Mapping of Earth Science Research in West Bengal: A Bibliometric Study

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Abstract -The present study is based on 393 PhD theses of Earth sciences submitted to the various universities of West Bengal for the award of doctoral degree during the period 1960-2012. Besides, a citation analysis has also been done through the study of 8910 citations appended to the theses for the period of 2008-2012. The main purpose of this study is to investigate chronological distribution of theses, gender-wise distribution, supervisor-ship pattern, subject-wise distribution. The findings of the study revealed that an average of 7.43 theses was published during the whole period under study; the relative growth rate and doubling time for theses under study work out to 0.631 and 0.966 respectively; the grand average number of citations per theses was 146 citations and journals is the most prolific bibliographic forms used by the researchers. This study also examines the conformity to Lotka's law with the distribution of data.
Keywords: Earth Sciences, Relative Growth Rate, Doubling time, Journals Ranking, Bradford's law, Lotka's law, Ph.D. Theses, West Bengal.

I. INTRODUCTION

In Universities and other higher level educational institutions research is carried out in science as well as in social science disciplines, pure research develops theories by discovering broad generalizations or Principles for further understanding of a phenomenon. The branch of science dealing with the physical constitution of the earth and its atmosphere is popularly known as earth science. Bibliometric indicators are quite useful in examining the direction and flow of research based knowledge and also for mapping the structure and changing the shape of knowledge creation, resources and infrastructure of a particular journal, institution and a country. In the present communication we propose to make an in-depth survey of the contributions of universities of West Bengal in the Earth Sciences research through the analysis of doctoral theses awarded by them.

II. OBJECTIVES OF THE STUDY

1. To study the chronological distribution of theses;
2. To study gender-wise distribution of theses for research scholars;
3. To study the supervisor-ship pattern;
4. To study trend of research in earth sciences (subject trend);
5. To analysis citations in order to highlights the following aspects:
   a. Average number of citations per theses;
   b. Identify the bibliographic forms of citations;
   c. Testify the Lotka's law of author's productivity.

III. SCOPE AND COVERAGE

An attempt has been made in this study to what extent the Ph.D. programs in Earth science so far completed in the premier universities in West Bengal after independence period. The present study covers five general universities of West Bengal, namely, University of Calcutta, Jadavpur University, University of Burdwan, University of North Bengal, and Vidyasagar University. This study is also concerned with the analysis of citations appended to the doctoral theses awarded by the said universities for the period of 2008-2012 only.

IV. METHODOLOGY

Hard copies of different primary and secondary sources were manually as well as electronically scanned for collecting articles on earth science research. Citations of each thesis were recorded manually on a standardized way. With the aid of MS-Excel and SPSS software, we tried to analyse the collected data on the basis of objectives of this study. We also applied several bibliometric indicators for this study.

V. LITERATURE REVIEW

A number of bibliometric studies have been carried out to analyses the research productivity in certain subjects of different academic institutions of India or abroad. Some of these are as follows:

Chakraborty (1981) emphasized on the trend towards team research in geology in the following three spheres-1) total geological literature to project an overall picture in the subject; 2) Indian contributions in geology; and 3) three sub-fields of geology viz. paleontology, petrology and stratigraphy to indicate trend. Bibliography and Index of Geology published by the American Geological Institute had been taken as the base of this study.

Bandyopadhyay (1996) made an analysis of twenty seven PhD theses in mathematics submitted to the Burdwan University during 1981-1990. The author used dBase lll+ software for the analysis of citations appended to these dissertations. The bibliographic forms of citations, rank list

of periodicals according to Sengupta's formula and a correlation study between two lists found by the study had also been discussed.

Barooah, Begum, and Sharma (1999) conducted a bibliometric analysis on 4,253 citations appended to doctoral dissertations submitted to various universities in the area of organic chemistry from 1977 to 1997. The study mainly determined the use pattern of chemistry literature by the researchers. It also observed that major citations were from journal literature. Citations from books, proceedings, patents, reports and thesis were also occupied a significant share. The prevalence of foreign journals was also found. Journals from USA, UK occupied leading positions among the cited journals. The half-life of literature in the field of organic chemistry was 27 years.

Mahapatra and Das (2000) attempted to drive nature of growth of literature in Geology during 1987 to 1996, type of collaboration among authors and the trend of growth during this period, degree of collaboration among various categories of authors, correlation of the growth of various categories of authors and impact of collaboration on growth literature.

Shafi and Gazi (2005) analysed one hundred PhD theses submitted to Kashmir University during the period 1980-2000 in the field of natural sciences. Authors found that the number of citations given in support of literature review is not adequate which does not exceed 50-100 citations in 32 % theses. The highest citations were from journals followed by seminar proceedings. The half-life of journal citations was 37 years. The maximum numbers of journal use pertain to 1982-91 and 1972-76.

Agashe and Rajyalakshmi (2008) examined the research productivity of Science, Pharmaceutical Sciences and Home science departments in Nagpur University, during the 2000-2002. The period-wise, department-wise and supervisor-wise distributions of doctoral dissertations were also examined. To ascertain the types of most frequently used documents, the most frequently consulted journals and obsolescence rate of the journals, Vallmitijana and Sabate (2008) conducted a citation analysis of forty six doctoral dissertations in Chemistry presented at the Institute Quimic de Sarria (IQS) for the period 1995- 2003. The result revealed that the most frequently used document was scientific papers (79%). It also showed that about 50 percent of the information needs were satisfied by 33 journals only; and the age of 50 percent of the citations was below 9 years.

Verma and Thakur (2010) made an examination of thirty five doctoral dissertations in the area of botany awarded at Pt Ravishankar Shukla University from 1966 to 2004. A total of 7916 references were analysed in order to recognize their bibliographic form, identify the authorship pattern and determine the ranking of journals. The study revealed that journal (72.54%) was the most preferred by the researcher in the field of botany. The prevalence of solo research was

also observed. Researchers of this university were cited Indian journals mostly.

Krishna (2011) carried out a study on sixty eight theses of Rajasthan Agricultural University, Bikaner during 1996-2000. The period-wise distribution of theses, average citation pattern per thesis, subject-wise distribution of theses, forms of documents used, gender wise distribution of thesis, language wise distribution of cited documents, etc. were analysed thoroughly.

Haldua, Arya and Kaushik (2012) investigated citations attached to dissertations submitted by the doctoral students of the molecular biology and biotechnology sciences at the G B Pant University of Agriculture and Technology, Pantnagar, India for the period 1998-2010. The use pattern of molecular biology and biotechnology literature by doctoral students was mainly determined through this study.

Dutta and Rath (2013) studied 834 articles (from Web of Science) on Carbon nanotube research in India for the period 1999-2012. The study analysed literature growth trends, which reveals an initiation of potential growth of research in this area since 2008. The authors had also examined collaborations with different countries worldwide. The authorship pattern, document types involved and active Indian institutions co-coordinating research in this subject area had also been studied. Lotka's law was employed to study the authors' productivity pattern.

Anilkumar and Rajaram (2013) examined the cited resources used by the doctoral students of the Physical Research Laboratory (PRL) for the period 1997–2006. It was observed that electronic format was preferred to the printed format. Journal articles were the most preferred resource, followed by books and other resources like proceedings and reports by the students. The availability of online resources was noticed during the period of study.

Gohain and Saikia (2014) made a citation analysis of 10983 citations, affixed to thirty doctoral dissertations of Chemical sciences submitted to Tezpur University, Assam for the period 2008-2012. The investigation of authorship pattern, type and form of literature cited, and compilation of a rank list of core journals were the main objectives of this study. The study revealed that journals (78.83%) were the most preferred sources of information used by the researchers, followed by books with 15.57 % citations. The Journal of American Chemical Society occupied first rank accounting for 7.13% of the total journal citations, followed by Journal of Molecular Catalysis A: Chemical (6.57%) and Macromolecules (6.27%) respectively. It was also observed that the collaborative research was prevalent in chemical sciences.

VI. ANALYSIS AND INTERPRETATION

A. Analysis and Interpretation of data on theses
The present study is based on a total number of three ninety three theses in earth science, were accepted for the award of

a doctoral degree by the premier universities of West Bengal during 1960-2012. The growth rate of the theses, supervisor's contribution, and subject distribution of theses for a p eriod of fifty three years has been discussed in the following subsections.

1. Decade wise Distribution of Theses

Table I presents the decade wise distribution of doctoral theses which were accepted for the award during 1960-2012.

TABLE I DECADE WISE DISTRIBUTION OF THESES

Period	Number of Theses	% of Theses
1960-1969	31	7.86
1970-1979	60	15.22
1980-1989	63	15.98
1990-1999	100	25.38
2000-2012	139	35.53
Total	393	100

The first PhD was awarded by the Jadavpur University in the year 1960 in petrology. It is also clear from the above table that a total of one hundred thirty nine theses were awarded during 2000-2012, followed by one hundred thesesduring 1990-1999 and sixty three theses during 1980-1989. Only thirty one theses were awarded during 1960-1969, perhaps due to lack of sufficient manpower and infrastructure for research, during the early stages of development of the departments. It is also notable that almost 61% theses were awarded during the last two decades of period under study. An average of 7.43 theses was published during the whole period under study.
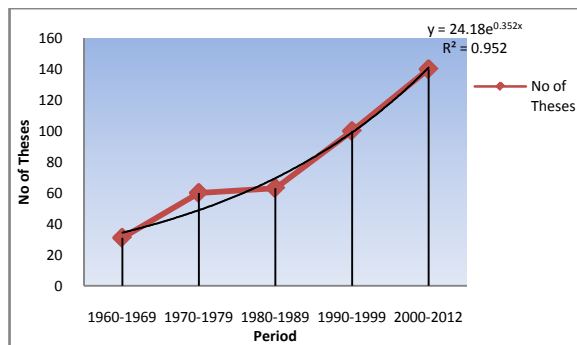

Fig. 1 Decade wise growth trend of theses

From the above figure, it is clear that the growth of doctoral theses follow an exponential growth trend. In this case, the value of R is 0.952. It is also clear that in the 1970s and 1980s the growth is almost same. But just in the next decade (1990s) the growth was almost double. The last decade of the study period was the most productive period. About 35% theses were submitted during this period.Thus, it can be inferred that the number of theseswere continuously increasing at a good increasing average annual rate.

2. University-wise Distribution of Theses

University wise traced theses during the year 1960 to 2012 in the field of Earth science have been presented in Table II.

TABLE II UNIVERSITY WISE DISTRIBUTION OF THESES

Name of the University	No of Theses	% of Contribution
Calcutta University (CU)	176	44.78
Jadavpur University (JU)	167	42.49
Burdwan University (BU)	34	8.65
North Bengal University (NBU)	11	2.79
Vidyasagar University (VU)	5	1.27
Total	393	100

The above table depicts that the Calcutta University contributed the highest number of theses i.e. 176 (44.78%) theses, followed by the Jadavpur University with 167 (42.49%) theses and the Burdwan University with 34 (8.65%) theses respectively. The minimum number of theses contribution is 5 (1.27%) by the Vidyasagar University. The bar diagram of the distribution of theses according to the university is given below in figure 2.
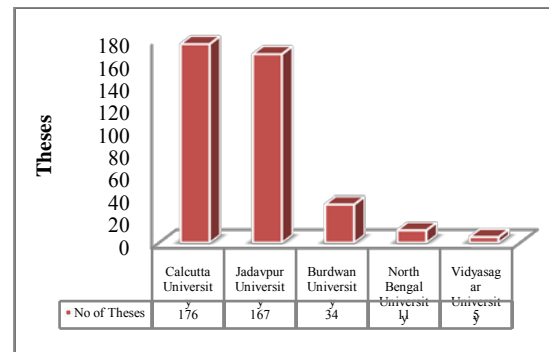

Fig. 2 University wise distribution of theses

C. Supervisor-wise Distribution of Theses

A PhD D supervisor is the most important person who provides guidance and support a researcher throughout his/her academic studies. The distribution of theses according to individual research supervisors for the period of study is presented in Table 3.

It is also evident that a total number of 393 PhD theses were awarded under the guidance of 84 research supervisors. Therefore, the average number of theses submission per supervisor is 4.67 as well.Ranks are given to individual research supervisors based on the number of theses guided by them. A general look at the above table reveals that the most active supervisor with 31 (7.86%) research works to his credit is S. C. Mukhopadhyay from the Calcutta University, followed by D. Mukhopadhyay with 14 (3.55%) theses from the Calcutta University and Subir Kumar Ghosh, Sukumar Basu Mallik from the Jadavpur University with 11 (2.79%) theses each to credit as a supervisor. Somnath Dasgupta from Jadavpur University has supervised 9 (2.28%) theses comes to next.

TABLE III SUPERVISOR WISE DISTRIBUTION OF THESES

Name of the Supervisors	No of These	Name of the University	Rank
S.C. Mukhopadhyay	31	Calcutta University	1
D. Mukhopadhyay	14	Calcutta University	2
Subir Kumar Ghosh	11	Jadavpur University	3
Sukumar Basu Mallik	11	Jadavpur University	3
Somnath Dasgupta	10	Jadavpur University	4
A.K. Saha	9	Calcutta University	5
Nageshwar Prasad	8	Burdwan University	6
Nikhil Kumar De	8	Burdwan University	6
K.L. Chakraborty	7	Jadavpur University	7
Subhendu Bardhan	7	Jadavpur University	7
Aniruddha De	6	Calcutta University	8
Pradip Kumar Bose	6	Jadavpur University	8
Supriya Roy	6	Jadavpur University	8
Sourindranath Sen	6	Calcutta University	8

D. Supervising Pattern

The following table reveals the supervising pattern of three hundred ninety four theses in earth science as under:

TABLE IV PATTERN OF SUPERVISION

Supervising Pattern	Number of theses	% of contribution
Single	327	83
Double	66	17
Total	393	100

It shows from the table 4 that, the single supervisors have supervised the lion share of 327 (83%) theses. Only 67 (17%) was from double supervisorship. There were not more than two supervisors. There were not more than two supervisors in any case.

E. Gender wise Distribution of Researchers

It is observed that male researchers were three hundred nine in numbers (78.68%) and the female researchers were eighty four (21.32%) only. The following figure 3 shows the gender wise distribution of researchers. So the dominancy of male researchers is prominently visible in this case.
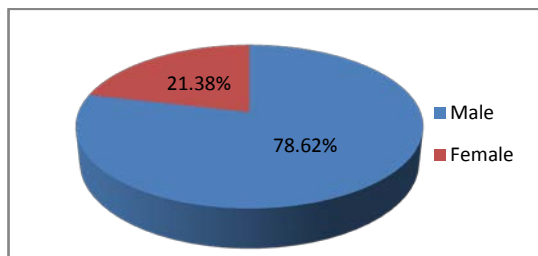

Fig. 3 Gender wise distribution of researchers

F. Discipline wise Distribution of Theses

The distribution of three hundred ninety fourtheses over eleven sub-discipline of earth science is presented in the following table V. Disciplines are ranked based on maximum number of PhDs awarded accordingly.

TABLE V DISCIPLINE WISE DISTRIBUTION OF THESES

S. No.	Name of the Subjects	No of theses	% of Contribution
1	Petrology	101	25.63
2	Geomorphology	88	22.35
3	Geology	44	11.16
4	Hydrology	43	10.91
5	Stratigraphy	29	7.36
6	Geochemistry	28	7.10
7	Sedimentology	26	6.59
8	Structural Geology	16	4.06
9	Geophysics	10	2.53
10	Climatology	6	1.52
11	Seismology	3	0.76

When we look forward towards distribution of theses (Fig.4) according to subject area, petrology has been found to be the popular area of the research with 101 (25.63%) theses, followed by geomorphology with 88 (22.35%) theses, geology with 44 (11.16%) theses and hydrology with 43 (10.91%) theses respectively. It is also found that 69% theses out of total theses had been shared by the four most preferred subject area of research. Only 31% contributions were from the rest of subjects.
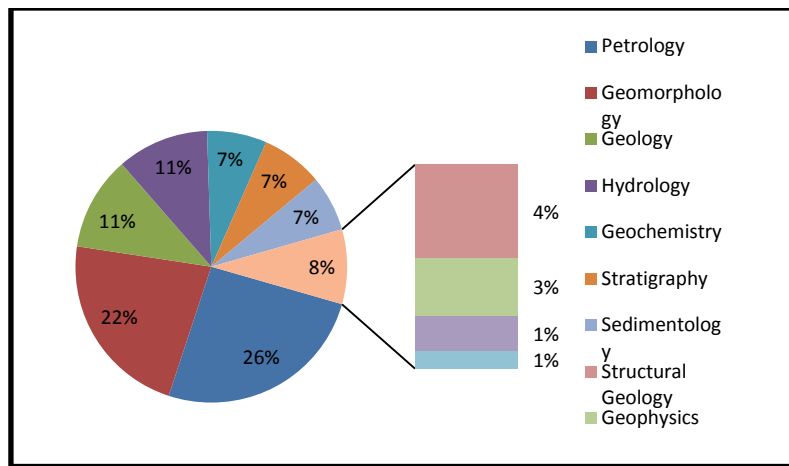
Fig.4 Discipline wise distribution of theses

Therefore this study indicates that petrology, geomorphology, geology and hydrology were the main thrust areas in earth science research in West Bengal during the period under study.

G. Relative Growth Rate and Doubling Time (DT)

The relative growth Rate (RGR) is the increase in number of articles/papers per unit of time. The mean Relative Growth Rate over specific period of interval can be calculated from the following equation:
$R = \log$ of $W_2 - \log$ of $W_1 / T_2 - T_1$
Whereas,
R= mean relative growth rate over the specific period of interval
$\log W_1$= natural log of initial number of articles
$\log W_2$= natural log of final number of articles

$T_2 - T_1$= the unit difference between the initial time and the final time

There exist a direct relationship between the relative growth rate and the doubling time. If the number of articles of a subject doubles during a given period then the difference between the logarithms of numbers at the beginning and end of this period must be logarithms of number 2. If natural logarithm is used this difference has a value of 0.693. So, the doubling time for the articles for each specific period of interval can be calculated by the formula:

Doubling Time (DT) =0.693/R

The following table shows the relative growth rate and doubling time of distribution of theses in the entire period under study. The average growth rate and doubling time work out to 0.631 and 0.966 respectively during this period.

TABLE VI RELATIVE GROWTH RATE AND DOUBLING TIME (1960-2012)

| Period	Number of papers (W_1)	Cumulative number of papers (W_2)	log W_1	log W_2	RGR	DT
1960-64	6	0	0.77815125	0	0	0
1965-69	25	31	1.39794001	1.49136169	0.71321044	0.97166272
1970-74	32	63	1.50514998	1.79934055	0.40140054	1.72645507
1975-79	28	91	1.44715803	1.95904139	0.45389141	1.52679689
1980-84	27	118	1.43136376	2.07188201	0.62472398	1.10928991
1985-89	36	154	1.5563025	2.18752072	0.75615696	0.91647639
1990-94	52	206	1.71600334	2.31386722	0.75756472	0.91477333
1995-99	48	254	1.68124124	2.40483372	0.68883037	1.0060532
2000-04	49	303	1.69897	2.48287358	0.80163235	0.86448607
2005-09	51	354	1.70757018	2.55022835	0.85125835	0.81408893
2010-12	39	393	1.59106461	2.59549622	0.88792605	0.7804704
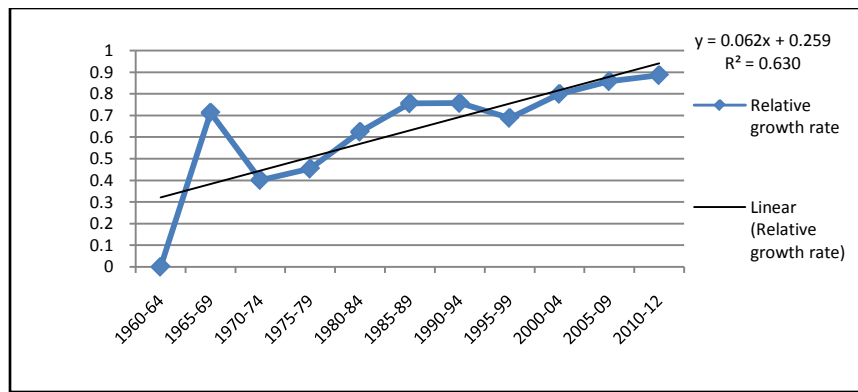
Fig. 5 Relative Growth Rate

A simple trend line (figure 5) gives the following regression equation y= 0.062x+0.259 and R^2=0.63, that means, the curve does not follow very well with linear trend of growth.

B.Citation Analysis

Citation studies try to study the characteristics of subject literature. Here, we have taken into consider the analysis of citations appended to the doctoral theses awarded by the premier universities of West Bengal for the period of 2008-2012 only. The analysis is carried out on 8910 c itations which are appended to 61 theses.

1. Average Number of Citations per Theses

The distribution of the number of citations that appeared at the end of theses during the year from 2008 to 2012 is shown in the following table.

TABLE VII AVERAGE CITATIONS PER THESIS

Year	No of theses	No of Citations	Average citation per thesis
2008	15	2302	153.46
2009	7	1317	188.14
2010	10	1373	137.3
2011	13	1745	134.23
2012	16	2173	135.81

The average number of citations per theses (188) appeared in the year 2009, followed by the year 2008 with 153 theses. The remaining three years under study has shown an almost similar trend in this perspective.

2. Form Wise Distribution of Citations

The literature of any discipline is published in different citation forms such as Journals (including journal articles, bulletins, transactions and abstracting periodicals), Books (including text books, reference books), Conference Papers (including conferences, conventions, meetings, seminars, symposiums, workshops), Reports (including annual reports, progress reports, project reports, research reports), Government publications, Professional papers, Theses & Dissertations, web resources, etc.

TABLE VIII FORM WISE DISTRIBUTION OF CITATIONS

S.No.	Name of Bibliographic form	No. of Citations	% of Citations
1	Journals	5568	62
2	Books	2234	25
3	Conference papers	449	5
4	Reports	311	3.5
5	Government Publications	89	1
6	Theses and Dissertations	78	0.9
7	Working papers	73	0.8
8	Cartographic materials	43	0.5
9	Web resources	27	0.3
10	Miscellaneous	38	0.4

It is evident from the table 8 that 5568 c itations have cited in journals publications which account for 62%. As regards citations from books, there are 2246 citations representing 25% and the cumulative citations of Books and journals are 87%. C onsidering the citations that have appeared in web information resources, there are 27 c itations representing 0.3% only.

3. Application of Lotka laws of Authors productivity for Journal Citations

The simplest equation to represent Lotka's law is
$x^a y = c$
Where x s tands for the contributions; y stands for the number of authors, and c is constant.
Using the above equation, the value of c will be determined according to Sen's method (Sen, 2010).
Take in account the value of as given in the first row of the following table 9, we get
$1^a . 2079 = c$ [as $1^a = 1$]
Hence, c = 2079
Now, using the data of the second row (table 9), we can find out the value of 'a'.
$2^a . 513 = 2079$

   a. $2^a = 2079/513$
   b. $2^a = 4.053$
   c. $a \log 2 = \log 4.053$

d. a. 0.301 = 0.608
e. a = 0.608/0.301
f. a = 2.019

Using the value of 'a' the expected values of 'y' has been determined in the following table:

TABLE IX OBSERVED VALUES AND EXPECTED VALUES OF Y

Number of papers	Number of authors (y) (observed value)	Number of authors (y) (with the value of authors i.e. a=2.019)
1	2079	2079
2	513	512.95
3	205	226.22
4	92	126.53
5	59	80.65
6	29	55.81
7	28	40.88
8	13	31.22
9	13	24.61
10	7	19.9
11	8	16.41
12	4	13.77
13	4	11.71
14	2	10.08
15	3	8.77
16	1	7.7
17	1	6.81
18	3	6.07
19	2	5.44
20	1	4.9
23	1	3.7
28	1	2.48
30	1	2.16
37	1	1.41

a. Goodness-of-Fit Tests

There are several statistics available for goodness of fit tests. Among those tests, we used the t-test as goodness-of-fit tool.

To find out the suitability of Lotka's law in the observed author productivity distribution, compare the calculated value obtained 2.012 with the critical value of t as shown in the table X. For a two-tailed test with 46 degree of freedom we can read the critical value at the 0.05 level is 2.013. On comparing, the calculated value of t-test is smaller than the critical value. Thus, the Lotka's law does fit in the observed given author productivity distribution of the first authors.

TABLE X SUITABILITY OF LOTKA'S LAW USING T- STATISTICAL TEST

Descriptive statistics	Variable 1	Variable 2
Mean	127.95833	137.4658
Variance	184720.04	183186.2
Observations	24	24
Pooled Variance	183953.14	
Hypothesized Mean Difference	0	
df	46	
t Stat	-0.07679	
P(T<=t) one-tail	0.4695619	
t Critical one-tail	1.6786604	
P(T<=t) two-tail	0.9391238	
t Critical two-tail	2.0128956	

VII. FINDINGS AND CONCLUSIONS

The major findings of this study are summarized as follows:

1. The maximum number of theses contribution is 177 (45%) in the Calcutta University during the period of study.
2. The period from 2000 to 2012 is the most productive period. The highest numbers of 140 (35%) theses are submitted during this period. Average number of theses submission per year is 7.43.
3. The relative growth rate and doubling time for theses under study work out to 0.631 and 0.966 respectively during this period.
4. The most active supervisor with 31 (7.86%) research works to his credit is S. C. Mukhopadhyay from the Calcutta University.
5. Three hundred nine in numbers (78.68%) male researchers and the female researchers are eighty four (21.32%) only who submitted theses during the period of study.
6. The grand average number of citations per theses is 146 citations.
7. The highest number of citations recorded is from journals with 5568 (62%) citations.
8. The Lotka's law does fit in the observed given author productivity distribution of the first authors.

It is evident from the present study that research scholars carried out an extensive study on almost every sub-discipline of Earth Science during the period under study. It is also noticed that research scholars consulted vast range of related literature during their research work as evident from citations analysis.The rank list of journals is very useful in the acquisition of journals in the library and could also help in evaluating the importance of journals. It is assumed that an improved collection for earth science literature and their

accessibility will better support the research needs of future PhD scholars in the field of Earth Sciences.

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