA
Industrial Wood Energy Forum 1982, USA
Nato Adv Study on Biomass Utilization 1983, Portugal
Proceeding of Regional Workshop on Biomass Energy

A core list based on all the services yielded 21 titles and contributed 25.7% papers. Maximum number of papers were abstracted from *Energy from Biomass* 1981, UK - a conference devoted entirely to different issues in biomass energy.

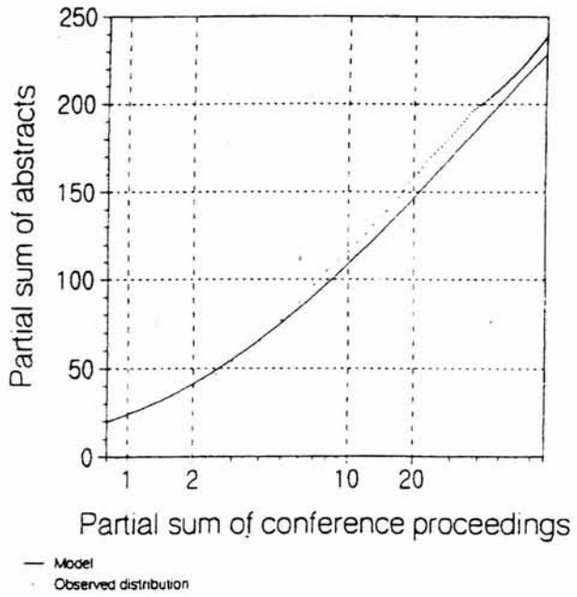

Figure 6 Bradford's bibliograph in the field of biomass (data from CA)

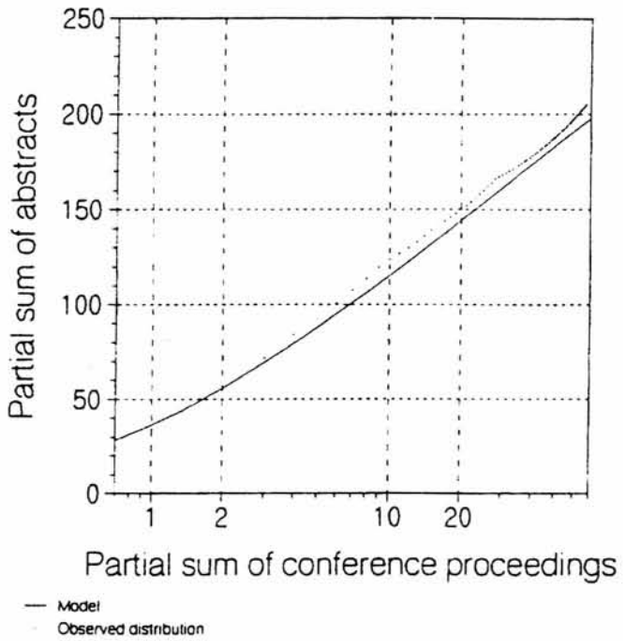

Figure 7 Bradford's bibliograph in the field of biomass (data from EAPA)

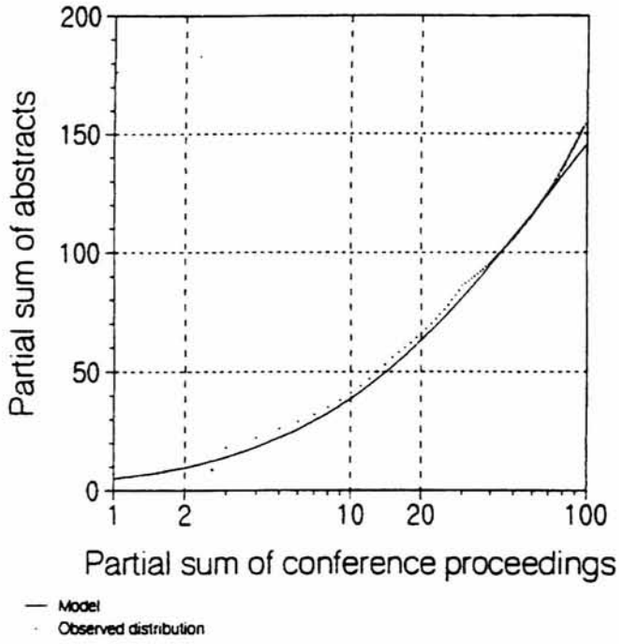

Figure 8 Bradford's bibliograph in the field of biomass (data from FA)

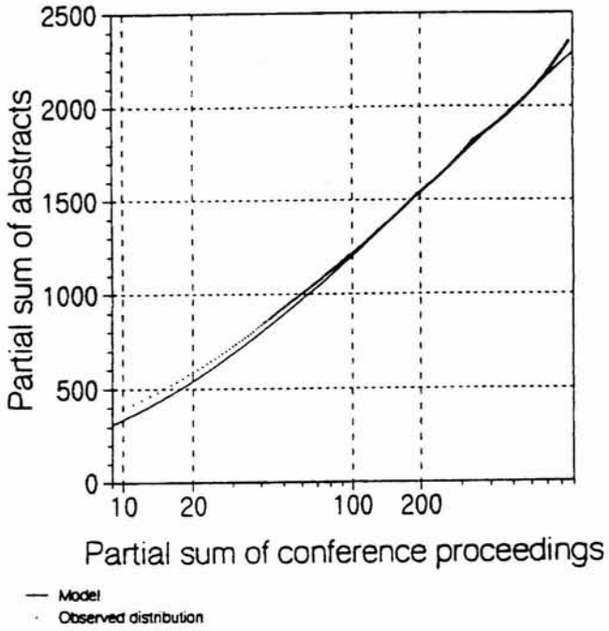

Figure 9 Bradford's bibliograph in the field of biomass (data from all services)

From the above discussion, it is clear that bio-energy literature published in the form of conference proceedings was concentrated among a few titles. Bradford's law might also hold good for conference literature. Keeping this in mind, an attempt was made to plot Bradford's bibliograph for each service by arranging the conference titles in decreasing order of their contribution on a semilog scale (Figures 6-9). Table 14 gives comparative data on Bradford's law as applicable for conference titles. The multiplication factor for conference literature/titles ranged between 2 and 3 except for IEA, where it is almost 5.

Table 14

Comparative data on Bradford's law as applicable for conference literature in the field of biomass

	No. of conference titles in the first zone (f)	f as % of total conference titles	No. of papers in the 1st zone (c)	c as % of total papers	Multiplication factor (p)	r^2
BA	21	09	125	28	2.14	0.996
CA	04	05	066	28	2.86	0.997
EA	02	04	030	31	3.55	0.989
EAPA	02	03	056	27	3.60	0.998
ERA	06	03	201	24	2.67	0.994
FA	13	13	047	31	2.02	0.995
FEA	03	05	050	31	3.19	0.991
FPA	05	13	019	32	2.15	0.991
IEA	02	09	060	46	4.59	0.936
ISA	-	-	-	-	-	-
Global	20	02	541	23	2.85	0.997

LOTKA'S DISTRIBUTION

Results and discussion

The number of authors and their respective distribution was obtained from the alphabetical sequence of author (Table 15). The productivity data for each service was also compiled from the alphabetical sequence of author (Table 15).

Table 15

Comparative data on the productivity of authors in the field of bio-energy

Service	No. of contributions														
	1	2	3	4	5	6	7	8	9	10	11	14	16	18	25	Total
BA	1274	48	9													1397
CA	648	64	14	7	2	1					1					873
EA	466	34	2	2												548
EAPA	367	26	4	4		1			1							462
ERA	1045	110	19	14	7	6	7		2	1	1	1	1	1		1597
FA	1389	64	11	3			1									1569
FEA	339	27	6	3	1	1	1	1					1		1	483
FPA	626	29	6													702
IEA	317	38	9	2	2	2	1				1					-
ISA	325	40	14	11	5	2		2								544
Global	6796	480	94	46	17	13	10	3	3	1	3	1	2	1	1	8638

Note : Total refers to sum of authors (and not sum of abstracts/papers) after removing Anonymous.

In the present study Lotka's distribution has been applied to the author productivity data of each of the ten abstracting services and also to all of them together (i.e. globally) using the following equation:

$x^n \cdot Y_x = c$ or $y = c/x^n$ - Equation (1)

The above equation can also be linearized by applying logarithms to both sides of the above equation:

$\log y_x = \log c - n \log x$ - Equation (2)

where y is the number of authors making x contributions to the subject, and n and c are two constants to be estimated for the specific set of data. Pao [23,24] defined a new term, C, as:

$C = c/(\Sigma y_x)$ - Equation (3)

Pao has also provided a formula to estimate the approximate value of C. We used the same formula in addition to estimating C through linear regression. Before doing the analysis we truncated the data set at either the first occurrence of $x_n = 1$ or the first occurrence of $x_{n+1} = x_n$ (i.e the curve begins to flatten out). This method has also been used by Nath and Jackson [21]. But in the case of ERA, ISA and Global, data were truncated based on selecting the most linear portion of the curve when data were plotted on a log-log graph.

The results of linear regression based on Equation 2 show that Lotka's distribution holds good for bio-energy literature and the value of n ranges between 2.9 and 4.5 (Table 16, Figures 10-13).

Table 16

Parameters of Lotka's distribution for ten abstracting services

Service	Number of data points	n	Value of c through regression	r^2	Value of C		
					Observed	using Pao's formula	through regression
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BA	3	4.532	1228	0.999	0.957	0.949	0.952
CA	6	3.576	716	0.994	0.880	0.894	0.897
EA	4	4.259	468	0.956	0.925	0.938	0.940
EAPA	3	4.082	386	0.997	0.924	0.929	0.934
ERA	3	3.605	1117	0.994	0.890	0.897	0.908
FA	4	4.420	1386	0.999	0.947	0.945	0.946
FEA	5	3.544	329	0.997	0.902	0.892	0.895
FPA	3	4.252	605	0.998	0.947	0.937	0.942
IEA	3	3.222	327	0.998	0.871	0.860	0.880
ISA	3	2.880	316	0.998	0.858	0.815	0.849
Global	5	3.684	6425	0.997	0.914	0.903	0.906

The Kolmonogorov-Smirnoff goodness-of-fit test was used to confirm the applicability of Lotka's distribution to this data (Table 17). We did not observe a significant difference in the estimate of C between PAO's formula and the linear regression method. But it was observed that a non-linear regression method based on Equation 1 provided a better fit to the data (r = 0.999 for all services, Table 18). In this case we did not truncate the data set. The COSTAT statistical package was used for performing the non-linear regression. The algorithm requires the user to provide initial guess values for the two parameters, n and c. We used the values presented in Table 16 (columns 3 and 4) for this purpose. The data on proportion of papers contributed by single author (s) revealed three distinct groups (Table 19) which are services where papers contributed by single author (s) were more than 80% (BA, EA, FA, & FPA); 67-70% (CA, EAPA, & IEA) and below 70% (ERA, FEA, & ISA). This also indicates that in the last group (ERA, FEA, & ISA) a greater fraction of papers were contributed by the more productive authors.

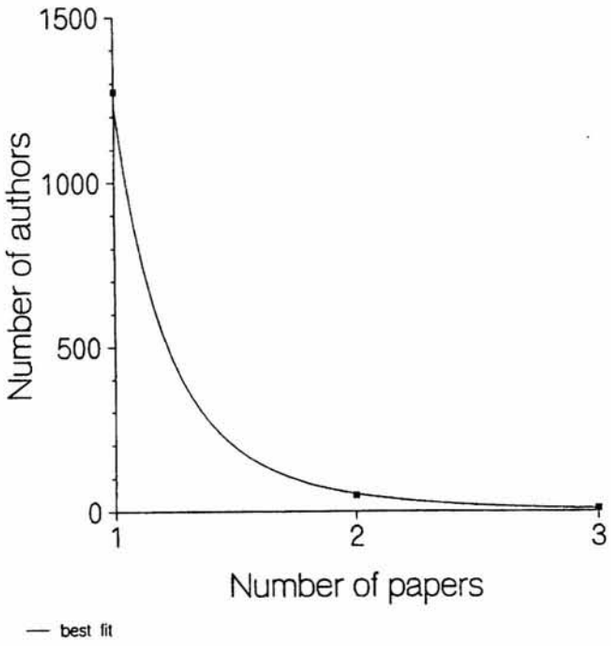

Figure 10 Lotka's distribution : *Biomass Abstracts*

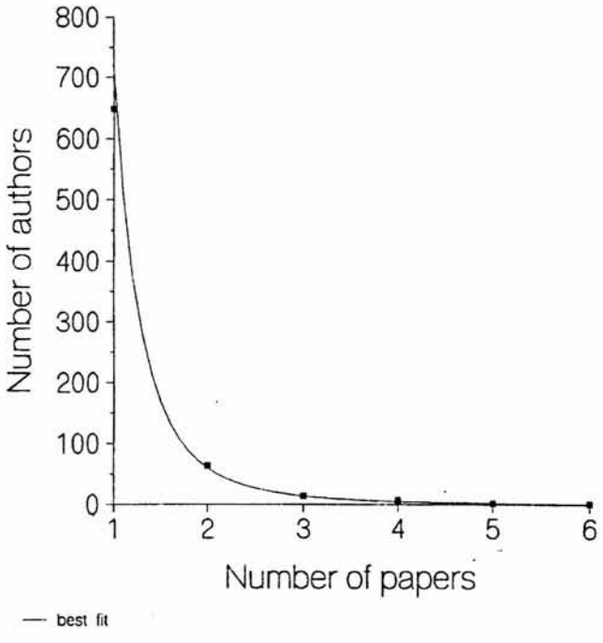

Figure 11 Lotka's distribution : *Chemical Abstracts*

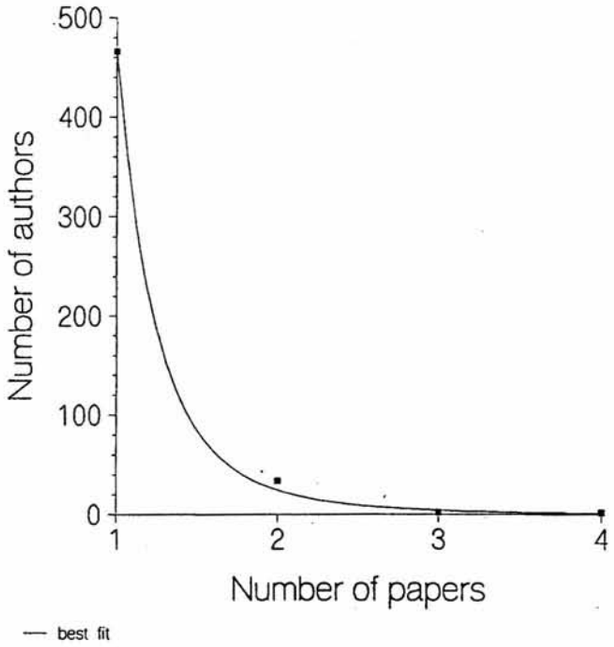

Figure 12 Lotka's distribution : *Energy Abstracts*

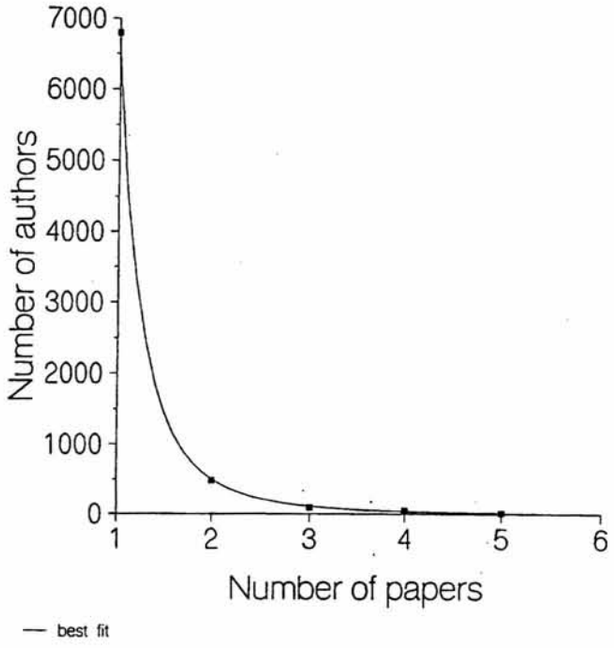

Figure 13 Lotka's distribution : Global

Table 17

Goodness of fit of the data to Lotka's distribution using Kolmonogorov-Smirnoff test

Service	Critical Value at $\mu = 0.01$	D_{max}	
		Using C derived from ordinary regression	Using Pao's formula for C
BA	0.045	0.005	0.008
CA	0.060	0.017	0.014
EA	0.073	0.015	0.013
EAPA	0.082	0.010	0.006
ERA	0.048	0.018	0.013
FA	0.043	0.001	0.002
FEA	0.084	0.007	0.010
FPA	0.063	0.005	0.010
IEA	0.085	0.009	0.023
ISA	0.084	0.009	0.043
Global	0.019	0.008	0.011

Table 18

Parameters of Lotka's distribution obtained through non-linear regression

Service	C	N
BA	1274	4.72
CA	648	3.36
EA	466	3.85
EAPA	367	3.83
ERA	1045	3.28
FA	1389	4.44
FEA	339	3.64
FPA	626	4.42
IEA	317	3.10
ISA	325	2.94
Global	6796	3.83

r^2 = 0.999 for all services

Table 19

Proportion of papers (%) contributed by given number of authors

Service	Number of authors					
	1	2	3	4	Others	Total
BA	91.2	6.9	1.9	-	-	1397
CA	74.2	14.8	4.8	3.2	3.0	873
EA	85.0	12.4	1.1	1.4	-	548
EAPA	79.4	11.2	2.6	3.5	3.3	462
ERA	65.6	13.8	3.3	3.5	13.8	1592
FA	88.5	8.1	2.1	0.8	0.5	1569
FEA	70.2	11.2	3.7	2.5	12.4	483
FPA	89.1	8.3	2.6	-	-	702
IEA	67.7	8.1	5.8	1.7	16.7	468
ISA	59.7	14.7	7.77	8.0	9.9	544
Global	78.7	11.1	3.3	2.1	4.8	8638

Note : Anonymous authors were not considered

CONCLUSIONS

The important findings of the study are summarized below.

It was found that bio-energy literature conforms to Bradford's law of scattering and that grouping of services (all the ten services together) also followed a Bradford distribution. The new model developed in this study fits the data very satisfactorily - r^2 value ranged from 0.952 to 0.998 (for papers from journal titles) and 0.989 to 0.998 (for papers from conference proceedings).

The value of p (multiplication factor) for bio-energy literature ranged from 2.19 to 4.09 (except for IEA and ISA) for articles from journal titles and from 2.02 to 4.59 for papers from conference titles. It was further observed that; (a) 2 to 12 percent journal titles contributed one-fifth to one-third of papers, and; (b) 3-13 percent of the conference titles contributed one-fourth to one-third of papers. The extremely high value of p for journal articles in IEA and ISA is perhaps because these services monitored few titles from the field of bio-energy.

The data also revealed that direct scanning of core journal titles in the first zone would ensure only 20-30 % coverage of journal literature. The additional coverage could only be obtained by use of *Current Contents* and scanning most appropriate abstracting service(s).

The data on the coverage pattern of journal titles indicated that annual subscription would range between US $ 150 - 9729 depending upon the number of titles selected from the first zone of a particular service (Table 9).

Out of fifty core journal titles in the first zone, twenty four (48%) were found to be covered by *Science Citation Index*. These twenty four titles contributed over 14% of biomass energy literature. Most of the biomass journals had an impact factor of less than one (except for *Biotechnology and Bioengineering*).

The data fits Lotka's distribution. This is true when data are considered separately for each service as well as when they are pooled together. This implies that in large samples multiple entries of the same abstract (from different services) does

not affect Lotka's distribution. The value of n ranged from 2.88 to 4.53, and that of C from 0.82 to 0.95.

It is observed that the abstracts of the most productive authors generally appear in *Chemical Abstracts, Energy Research Abstracts, Fuel and Energy Abstracts, Indian Energy Abstracts,* and *Indian Science Abstracts* (that is, in these cases value of C is comparatively less).

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