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Research Article

Author Productivity and the Application of Lotka's Law in Astrobiology Publications

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ABSTRACT

The study examines authorship pattern of papers published in the field of Astrobiology between 1991and 2023. The data included eleven thousand five hundred and twenty-three (11523) papers appended in the said field. It was found that only 1853 (16%) of the publications were written by single authors. Our results show collaboration trends in the Astrobiology field and Lotka's Law was tested on the publications using Kolmogorov-Smrinov goodness-of-fit. The K-S test revealed that Lotka's law did not applicable to the Astrobiology.

Keywords: Lotka's Law, Kolmogorov-Smirnov, Authorship Pattern, Astrobiology.

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INTRTODUCTION

Author productivity is a foundation of scientometric research, providing valuable insights into the dynamics of scientific contributions and shaping the global knowledge systems. Research collaboration commonly known as sharing knowledge of each other, sharing of resources with one institution to another institution and working together to reach the goal (Melin G and Persson O., 1996). It is believed that collaborative research improves the impact of publications in relationship with citation (Priti Kumaria and Rajeev Kumarb., 2023). The citation performance of coauthored papers was significantly higher than papers with a single author (Gazni A and Didegah F., 2011). Researchers found that publications with international collaboration obtained additional citations than those of nationally and institutionally collaborated paper (Ibanez A, Bielza C and Larranaga P., 2013). The trend of collaboration in the field of Artificial Intelligence (AI) is to some extent negative when comparing the relationship between the number of authors and their citation (Fan L. *et al.*, 2020). LIS productivity revealed that most of the samples differ based on their size and breadth of source than those in Lotka's study. Based on such observations Lotka's law in LIS and other fields recommended that the studies testing the appropriateness of Lotka's formula should be conducted in order to attain valid outcomes (Pao M L., 1885).

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LITERATURE REVIEW

Several studies in different disciplines explained the co-authorship trends and the application of Lotka's Law. Zehra Taşkın and Arsev U. Aydinoglu explored the bibliometric investigation of the NASA Astrobiology Institute (NAI) funded research published between 2008 and 2012 and concluded that there are prominent scholars in the NASA Astrobiology Institute (NAI) belongs to the co-author network but none dominates astrobiology (Taşkın, Z and Aydinoglu, A.U., 2015). Santhakumar, examined that astrobiology research field by conducting a bibliometric analysis with 1,848 publications between 2012 and 2021 from the Web of Science database and the findings showed that Cockell, C S is the most influential author in the field of Astrobiology (Santhakumar, R., 2023). Luca Tonietti *et al.*, quantitatively reviewed the global literature on astrobiology, with a focus on biomining and bioleaching through bibliometric network analysis, investigating patterns and trends in its development and concluded that the research is currently addressing the recognition of network analysis and temporal analyses found that the biotechnological applications are expected to play a crucial role in long-term human space exploration (Tonietti, L., 2023). Vinay Kumar Dattempted to quantify the research publications on Astrobiology and the data collected from Web of Science (WoS) database and the study found that the growth of literature was gradual. Charles S. Cockell was the most prolific author whereas Manasvi Lingam was the most promising author for recent years (Vinay

Kumar D, Arun Kumar T. and Santhosh Kumar T. S., 2023). Christophe Malaterre and Francis Lareau illustrated that author networks are not from citation analyses but from topic similarity based on a topic-model of published documents and found that the underlying communities of authors by measuring author correlations in terms of topic distributions (Malaterre, C and Lareau, F., 2024). Michael Gowanlock and Rich Gazan combines bibliometric techniques with a machine learning algorithm, the sequential information bottleneck and conclude that the majority of the UHNAI team is engaged in interdisciplinary research (Gowanlock, M. and Gazan, R., 2013). Kent A. Peacock applied Lotk's Law, that the number of survivors isa very small fraction of the species that evolve on various planets (Kent A. Peacock, 2018). Mario Coccia analysed that recent studies in monograph productivity recommend that Lotka's law might reflect an underlying pattern in people who produce publications when the time period covered is ten years or more showing that the author productivity approximates the frequency distribution (Coccia, Mario, 2018). Mason Youngblood and David Lahti revealed an increase in productivity and collaboration over time, although a higher difference in author productivity than expected (Youngblood, M. and Lahti, D., 2018).

OBJECTIVES

- To analyse the authorship pattern.
- To examine the collaborative measures.
- To evaluate the application of Lotka's Law.

METHODOLOGY

The data consisted of 11523 papers were published in the field of Astrobiology during 1991 to 2023 from Web of Science Citation database downloaded in plaintext format and the analysis was done with the help of the Bibexcel software and the data was exported in Excel for further calculations. Out of the total publications, only 11520 papers were taken for consideration due to the lack of year and one paper was listed in the year 2024 (Hemavathy. C. and C. Baskaran., 2024). The Collaborative Coefficient (CC) has been measured by the method suggested by Ajiferuke (1988). The degree of collaboration is determined according to the formula given by Subramanyam (1983). In Lotka's Law, $x^n y = c$, the parameters n and c are calculated as per the steps followed by Pao (1985).

ANALYSIS AND INTERPRETATION

Table 1 and Figure 1 depicts the authorship pattern for the period of 1991-2023. The analysis of the table shows that the single author contribution is 1870, two-author share and three author shares are 1583 and 1558 respectively. More than ten authors contributions are 1121. It shows that multiple author research articles have made major contributions in the field of Astrobiology literature.

COLLABORATIVE MEASURES IN ASTROBIOLOGY LITERATURE

Collaborative Index (CI)

Table 1 shows the Authorship Pattern in the Astrobiology Literature. Neelamma G and Gavisiddappa Anandhalli find authorship pattern in the crystallography literature from 1989 to 2013 (Neelamma G. and Gavisiddappa Anandhalli., 2018). They done Collaborative index, Degree of Collaboration, Collaborative Co-efficient and applied Lotka's Law. The following is one of the earliest methods to find the degree of Collaboration given by Lawani (1980).

$$CI = \frac{\sum_{j=1}^{A} jfj}{N}$$

Where, j = the number authors in an article i.e. 1, 2, 3 ……

fj = the number of j authored articles.

N = the total number of articles published in a year.

A = the total number of authors per article.

Eg.: CI for the year 1995 is,

$$CI = \frac{(f1)1+(f2)2+(f3)3+L+(fk)k}{N}$$

$$CI = \frac{(1)1+(2)2+(1)4+(1)6}{5}$$

$$CI = \frac{15}{5} = 3$$

Table 2 shows the Collaborative Index (CI) in the Astrobiology Literature over 33 years from 1991 to 2023. The Collaborative index is 6 in the year 1991 and has been decreased in the following year1992 as 1.6667 and increased gradually up to the year 2016 as 4.0858, again from 2017 onwards decreasing happens in the calculation of Collaborative Index (CI). On the whole, the Collaborative Index (CI) is fluctuating in the field of Astrobiology publications.

Degree of Collaboration (DC)

Table 3 reveals the Degree of Collaboration (DC) during the period of study. It can be defined as the number of multiple author publications in the discipline published during a year as against the total number of papers (multi author and single author) published in the same year. An indicator known as the Degree of Collaboration has been used nowadays and was proposed by Subramanyam, K (1983).

$$DC = \frac{Nm}{Nm+Ns}$$

Where, Nm = number of multi authors during a specific period in a discipline.

Ns = number of single authors publication in a discipline during a given period of time.

Table 1: Authorship pattern in Astrobiology.

Authorship pattern in Astrobiology Literature													Multiple Authored paper	Total No. of Multiple Authors	Total Authors
Year	Total No. of Publications	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten			
1991	1						1						1	6	6
1992	3	1	2										2	4	5
1993	11	5	2	3		1							6	18	23
1994	9	1	2	2	1	1		1				1	8	37	38
1995	5	1	2		1		1						4	14	15
1996	7	4	1		1	1							3	11	15
1997	9	7	1		1								2	6	13
1998	33	14	4	7	1	2		1	3	1			19	83	97
1999	39	11	8	1	2	3	4	3	3			4	28	155	166
2000	33	11	6	6	1		1	2	1	1	1	3	22	114	125
2001	70	34	10	8	6	6	1	1		1		3	36	153	187
2002	85	27	30	11	7	5	2			1	1	1	58	188	215
2003	121	35	24	17	13	14	9	1	3	2	2	1	86	355	390
2004	128	38	26	19	13	5	7	3	5	3	1	8	90	414	452
2005	344	205	31	23	29	19	14	3	4	5	2	9	139	643	848
2006	556	409	43	27	22	15	10	8	2	2	2	16	147	676	1085
2007	399	111	80	65	37	33	24	12	9	12	4	12	288	1248	1359
2008	340	64	44	62	52	38	22	9	11	3	9	26	276	1358	1422
2009	462	55	85	85	68	41	41	21	23	13	4	26	407	1922	1977
2010	524	52	98	82	69	63	45	34	22	14	13	32	472	2325	2377
2011	557	55	79	98	72	71	57	39	22	13	9	42	502	2555	2610
2012	611	81	71	112	75	78	57	50	18	12	8	49	530	2731	2812
2013	635	54	104	90	94	73	62	43	31	16	15	53	581	3017	3071
2014	616	60	88	90	86	78	49	42	32	23	12	56	556	2967	3027
2015	675	62	99	115	104	77	53	38	37	26	9	55	613	3153	3215
2016	627	62	93	90	80	73	55	50	30	32	15	47	565	3016	3078
2017	686	62	86	94	100	69	63	61	34	28	18	71	624	3489	3551
2018	681	52	99	79	97	88	67	48	38	27	20	66	629	3474	3526
2019	685	73	78	94	67	77	62	53	38	30	27	86	612	3624	3697
2020	730	70	102	82	75	83	60	46	37	30	25	120	660	3983	4053
2021	637	56	58	72	84	77	62	49	30	22	25	102	581	3578	3634
2022	666	60	77	69	81	76	48	43	26	25	30	131	606	3828	3888
2023	535	38	50	55	81	51	50	35	32	19	23	101	497	3157	3195
	11520	1870	1583	1558	1420	1218	927	696	491	361	275	1121	9650	52302	54172

Eg.: DC for the year 1995 is,

$$DC = \frac{4}{4+1}$$

$$DC = \frac{4}{5} = 0.8000$$

The analysis of the Degree of Collaboration shows that in 1991 it was 1 and it has decreased to 0.2222 in the year 1997. The overall Degree of Collaboration in Astrobiology shows fluctuating trend. After the year 1991 the Degree of Collaboration reached high in the year 2023 as 0.9290.

Collaborative Coefficient (CC)

Table 4 gives a clear understanding of the collaboration coefficient during the study period. if a publication has a single author, the

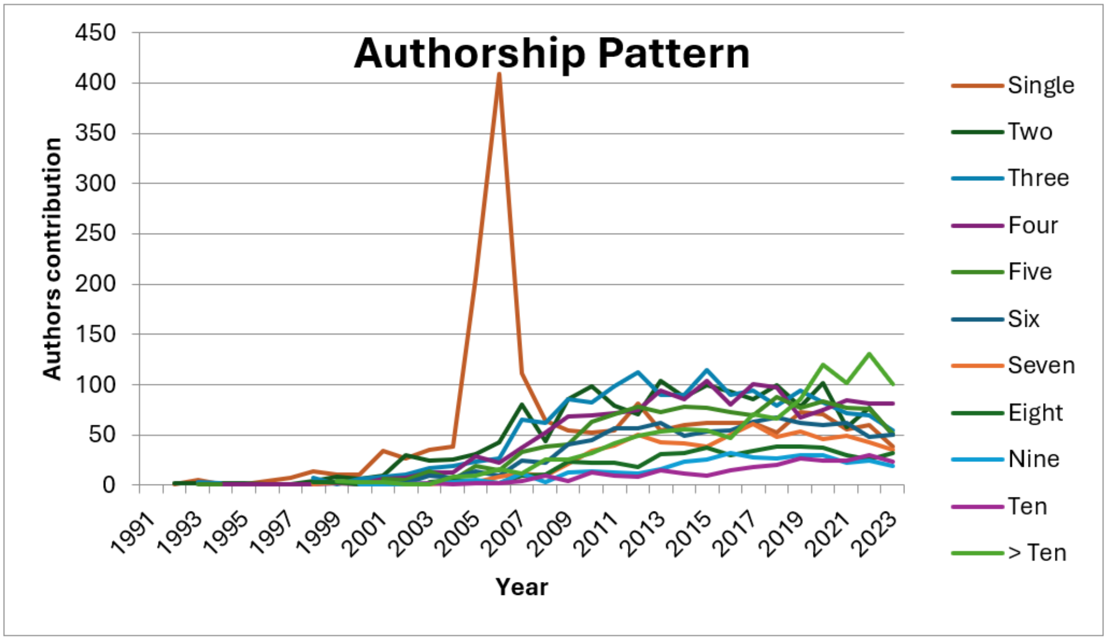

Figure 1: Authorship Pattern of Astrobiology Literature.

author receives one credit; if a publications has a single author the authors receives one credit; if two, each receives ½ credit and in general, if we have 'n' authors each receives 1/n credits.

The Collaboration Coefficient (CC) counted by using the following formula suggested by Ajiferuke (1988).

$$CC = 1 - \frac{\sum_{j=1}^{A}\left(\frac{1}{j}\right)f(j)}{N}$$

Where, j=the number of authors in an article i.e.1,2,3…..

fj=the number of j authored articles.

N=the total number of articles published in a year, and

A= the total number of authors per articles.

Eg.: CC for the year 1996 is,

$$CC = 1 - \frac{f1+\left(\frac{1}{2}\right)f2+\left(\frac{1}{3}\right)f3+\cdots+\left(\frac{1}{k}\right)fk}{N}$$

$$CC = 1 - \frac{\left(\frac{1}{1}\right)*4+\left(\frac{1}{2}\right)*1+\left(\frac{1}{4}\right)*1+\left(\frac{1}{5}\right)*1}{N}$$

$$CC = 1 - \frac{4+0.5+0.25+0.2}{7}$$

$$CC = 1 - \frac{4.95}{7} = 0.2929$$

The highest collaboration coefficient is found in 1991as 0.8333, and it has been decreased in the following year and gradually increased from 1998 onwards and again got decreased in the year 2006 and increased in the following years. In general, the Collaborative Co-efficient in Astrobiology literature shows fluctuating trend.

Modified Collaboration Coefficient (MCC)

Table 5 shows modified collaboration coefficient during the study period. The main purpose of MCC is to quantify how collaborative a research output is, and by analysing the contributions of multiple authors. It regulates the situations where a few authors might dominate or contribute disproportionately. Modified Collaborative Coefficient (MCC) is calculated by using the following formula suggested by Savanur and Srikanth, (2010).

Eg.: MCC for the year 1996 is,

$$MCC = \left(\frac{N}{N-1}\right)\left\{1 - \frac{\sum_{j=1}^{A}\left(\frac{1}{j}\right)f(j)}{N}\right\}$$

$$MCC = \left(\frac{N}{N-1}\right)\left\{1 - \frac{f1+\left(\frac{1}{2}\right)f2+\left(\frac{1}{3}\right)f3+\cdots+\left(\frac{1}{k}\right)fk}{N}\right\}$$

$$MCC = \left(\frac{11520}{11520-1}\right)\left\{1 - \frac{\left(\frac{1}{1}\right)*4+\left(\frac{1}{2}\right)*1+\left(\frac{1}{4}\right)*1+\left(\frac{1}{5}\right)*1}{7}\right\}$$

$$MCC = \left(\frac{11520}{11519}\right)\{0.2929\} = 0.2929$$

The highest modified collaboration is counted in the year 1991and decreased in the following years up to 1997 and starts increased from 1998 onwards and much decreased in the year 2006. From 2007 onwards, slight increase and decreases take place. Finally, Astrobiology literature shows instability during the study period.

Lotka's Law

In 1926 Alfred J. Lotka tested the frequency distribution of scientific productivity from chemical abstracts between 1907 and 1916 (Lotka, A.J., 1926). Lotka concluded that the number of authors making n contributions is about $1/n^2$ of those making one and the proportion of all contributors. The main concept of this law is that a "maximum number of articles are produced by a minimum number of authors" (A. Thirumagal, A. Vanitha and M. Mani, 2017).

$$x^n y = c$$

Where, x is the number of publications of interest (1,2,3…),

y is the expected percentage of authors with frequency x of publications and,

c is a constant.

To determine the value of n,

$$n = \frac{N * \Sigma XY - \Sigma X \Sigma Y}{N * \Sigma X^2 - (\Sigma X)^2}$$

$$n = \frac{86 * 85.8861 - 132.679 * 77.0419}{86 * 220.2635 - (132.679)^2}$$

$$n = \frac{7386.2046 - 10221.8422}{18942.661 - 17603.717}$$

$$n = \frac{-2835.6376}{1338.944}$$

$$\mathbf{n = 2.1178}$$

To determine the value of c,

$$c = \frac{1}{\Sigma \frac{1}{x^n}}$$

$$c = \frac{1}{1.5398} \ (\Sigma \frac{1}{x^n} \text{ from the table 6 is } 1.5398)$$

$$\mathbf{c = 0.6494}$$

To determine the value of critical value (c.v.),

$$c.v. = \frac{n}{\sqrt{\Sigma y}}$$

$$c.v. = \frac{2.1178}{\sqrt{11520}}$$

$$c.v. = \frac{2.1178}{107.3313}$$

$$\mathbf{c.v. = 0.0197}$$

$$D_{max} = 0.4993$$

Goodness of Fit Test

Kolmogorov-Smirnov (K-S) test and Chi-Square test are frequently applied to find out the goodness of fit. In this study, from Table 6 K-S test used to verify Lotka's law. This test is carried out by calculating the theoretical and observed cumulative frequency distribution of authors. The difference at each level of cumulative frequency distribution is counted. The maximum difference is observed and compared with the critical value. In the difference, if it shows less than the critical value, it has been accepted; otherwise rejected (Chaturbhuj S B and Sadik Batcha M., 2020).

The difference (D_{max}) from the table value is more than the critical value. It can be affirmed that the K-S test reveals that the present data set does not fit Lotka's Law. Hence, the authors in the field of Astrobiology have expected to produce more research papers to fix the data for Lotka's Law application.

The maximum deviation between cumulative of observed and expected distributions of author's productivity as per Lotkas's law.

Where,

$$n = 2$$

$$c = 0.6079$$

$$c.v. = \frac{n}{\sqrt{\Sigma y}}$$

$$c.v. = \frac{2}{\sqrt{11520}}$$

$$c.v. = \frac{2}{107.3313}$$

$$c.v. = 0.0186$$

$$(D_{max}) = 0.4663$$

In this case with Lotka's inverse square law, the D_{max} = 0.4663 from Table 7 is more than the critical value 0.0186. It shows Lotka's inverse square law is also not fixing for the Astrobiology field.

Table 2: Collaborative Index (CI) for Astrobiology.

Collaborative Index (CI) for Astrobiology													
Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten	Total No. of Papers	Total Authors	CI
1991						1						1	6	6.0000
1992	1	2										3	5	1.6667
1993	5	2	3		1							11	23	2.0909
1994	1	2	2	1	1		1				1	9	28	3.1358
1995	1	2		1		1						5	15	3.0000
1996	4	1		1	1							7	15	2.1429
1997	7	1		1								9	13	1.4444
1998	14	4	7	1	2		1	3	1			33	97	2.9394

Collaborative Index (CI) for Astrobiology

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten	Total No. of Papers	Total Authors	CI
1999	11	8	1	2	3	4	3	3			4	39	123	3.1571
2000	11	6	6	1		1	2	1	1	1	3	33	93	2.8182
2001	34	10	8	6	6	1	1		1		3	70	154	2.2067
2002	27	30	11	7	5	2			1	1	1	85	204	2.4015
2003	35	24	17	13	14	9	1	3	2	2	1	121	379	3.1330
2004	38	26	19	13	5	7	3	5	3	1	8	128	365	2.8491
2005	205	31	23	29	19	14	3	4	5	2	9	344	749	2.1782
2006	409	43	27	22	15	10	8	2	2	2	16	556	909	1.6355
2007	111	80	65	37	33	24	12	9	12	4	12	399	1227	3.0760
2008	64	44	62	52	38	22	9	11	3	9	26	340	1137	3.3437
2009	55	85	85	68	41	41	21	23	13	4	26	462	1692	3.6615
2010	52	98	82	69	63	45	34	22	14	13	32	524	2026	3.8658
2011	55	79	98	72	71	57	39	22	13	9	42	557	2149	3.8579
2012	81	71	112	75	78	57	50	18	12	8	49	611	2274	3.7216
2013	54	104	90	94	73	62	43	31	16	15	53	635	2489	3.9196
2014	60	88	90	86	78	49	42	32	23	12	56	616	2412	3.9156
2015	62	99	115	104	77	53	38	37	26	9	55	675	2611	3.8680
2016	62	93	90	80	73	55	50	30	32	15	47	627	2562	4.0858
2017	62	86	94	100	69	63	61	34	28	18	71	686	2771	4.0396
2018	52	99	79	97	88	67	48	38	27	20	66	681	2801	4.1132
2019	73	78	94	67	77	62	53	38	30	27	86	685	2752	4.0181
2020	70	102	82	75	83	60	46	37	30	25	120	730	2735	3.7463
2021	56	58	72	84	77	62	49	30	22	25	102	637	2514	3.9463
2022	60	77	69	81	76	48	43	26	25	30	131	666	2449	3.6774
2023	38	50	55	81	51	50	35	32	19	23	101	535	2086	3.8992

Table 3: Degree of Collaboration (DC) for Astrobiology.

	Degree of Collaboration (DC) in Astrobiology Literature											Multiple Authored paper	Total No. of Papers	DC
Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten			
1991						1						1	1	1.0000
1992	1	2										2	3	0.6667
1993	5	2	3		1							6	11	0.5455
1994	1	2	2	1	1		1				1	8	9	0.8889

	Degree of Collaboration (DC) in Astrobiology Literature											Multiple Authored paper	Total No. of Papers	DC
Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten			
1995	1	2		1		1						4	5	0.8000
1996	4	1		1	1							3	7	0.4286
1997	7	1		1								2	9	0.2222
1998	14	4	7	1	2		1	3	1			19	33	0.5758
1999	11	8	1	2	3	4	3	3			4	28	39	0.7179
2000	11	6	6	1		1	2	1	1	1	3	22	33	0.6667
2001	34	10	8	6	6	1	1		1		3	36	70	0.5143
2002	27	30	11	7	5	2			1	1	1	58	85	0.6824
2003	35	24	17	13	14	9	1	3	2	2	1	86	121	0.7107
2004	38	26	19	13	5	7	3	5	3	1	8	90	128	0.7031
2005	205	31	23	29	19	14	3	4	5	2	9	139	344	0.4041
2006	409	43	27	22	15	10	8	2	2	2	16	147	556	0.2644
2007	111	80	65	37	33	24	12	9	12	4	12	288	399	0.7218
2008	64	44	62	52	38	22	9	11	3	9	26	276	340	0.8118
2009	55	85	85	68	41	41	21	23	13	4	26	407	462	0.8810
2010	52	98	82	69	63	45	34	22	14	13	32	472	524	0.9008
2011	55	79	98	72	71	57	39	22	13	9	42	502	557	0.9013
2012	81	71	112	75	78	57	50	18	12	8	49	530	611	0.8674
2013	54	104	90	94	73	62	43	31	16	15	53	581	635	0.9150
2014	60	88	90	86	78	49	42	32	23	12	56	556	616	0.9026
2015	62	99	115	104	77	53	38	37	26	9	55	613	675	0.9081
2016	62	93	90	80	73	55	50	30	32	15	47	565	627	0.9011
2017	62	86	94	100	69	63	61	34	28	18	71	624	686	0.9096
2018	52	99	79	97	88	67	48	38	27	20	66	629	681	0.9236
2019	73	78	94	67	77	62	53	38	30	27	86	612	685	0.8934
2020	70	102	82	75	83	60	46	37	30	25	120	660	730	0.9041
2021	56	58	72	84	77	62	49	30	22	25	102	581	637	0.9121
2022	60	77	69	81	76	48	43	26	25	30	131	606	666	0.9099
2023	38	50	55	81	51	50	35	32	19	23	101	497	535	0.9290

Table 4: **Collaborative Co-efficient (CC) for Astrobiology.**

Collaborative Co-efficient in Astrobiology Literature														
Sl. No.	Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten	Total No. of Papers	CC
1	1991						1						1	0.8333
2	1992	1	2										3	0.3333
3	1993	5	2	3		1							11	0.3455
4	1994	1	2	2	1	1		1				1	9	0.6277
5	1995	1	2		1		1						5	0.5167
6	1996	4	1		1	1							7	0.2929
7	1997	7	1		1								9	0.1389
8	1998	14	4	7	1	2		1	3	1			33	0.4057
9	1999	11	8	1	2	3	4	3	3			4	39	0.5316
10	2000	11	6	6	1		1	2	1	1	1	3	33	0.4754
11	2001	34	10	8	6	6	1	1		1		3	70	0.3563
12	2002	27	30	11	7	5	2			1	1	1	85	0.4229
13	2003	35	24	17	13	14	9	1	3	2	2	1	121	0.4938
14	2004	38	26	19	13	5	7	3	5	3	1	8	128	0.4925
15	2005	205	31	23	29	19	14	3	4	5	2	9	344	0.2905
16	2006	409	43	27	22	15	10	8	2	2	2	16	556	0.1854
17	2007	111	80	65	37	33	24	12	9	12	4	12	399	0.5033
18	2008	64	44	62	52	38	22	9	11	3	9	26	340	0.5965
19	2009	55	85	85	68	41	41	21	23	13	4	26	462	0.6365
20	2010	52	98	82	69	63	45	34	22	14	13	32	524	0.6583
21	2011	55	79	98	72	71	57	39	22	13	9	42	557	0.6708
22	2012	81	71	112	75	78	57	50	18	12	8	49	611	0.6503
23	2013	54	104	90	94	73	62	43	31	16	15	53	635	0.6810
24	2014	60	88	90	86	78	49	42	32	23	12	56	616	0.6784
25	2015	62	99	115	104	77	53	38	37	26	9	55	675	0.6757
26	2016	62	93	90	80	73	55	50	30	32	15	47	627	0.6771
27	2017	62	86	94	100	69	63	61	34	28	18	71	686	0.6939
28	2018	52	99	79	97	88	67	48	38	27	20	66	681	0.7012
29	2019	73	78	94	67	77	62	53	38	30	27	86	685	0.6905
30	2020	70	102	82	75	83	60	46	37	30	25	120	730	0.6964
31	2021	56	58	72	84	77	62	49	30	22	25	102	637	0.7163
32	2022	60	77	69	81	76	48	43	26	25	30	131	666	0.7117
33	2023	38	50	55	81	51	50	35	32	19	23	101	535	0.7333

Table 5: Moderate Collaborative Co-efficient (MCC) for Astrobiology.

Moderate Collaboration Co-efficient in Astrobiology Literature														
Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten	Total No. of Papers	CC	MCC
1991						1						1	0.8333	0.8334
1992	1	2										3	0.3333	0.3334
1993	5	2	3		1							11	0.3455	0.3455
1994	1	2	2	1	1		1				1	9	0.6277	0.6278
1995	1	2		1		1						5	0.5167	0.5167
1996	4	1		1	1							7	0.2929	0.2929
1997	7	1		1								9	0.1389	0.1389
1998	14	4	7	1	2		1	3	1			33	0.4057	0.4057
1999	11	8	1	2	3	4	3	3			4	39	0.5316	0.5317
2000	11	6	6	1		1	2	1	1	1	3	33	0.4754	0.4755
2001	34	10	8	6	6	1	1		1		3	70	0.3563	0.3563
2002	27	30	11	7	5	2			1	1	1	85	0.4229	0.4230
2003	35	24	17	13	14	9	1	3	2	2	1	121	0.4938	0.4939
2004	38	26	19	13	5	7	3	5	3	1	8	128	0.4925	0.4925
2005	205	31	23	29	19	14	3	4	5	2	9	344	0.2905	0.2906
2006	409	43	27	22	15	10	8	2	2	2	16	556	0.1854	0.1854
2007	111	80	65	37	33	24	12	9	12	4	12	399	0.5033	0.5034
2008	64	44	62	52	38	22	9	11	3	9	26	340	0.5965	0.5965
2009	55	85	85	68	41	41	21	23	13	4	26	462	0.6365	0.6365
2010	52	98	82	69	63	45	34	22	14	13	32	524	0.6583	0.6583
2011	55	79	98	72	71	57	39	22	13	9	42	557	0.6708	0.6709
2012	81	71	112	75	78	57	50	18	12	8	49	611	0.6503	0.6504
2013	54	104	90	94	73	62	43	31	16	15	53	635	0.6810	0.6811
2014	60	88	90	86	78	49	42	32	23	12	56	616	0.6784	0.6784
2015	62	99	115	104	77	53	38	37	26	9	55	675	0.6757	0.6757
2016	62	93	90	80	73	55	50	30	32	15	47	627	0.6771	0.6771
2017	62	86	94	100	69	63	61	34	28	18	71	686	0.6939	0.6940
2018	52	99	79	97	88	67	48	38	27	20	66	681	0.7012	0.7013
2019	73	78	94	67	77	62	53	38	30	27	86	685	0.6905	0.6906
2020	70	102	82	75	83	60	46	37	30	25	120	730	0.6964	0.6965
2021	56	58	72	84	77	62	49	30	22	25	102	637	0.7163	0.7164
2022	60	77	69	81	76	48	43	26	25	30	131	666	0.7117	0.7117
2023	38	50	55	81	51	50	35	32	19	23	101	535	0.7333	0.7333

Table 6: Distribution of Author Productivity based on Kolmogorov-Smirnov (K-S) Test.

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	∑Yx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	∑	D
1	1	1870	0.0000	3.2718	0.0000	0.0000	0.1623	0.1623	1.0000	1.0000	0.6494	0.6494	0.4871
2	2	1583	0.3010	3.1995	0.9631	0.0906	0.1374	0.2997	4.3403	0.2304	0.1496	0.7990	0.4993
3	3	1558	0.4771	3.1926	1.5232	0.2276	0.1352	0.4350	10.2435	0.0976	0.0634	0.8624	0.4275
4	4	1420	0.6021	3.1523	1.8979	0.3625	0.1233	0.5582	18.8383	0.0531	0.0345	0.8969	0.3387
5	5	1218	0.6990	3.0856	2.1568	0.4886	0.1057	0.6639	30.2189	0.0331	0.0215	0.9184	0.2544
6	6	927	0.7782	2.9671	2.3088	0.6055	0.0805	0.7444	44.4599	0.0225	0.0146	0.9330	0.1886
7	7	696	0.8451	2.8426	2.4023	0.7142	0.0604	0.8048	61.6238	0.0162	0.0105	0.9435	0.1387
8	8	491	0.9031	2.6911	2.4303	0.8156	0.0426	0.8475	81.7643	0.0122	0.0079	0.9515	0.1040
9	9	361	0.9542	2.5575	2.4405	0.9106	0.0313	0.8788	104.9288	0.0095	0.0062	0.9577	0.0789
10	10	275	1.0000	2.4393	2.4393	1.0000	0.0239	0.9027	131.1596	0.0076	0.0050	0.9626	0.0599
11	11	196	1.0414	2.2923	2.3871	1.0845	0.0170	0.9197	160.4950	0.0062	0.0040	0.9667	0.0470
12	12	146	1.0792	2.1644	2.3357	1.1646	0.0127	0.9324	192.9701	0.0052	0.0034	0.9700	0.0377
13	13	118	1.1139	2.0719	2.3080	1.2409	0.0102	0.9426	228.6174	0.0044	0.0028	0.9729	0.0303
14	14	83	1.1461	1.9191	2.1995	1.3136	0.0072	0.9498	267.4668	0.0037	0.0024	0.9753	0.0255
15	15	59	1.1761	1.7709	2.0827	1.3832	0.0051	0.9549	309.5466	0.0032	0.0021	0.9774	0.0225
16	16	61	1.2041	1.7853	2.1498	1.4499	0.0053	0.9602	354.8831	0.0028	0.0018	0.9792	0.0190
17	17	41	1.2304	1.6128	1.9844	1.5140	0.0036	0.9638	403.5011	0.0025	0.0016	0.9808	0.0170
18	18	34	1.2553	1.5315	1.9224	1.5757	0.0030	0.9667	455.4242	0.0022	0.0014	0.9822	0.0155
19	19	31	1.2788	1.4914	1.9071	1.6352	0.0027	0.9694	510.6747	0.0020	0.0013	0.9835	0.0141
20	20	33	1.3010	1.5185	1.9756	1.6927	0.0029	0.9723	569.2740	0.0018	0.0011	0.9847	0.0124
21	21	30	1.3222	1.4771	1.9531	1.7483	0.0026	0.9749	631.2422	0.0016	0.0010	0.9857	0.0108
22	22	30	1.3424	1.4771	1.9829	1.8021	0.0026	0.9775	696.5989	0.0014	0.0009	0.9866	0.0091
23	23	16	1.3617	1.2041	1.6397	1.8543	0.0014	0.9789	765.3626	0.0013	0.0008	0.9875	0.0086
24	24	18	1.3802	1.2553	1.7325	1.9050	0.0016	0.9804	837.5512	0.0012	0.0008	0.9882	0.0078
25	25	11	1.3979	1.0414	1.4558	1.9542	0.0010	0.9814	913.1820	0.0011	0.0007	0.9890	0.0076
26	26	14	1.4150	1.1461	1.6217	2.0021	0.0012	0.9826	992.2716	0.0010	0.0007	0.9896	0.0070
27	27	12	1.4314	1.0792	1.5447	2.0488	0.0010	0.9837	1074.8359	0.0009	0.0006	0.9902	0.0066
28	28	8	1.4472	0.9031	1.3069	2.0943	0.0007	0.9843	1160.8906	0.0009	0.0006	0.9908	0.0064
29	29	9	1.4624	0.9542	1.3955	2.1386	0.0008	0.9851	1250.4504	0.0008	0.0005	0.9913	0.0062
30	30	9	1.4771	0.9542	1.4095	2.1819	0.0008	0.9859	1343.5301	0.0007	0.0005	0.9918	0.0059
31	31	12	1.4914	1.0792	1.6094	2.2242	0.0010	0.9870	1440.1436	0.0007	0.0005	0.9922	0.0053
32	32	7	1.5051	0.8451	1.2720	2.2655	0.0006	0.9876	1540.3046	0.0006	0.0004	0.9927	0.0051
33	33	8	1.5185	0.9031	1.3714	2.3059	0.0007	0.9883	1644.0265	0.0006	0.0004	0.9930	0.0048
34	34	5	1.5315	0.6990	1.0705	2.3454	0.0004	0.9887	1751.3222	0.0006	0.0004	0.9934	0.0047
35	35	4	1.5441	0.6021	0.9296	2.3841	0.0003	0.9890	1862.2042	0.0005	0.0003	0.9938	0.0047
36	36	3	1.5563	0.4771	0.7425	2.4221	0.0003	0.9893	1976.6849	0.0005	0.0003	0.9941	0.0048
37	37	7	1.5682	0.8451	1.3253	2.4593	0.0006	0.9899	2094.7761	0.0005	0.0003	0.9944	0.0045
38	38	5	1.5798	0.6990	1.1042	2.4957	0.0004	0.9903	2216.4896	0.0005	0.0003	0.9947	0.0044
39	39	5	1.5911	0.6990	1.1121	2.5315	0.0004	0.9908	2341.8368	0.0004	0.0003	0.9950	0.0042
40	40	2	1.6021	0.3010	0.4823	2.5666	0.0002	0.9909	2470.8288	0.0004	0.0003	0.9952	0.0043
41	41	2	1.6128	0.3010	0.4855	2.6011	0.0002	0.9911	2603.4764	0.0004	0.0002	0.9955	0.0044
42	42	2	1.6232	0.3010	0.4886	2.6349	0.0002	0.9913	2739.7904	0.0004	0.0002	0.9957	0.0044

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	ΣYx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	Σ	D
43	43	4	1.6335	0.6021	0.9834	2.6682	0.0003	0.9916	2879.7812	0.0003	0.0002	0.9959	0.0043
44	44	2	1.6435	0.3010	0.4947	2.7009	0.0002	0.9918	3023.4590	0.0003	0.0002	0.9962	0.0043
45	46	3	1.6628	0.4771	0.7933	2.7648	0.0003	0.9921	3321.9152	0.0003	0.0002	0.9964	0.0043
46	47	2	1.6721	0.3010	0.5034	2.7959	0.0002	0.9922	3476.7130	0.0003	0.0002	0.9965	0.0043
47	48	5	1.6812	0.6990	1.1751	2.8266	0.0004	0.9927	3635.2367	0.0003	0.0002	0.9967	0.0040
48	49	7	1.6902	0.8451	1.4284	2.8568	0.0006	0.9933	3797.4954	0.0003	0.0002	0.9969	0.0036
49	50	1	1.6990	0.0000	0.0000	2.8865	0.0001	0.9934	3963.4983	0.0003	0.0002	0.9971	0.0037
50	51	2	1.7076	0.3010	0.5140	2.9158	0.0002	0.9936	4133.2542	0.0002	0.0002	0.9972	0.0037
51	52	2	1.7160	0.3010	0.5166	2.9447	0.0002	0.9937	4306.7720	0.0002	0.0002	0.9974	0.0036
52	53	3	1.7243	0.4771	0.8227	2.9731	0.0003	0.9940	4484.0602	0.0002	0.0001	0.9975	0.0035
53	54	1	1.7324	0.0000	0.0000	3.0012	0.0001	0.9941	4665.1274	0.0002	0.0001	0.9977	0.0036
54	55	3	1.7404	0.4771	0.8304	3.0289	0.0003	0.9943	4849.9817	0.0002	0.0001	0.9978	0.0035
55	56	5	1.7482	0.6990	1.2219	3.0562	0.0004	0.9948	5038.6316	0.0002	0.0001	0.9979	0.0031
56	58	1	1.7634	0.0000	0.0000	3.1097	0.0001	0.9949	5427.3497	0.0002	0.0001	0.9980	0.0032
57	59	2	1.7709	0.3010	0.5331	3.1359	0.0002	0.9950	5627.4337	0.0002	0.0001	0.9981	0.0031
58	60	1	1.7782	0.0000	0.0000	3.1618	0.0001	0.9951	5831.3448	0.0002	0.0001	0.9983	0.0031
59	61	5	1.7853	0.6990	1.2479	3.1874	0.0004	0.9955	6039.0903	0.0002	0.0001	0.9984	0.0028
60	62	3	1.7924	0.4771	0.8552	3.2127	0.0003	0.9958	6250.6779	0.0002	0.0001	0.9985	0.0027
61	63	2	1.7993	0.3010	0.5417	3.2376	0.0002	0.9960	6466.1149	0.0002	0.0001	0.9986	0.0026
62	65	3	1.8129	0.4771	0.8650	3.2867	0.0003	0.9962	6908.5659	0.0001	0.0001	0.9987	0.0024
63	66	2	1.8195	0.3010	0.5477	3.3107	0.0002	0.9964	7135.5942	0.0001	0.0001	0.9988	0.0023
64	67	2	1.8261	0.3010	0.5497	3.3345	0.0002	0.9966	7366.5004	0.0001	0.0001	0.9988	0.0023
65	69	1	1.8388	0.0000	0.0000	3.3814	0.0001	0.9967	7839.9737	0.0001	0.0001	0.9989	0.0023
66	70	5	1.8451	0.6990	1.2897	3.4044	0.0004	0.9971	8082.5543	0.0001	0.0001	0.9990	0.0019
67	71	2	1.8513	0.3010	0.5573	3.4272	0.0002	0.9973	8329.0397	0.0001	0.0001	0.9991	0.0018
68	72	1	1.8573	0.0000	0.0000	3.4497	0.0001	0.9974	8579.4364	0.0001	0.0001	0.9992	0.0018
69	74	1	1.8692	0.0000	0.0000	3.4940	0.0001	0.9975	9091.9897	0.0001	0.0001	0.9992	0.0018
70	75	2	1.8751	0.3010	0.5644	3.5159	0.0002	0.9976	9354.1589	0.0001	0.0001	0.9993	0.0017
71	76	1	1.8808	0.0000	0.0000	3.5375	0.0001	0.9977	9620.2648	0.0001	0.0001	0.9994	0.0017
72	78	1	1.8921	0.0000	0.0000	3.5800	0.0001	0.9978	10164.3111	0.0001	0.0001	0.9994	0.0016
73	81	1	1.9085	0.0000	0.0000	3.6423	0.0001	0.9979	11010.0571	0.0001	0.0001	0.9995	0.0016
74	82	1	1.9138	0.0000	0.0000	3.6627	0.0001	0.9980	11299.9098	0.0001	0.0001	0.9996	0.0016
75	85	2	1.9294	0.3010	0.5808	3.7227	0.0002	0.9982	12193.3601	0.0001	0.0001	0.9996	0.0015
76	88	1	1.9445	0.0000	0.0000	3.7810	0.0001	0.9982	13122.7666	0.0001	0.0000	0.9997	0.0014
77	96	1	1.9823	0.0000	0.0000	3.9294	0.0001	0.9983	15778.0750	0.0001	0.0000	0.9997	0.0014
78	97	1	1.9868	0.0000	0.0000	3.9473	0.0001	0.9984	16128.1732	0.0001	0.0000	0.9997	0.0013
79	100	1	2.0000	0.0000	0.0000	4.0000	0.0001	0.9985	17202.8341	0.0001	0.0000	0.9998	0.0013
80	110	1	2.0414	0.0000	0.0000	4.1673	0.0001	0.9986	21050.4521	0.0000	0.0000	0.9998	0.0012
81	112	1	2.0492	0.0000	0.0000	4.1993	0.0001	0.9987	21869.2520	0.0000	0.0000	0.9998	0.0012
82	114	2	2.0569	0.3010	0.6192	4.2309	0.0002	0.9988	22704.5602	0.0000	0.0000	0.9999	0.0010
83	122	1	2.0864	0.0000	0.0000	4.3529	0.0001	0.9989	26211.5588	0.0000	0.0000	0.9999	0.0010
84	130	1	2.1139	0.0000	0.0000	4.4688	0.0001	0.9990	29985.3575	0.0000	0.0000	0.9999	0.0009
85	131	1	2.1173	0.0000	0.0000	4.4828	0.0001	0.9991	30475.9428	0.0000	0.0000	0.9999	0.0008

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	ΣYx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	Σ	D
86	196	1	2.2923	0.0000	0.0000	5.2544	0.0001	0.9992	71538.5129	0.0000	0.0000	0.9999	0.0007
	4241	11520	132.6790	77.0419	85.8861	220.2635	0.9992	81.3500	538550.3688	1.5398	0.9999	84.4049	

Table 7: Distribution of Author Productivity based on Lotka's Law.

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	ΣYx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	Σ	D
1	1	1870	0.0000	3.2718	0.0000	0.0000	0.1623	0.1623	1.0000	1.0000	0.6128	0.6128	0.4505
2	2	1583	0.3010	3.1995	0.9631	0.0906	0.1374	0.2997	4.0000	0.2500	0.1532	0.7660	0.4663
3	3	1558	0.4771	3.1926	1.5232	0.2276	0.1352	0.4350	9.0000	0.1111	0.0681	0.8341	0.3991
4	4	1420	0.6021	3.1523	1.8979	0.3625	0.1233	0.5582	16.0000	0.0625	0.0383	0.8724	0.3142
5	5	1218	0.6990	3.0856	2.1568	0.4886	0.1057	0.6639	25.0000	0.0400	0.0245	0.8969	0.2330
6	6	927	0.7782	2.9671	2.3088	0.6055	0.0805	0.7444	36.0000	0.0278	0.0170	0.9139	0.1695
7	7	696	0.8451	2.8426	2.4023	0.7142	0.0604	0.8048	49.0000	0.0204	0.0125	0.9264	0.1216
8	8	491	0.9031	2.6911	2.4303	0.8156	0.0426	0.8475	64.0000	0.0156	0.0096	0.9360	0.0885
9	9	361	0.9542	2.5575	2.4405	0.9106	0.0313	0.8788	81.0000	0.0123	0.0076	0.9436	0.0648
10	10	275	1.0000	2.4393	2.4393	1.0000	0.0239	0.9027	100.0000	0.0100	0.0061	0.9497	0.0470
11	11	196	1.0414	2.2923	2.3871	1.0845	0.0170	0.9197	121.0000	0.0083	0.0051	0.9548	0.0351
12	12	146	1.0792	2.1644	2.3357	1.1646	0.0127	0.9324	144.0000	0.0069	0.0043	0.9590	0.0267
13	13	118	1.1139	2.0719	2.3080	1.2409	0.0102	0.9426	169.0000	0.0059	0.0036	0.9626	0.0200
14	14	83	1.1461	1.9191	2.1995	1.3136	0.0072	0.9498	196.0000	0.0051	0.0031	0.9658	0.0160
15	15	59	1.1761	1.7709	2.0827	1.3832	0.0051	0.9549	225.0000	0.0044	0.0027	0.9685	0.0136
16	16	61	1.2041	1.7853	2.1498	1.4499	0.0053	0.9602	256.0000	0.0039	0.0024	0.9709	0.0107
17	17	41	1.2304	1.6128	1.9844	1.5140	0.0036	0.9638	289.0000	0.0035	0.0021	0.9730	0.0092
18	18	34	1.2553	1.5315	1.9224	1.5757	0.0030	0.9667	324.0000	0.0031	0.0019	0.9749	0.0082
19	19	31	1.2788	1.4914	1.9071	1.6352	0.0027	0.9694	361.0000	0.0028	0.0017	0.9766	0.0072
20	20	33	1.3010	1.5185	1.9756	1.6927	0.0029	0.9723	400.0000	0.0025	0.0015	0.9781	0.0058
21	21	30	1.3222	1.4771	1.9531	1.7483	0.0026	0.9749	441.0000	0.0023	0.0014	0.9795	0.0046
22	22	30	1.3424	1.4771	1.9829	1.8021	0.0026	0.9775	484.0000	0.0021	0.0013	0.9808	0.0033
23	23	16	1.3617	1.2041	1.6397	1.8543	0.0014	0.9789	529.0000	0.0019	0.0012	0.9819	0.0031
24	24	18	1.3802	1.2553	1.7325	1.9050	0.0016	0.9804	576.0000	0.0017	0.0011	0.9830	0.0026
25	25	11	1.3979	1.0414	1.4558	1.9542	0.0010	0.9814	625.0000	0.0016	0.0010	0.9840	0.0026
26	26	14	1.4150	1.1461	1.6217	2.0021	0.0012	0.9826	676.0000	0.0015	0.0009	0.9849	0.0023
27	27	12	1.4314	1.0792	1.5447	2.0488	0.0010	0.9837	729.0000	0.0014	0.0008	0.9857	0.0021
28	28	8	1.4472	0.9031	1.3069	2.0943	0.0007	0.9843	784.0000	0.0013	0.0008	0.9865	0.0022
29	29	9	1.4624	0.9542	1.3955	2.1386	0.0008	0.9851	841.0000	0.0012	0.0007	0.9872	0.0021
30	30	9	1.4771	0.9542	1.4095	2.1819	0.0008	0.9859	900.0000	0.0011	0.0007	0.9879	0.0020
31	31	12	1.4914	1.0792	1.6094	2.2242	0.0010	0.9870	961.0000	0.0010	0.0006	0.9886	0.0016
32	32	7	1.5051	0.8451	1.2720	2.2655	0.0006	0.9876	1024.0000	0.0010	0.0006	0.9892	0.0016
33	33	8	1.5185	0.9031	1.3714	2.3059	0.0007	0.9883	1089.0000	0.0009	0.0006	0.9897	0.0015
34	34	5	1.5315	0.6990	1.0705	2.3454	0.0004	0.9887	1156.0000	0.0009	0.0005	0.9903	0.0016
35	35	4	1.5441	0.6021	0.9296	2.3841	0.0003	0.9890	1225.0000	0.0008	0.0005	0.9908	0.0017
36	36	3	1.5563	0.4771	0.7425	2.4221	0.0003	0.9893	1296.0000	0.0008	0.0005	0.9912	0.0019
37	37	7	1.5682	0.8451	1.3253	2.4593	0.0006	0.9899	1369.0000	0.0007	0.0004	0.9917	0.0018
38	38	5	1.5798	0.6990	1.1042	2.4957	0.0004	0.9903	1444.0000	0.0007	0.0004	0.9921	0.0018

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	ΣYx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	Σ	D
39	39	5	1.5911	0.6990	1.1121	2.5315	0.0004	0.9908	1521.0000	0.0007	0.0004	0.9925	0.0017
40	40	2	1.6021	0.3010	0.4823	2.5666	0.0002	0.9909	1600.0000	0.0006	0.0004	0.9929	0.0019
41	41	2	1.6128	0.3010	0.4855	2.6011	0.0002	0.9911	1681.0000	0.0006	0.0004	0.9933	0.0021
42	42	2	1.6232	0.3010	0.4886	2.6349	0.0002	0.9913	1764.0000	0.0006	0.0003	0.9936	0.0023
43	43	4	1.6335	0.6021	0.9834	2.6682	0.0003	0.9916	1849.0000	0.0005	0.0003	0.9939	0.0023
44	44	2	1.6435	0.3010	0.4947	2.7009	0.0002	0.9918	1936.0000	0.0005	0.0003	0.9942	0.0024
45	46	3	1.6628	0.4771	0.7933	2.7648	0.0003	0.9921	2116.0000	0.0005	0.0003	0.9945	0.0025
46	47	2	1.6721	0.3010	0.5034	2.7959	0.0002	0.9922	2209.0000	0.0005	0.0003	0.9948	0.0026
47	48	5	1.6812	0.6990	1.1751	2.8266	0.0004	0.9927	2304.0000	0.0004	0.0003	0.9951	0.0024
48	49	7	1.6902	0.8451	1.4284	2.8568	0.0006	0.9933	2401.0000	0.0004	0.0003	0.9953	0.0020
49	50	1	1.6990	0.0000	0.0000	2.8865	0.0001	0.9934	2500.0000	0.0004	0.0002	0.9956	0.0022
50	51	2	1.7076	0.3010	0.5140	2.9158	0.0002	0.9936	2601.0000	0.0004	0.0002	0.9958	0.0023
51	52	2	1.7160	0.3010	0.5166	2.9447	0.0002	0.9937	2704.0000	0.0004	0.0002	0.9960	0.0023
52	53	3	1.7243	0.4771	0.8227	2.9731	0.0003	0.9940	2809.0000	0.0004	0.0002	0.9963	0.0023
53	54	1	1.7324	0.0000	0.0000	3.0012	0.0001	0.9941	2916.0000	0.0003	0.0002	0.9965	0.0024
54	55	3	1.7404	0.4771	0.8304	3.0289	0.0003	0.9943	3025.0000	0.0003	0.0002	0.9967	0.0023
55	56	5	1.7482	0.6990	1.2219	3.0562	0.0004	0.9948	3136.0000	0.0003	0.0002	0.9969	0.0021
56	58	1	1.7634	0.0000	0.0000	3.1097	0.0001	0.9949	3364.0000	0.0003	0.0002	0.9970	0.0022
57	59	2	1.7709	0.3010	0.5331	3.1359	0.0002	0.9950	3481.0000	0.0003	0.0002	0.9972	0.0022
58	60	1	1.7782	0.0000	0.0000	3.1618	0.0001	0.9951	3600.0000	0.0003	0.0002	0.9974	0.0023
59	61	5	1.7853	0.6990	1.2479	3.1874	0.0004	0.9955	3721.0000	0.0003	0.0002	0.9976	0.0020
60	62	3	1.7924	0.4771	0.8552	3.2127	0.0003	0.9958	3844.0000	0.0003	0.0002	0.9977	0.0019
61	63	2	1.7993	0.3010	0.5417	3.2376	0.0002	0.9960	3969.0000	0.0003	0.0002	0.9979	0.0019
62	65	3	1.8129	0.4771	0.8650	3.2867	0.0003	0.9962	4225.0000	0.0002	0.0001	0.9980	0.0018
63	66	2	1.8195	0.3010	0.5477	3.3107	0.0002	0.9964	4356.0000	0.0002	0.0001	0.9982	0.0017
64	67	2	1.8261	0.3010	0.5497	3.3345	0.0002	0.9966	4489.0000	0.0002	0.0001	0.9983	0.0017
65	69	1	1.8388	0.0000	0.0000	3.3814	0.0001	0.9967	4761.0000	0.0002	0.0001	0.9984	0.0018
66	70	5	1.8451	0.6990	1.2897	3.4044	0.0004	0.9971	4900.0000	0.0002	0.0001	0.9986	0.0014
67	71	2	1.8513	0.3010	0.5573	3.4272	0.0002	0.9973	5041.0000	0.0002	0.0001	0.9987	0.0014
68	72	1	1.8573	0.0000	0.0000	3.4497	0.0001	0.9974	5184.0000	0.0002	0.0001	0.9988	0.0014
69	74	1	1.8692	0.0000	0.0000	3.4940	0.0001	0.9975	5476.0000	0.0002	0.0001	0.9989	0.0014
70	75	2	1.8751	0.3010	0.5644	3.5159	0.0002	0.9976	5625.0000	0.0002	0.0001	0.9990	0.0014
71	76	1	1.8808	0.0000	0.0000	3.5375	0.0001	0.9977	5776.0000	0.0002	0.0001	0.9991	0.0014
72	78	1	1.8921	0.0000	0.0000	3.5800	0.0001	0.9978	6084.0000	0.0002	0.0001	0.9992	0.0014
73	81	1	1.9085	0.0000	0.0000	3.6423	0.0001	0.9979	6561.0000	0.0002	0.0001	0.9993	0.0014
74	82	1	1.9138	0.0000	0.0000	3.6627	0.0001	0.9980	6724.0000	0.0001	0.0001	0.9994	0.0014
75	85	2	1.9294	0.3010	0.5808	3.7227	0.0002	0.9982	7225.0000	0.0001	0.0001	0.9995	0.0013
76	88	1	1.9445	0.0000	0.0000	3.7810	0.0001	0.9982	7744.0000	0.0001	0.0001	0.9996	0.0013
77	96	1	1.9823	0.0000	0.0000	3.9294	0.0001	0.9983	9216.0000	0.0001	0.0001	0.9996	0.0013
78	97	1	1.9868	0.0000	0.0000	3.9473	0.0001	0.9984	9409.0000	0.0001	0.0001	0.9997	0.0013
79	100	1	2.0000	0.0000	0.0000	4.0000	0.0001	0.9985	10000.0000	0.0001	0.0001	0.9998	0.0013
80	110	1	2.0414	0.0000	0.0000	4.1673	0.0001	0.9986	12100.0000	0.0001	0.0001	0.9998	0.0012
81	112	1	2.0492	0.0000	0.0000	4.1993	0.0001	0.9987	12544.0000	0.0001	0.0000	0.9999	0.0012
82	114	2	2.0569	0.3010	0.6192	4.2309	0.0002	0.9988	12996.0000	0.0001	0.0000	0.9999	0.0011
83	122	1	2.0864	0.0000	0.0000	4.3529	0.0001	0.9989	14884.0000	0.0001	0.0000	0.9999	0.0010

Sl. No.	No. of Authors (x)	No. of Papers (y)	X (log x)	Y (log y)	XY	X^2	Yx	ΣYx (Syx)	x^n	$1/x^n$	$f=c*1/x^n$	Σ	D
84	130	1	2.1139	0.0000	0.0000	4.4688	0.0001	0.9990	16900.0000	0.0001	0.0000	1.0000	0.0010
85	131	1	2.1173	0.0000	0.0000	4.4828	0.0001	0.9991	17161.0000	0.0001	0.0000	1.0000	0.0009
86	196	1	2.2923	0.0000	0.0000	5.2544	0.0001	0.9992	38416.0000	0.0000	0.0000	1.0000	0.0008
	4241	11520	132.6790	77.0419	85.8861	220.2635	0.9992	81.3500	317867.0000	1.6319	1.0000	83.9813	

In both cases the data does not fit for the application of Lotka's Law. Hence, the authors in the field are expected to publish more research papers in the field of Astrobiology.

CONCLUSION

In the present study, the maximum number of papers has contributed based on collaboration. Collaboration patterns offer advantages to the funding agency, policymakers, the scientific community, and researchers by providing insights for the development of research. It would also motivate other researchers to carry out further research in other disciplines. This study provided perceptions into the authorship trend of published literature in the Astrobiology field. Authorship pattern is nowadays considered one of the main aspects of scientometric studies. It includes analysis of types of authors, their collaboration pattern, and the number of authors, etc. The Lotka's Inverse Square law does not conform to the study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

CI: Collaborative Index; **DC:** Degree of Collaboration; **CC:** Collaborative Coefficient; **MCC:** Modified Collaboration Coefficient; **(K-S) test:** Kolmogorov-Simrnov test.

SUMMARY

This paper presents a comprehensive bibliometric analysis of Astrobiology literature between 1991 and 2023. It highlights the way to calculate the collaborative Index, Degree of Collaboration, Collaborative Coefficient, Modified Collaborative Coefficient, Kolmogorov-smirnov test and Goodness of Fit test with formulas given by legends. The results show that the The Lotka's Inverse Square law does not conform to the study. This paper helps the beginners in bibliometric calculation to find out collaborative Index, Degree of Collaboration, Collaborative Coefficient, Modified Collaborative Coefficient, Kolmogorov-smirnov test and Goodness of Fit test.

REFERENCES

1. Ajiferuke, I., Burell, Q., & Tague, J. (1988). Collaborative coefficients: A single measure of the degree of collaboration in research. Scientometrics, 14(5-6), 421-433. https://doi.org/10.1007/BF02017100
2. Baskaran, C., & Batcha, M. S. (2012). PublicationsPattern and author collaboration of cardiology research. SRELS Journal of Information Management, 49(2), 199-207.
3. A. Thirumagal¸ A. Vanitha and M. Mani. (2017). Bibliometric analysis of research literature on piper betle. Library Philosophy and Practice (e-journal).
4. Chaturbhuj, S. B., & Sadik Batcha, M. (2020). Application of Lotka to the research productivity in the field of Thermodynamics during 2015-2019. Library Philosophy and Practice(e-journal).
5. Coccia, M. (2018). Theories and laws of scientific development. In Working, (50/2020). SSRN.2020 (pp. 1-33), Paper CocciaLab.
6. Fan, L., Wang, Y., Ding, S., & Qi, B. (2020). Productivity trends and citation impact of different institutional collaboration patterns at the research units' level. Scientometrics, 125(2), 1179-1196. https://doi.org/10.1007/s11192-020-03609-z
7. Gazni, A., & Didegah, F. (2011). Investigating different types of research collaboration and citation impact: A case study of Harvard University's publications. Scientometrics, 87(2), 251-265. https://doi.org/10.1007/s11192-011-0343-8
8. Gowanlock, M., & Gazan, R. (2013). Assessing researcher interdisciplinarity: A case study of the University of Hawaii NASA Astrobiology Institute. Scientometrics, 94(1), 133-161. https://doi.org/10.1007/s11192-012-0765-y
9. Hemavathy, C., & Baskaran, C. (2024). Application of growth models in astrobiology literature: A forecast study based on Web of Science during 1991 to 2023. Kelpro Bulletin, 28(2), 142-153.
10. Ibáñez, A., Bielza, C., & Larrañaga, P. (2013). Relationship among research collaboration, number of documents and number of citations: A case study in Spanish computer science production in 2000-2009. Scientometrics, 95(2), 689-716. https://doi.org/10.1007/s11192-012-0883-6
11. Kumaria, P., & Kumarb, R. (2023). Collaborative authorship patterns in computer science publications. Annals of Library and Information Studies, 70, 22-32.
12. Lawani, S. (1980). Quality, collaboration, and citations in cancer research: A bibliometric study [Unpublished PhD dissertation]. In Florida State University p. 395.
13. Lotka, A. J. (1926). The frequency distribution of scientific productivity. Journal of the Washington Academy of Sciences, 16, 317-323.
14. Malaterre, C., & Lareau, F. (2024). Visualizing hidden communities of interest: A case-study analysis of topic-based social networks in astrobiology. Scientometrics, 129(10), 6167-6181. https://doi.org/10.1007/s11192-024-05047-7
15. Melin, G., & Persson, O. (1996). Studying research collaboration using co authorships. Scientometrics, 36(3), 363-377. https://doi.org/10.1007/BF02129600
16. Neelamma, G., & GavisiddappaAnandhalli. (2018). Authorship pattern and Collaborative measures in the field of crystallography. Library Philosophy and Practice (e-journal).
17. Pao, M. L. (1985). Lotka's law: A testing procedure. Information Processing and Management, 21(4), 305-320. https://doi.org/10.1016/0306-4573(85)90055-X
18. Peacock, K. A. (2018). Fermi and Lotka: the long odds of survival in a dangerous universe. Journal of the British Interplanetary Society, 71(3), 1–12.
19. Santhakumar, R. (2023). Global trends in astrobiology research: Bibliometric and visualization studies. Water Research, 1(1), 01-11.
20. Saravanan, S., Baskaran, C., & Thangavel, V. (2022). Bibliometric analysis of bioremediation literature in India. SSRN.
21. Savanur, K., & Srikanth, R. (2010). Modified collaborative coefficient: A new measure for quantifying the degree of research collaboration. Scientometrics, 84(2), 365-371. https://doi.org/10.1007/s11192-009-0100-4
22. Subramanyam, K. (1983). Bibliometric studies of research in collaboration: A review. Journal of Information Science, 6(1), 33–38. https://doi.org/10.1177/016555158300600105
23. Taşkın, Z., & Aydinoglu, A. U. (2015). Collaborative interdisciplinary astrobiology research: A bibliometric study of the NASA Astrobiology Institute. Scientometrics, 103(3), 1003–1022. https://doi.org/10.1007/s11192-015-1576-8
24. Tonietti, L., Barosa, B., Pioltelli, E., Giovannelli, D., Covone, G., Di Donato, P., Cordone, A., Inno, L., Magliano, C., Fiscale, S., Muscari Tomajoli, M. T., Napolitano, G., Piccirillo, A.

M., Della Corte, V., Santomartino, R., & Rotundi, A. (2023). Exploring the development of astrobiology scientific research through bibliometric network analysis: A focus on biomining and bioleaching. Minerals, 13(6), 1-13. https://doi.org/10.3390/min13060797

25. Vinay Kumar, D., & Santhosh Kumar, A. K. T. (2023). Scientometrics analysis of 'Astrobiology' research. The Journal of Indian Library Association. T S, 59(1), 15-24.
26. Youngblood, M., & Lahti, D. (2018). A bibliometric analysis of the interdisciplinary field of cultural evolution. Palgrave Communications, 4(1). https://doi.org/10.1057/s41599-018-0175-8.

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