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Global "Drone Technology" Research During 1991-2020: A Scientometrics Analysis

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Abstract: *This paper focus on the growth and development of Drone Technology research publications output as reflected in Web of Science during 1991-2020. Total 13002 papers were published and received 264247 citations with 20.32 ACPP. Results of the study revealed that, publications have increased significantly on Drone Technology. The Compound Annual Growth Rate (CAGR) for the period was 0.314639, Relative Growth Rate for the period (RGR) was 0.32 and Doubling Time (Dt.) for the period was 2.24. Results also revealed that, China, USA and European countries were the highly productive countries particularly; China has dominated the Drone Technology research.*

KeyWords: *Scientometrics, Drone Technology, Unmanned Aerial Vehicle (UAV), Web of Science, Annual Growth Rate (AGR),Relative Growth Rate (RGR), Doubling Time (Dt.)*

1. INTRODUCTION:

Unmanned Aerial Vehicle (UAV) or popularly known as Droneis an aircraft without a human pilot on board, instead controlled by a ground operator[1]. D'Andrea[2] defined drone as "autonomous or tele-operated flying machine". Drones can be operated nearby or even from half-a world away hence; they are being used in warfare for many decades. With recent developments in Drone Technology, they are used in number of fields such as, military, security, agriculture, photography, film-making, health, logistics and disaster management etc[3, 4]. Further efforts are being made to extend usage of Drone also to other fields through research. Another important thing with Drone is that people get fascinated and joyous looking at it and captured the imagination. As a result, research publications have increased in the last three decades on Drone Technology. Hence, it felt appropriate to conduct a scientometric study on this subject to get a state of the art report. The present paper examines the global research output on Drone Technology for 30 years period of 1991-2020 using scientometric indicators.

2. REVIEW OF LITERATURE:

Pichai, Stanleay and Kannan[5] applied Bradford's Bibliometric law to find out top journals, countries and authors in the field of 'Drone' by using various indices. Golizadeh et al.[6] reveled research areas which are presently missing in remotely piloted aircraft research (Drone) in order to increase researchers awareness on latest developments and potential applicability of Drone. Lakshminarasimhappa and Kemparaju[7] discovered that, USA, China, South Korea and UK are more active in 'Drone' research compared to other countries.Chauhan[3] found that, majority of the publications on drones were produced in the last decade and also that most of the publications were multi authored. Wang et al.[8] lay out scientific foundation and guidance for developments of Unmanned Aerial Vehicle (UAV) Remote Sensing (RS) applications to help the researchers.

3. OBJECTIVES OF THE STUDY:

The study undertakes a quantitative and qualitative analysis of global publications on Drone Technology research. The broad objectives of the study are to: 1) study the growth and distribution of world literature on Drone Technology. 2) determine the Annual Growth Rate (AGR), Relative Growth Rate (RGR) and Doubling Time (Dt.) of Drone Technology 3) reveal top ten subject categories, countries, authors, institutions, funding agencies and journals on Drone Technology. 4)identify the top ten highly cited papers among the scholarly literature published on Drone Technology.

4. MATERIALS AND METHODS

This study is based on the world scholarly literature on Drone Technology retrieved from the Web of Science database (www.isiknowledge.com)[9]covering 30 years period i.e. 1991-2020. The search string used to retrieve the data is as follows: ((TS= (Unmanned aerial vehicle)) OR TS= (Drone Aircraft) OR TS= (Drone Camera). A total of 13,002 bibliographic records were retrieved from the Web of Science database. Collected data was than analyzed using MS-Excel. Relevant scientometric techniques and indicators were used for publication analysis.

5. ANALYSIS AND INTERPRETATION:

5.1 Year-wise World research output on Drone Technology:

The table 1 illustrates the year-wise world research output (publications and citations) on Drone Technology. According to the web of Science database the first paper on Drone Technology was indexed in the year 1991. Hence, total 30 years i.e. 1991 to 2020 considered for study. Between 1991 and 2020, a total of 13002 papers were published during the period and received 264247citations with 20.32 ACPP. The highest number of papers were published in 2020 i.e. 3667. The highest citations were received in 2018 i.e. 39484 whereas, highest ACPP was recorded in 2012 i.e. 52.93.

Table-1: Year-wise World research output on Drone Technology

Sl. No	Year	TP	TC	ACPP
1	1991	1	0	0
2	1992	0	0	0
3	1993	2	0	0
4	1994	3	6	2
5	1995	5	10	2
6	1996	3	27	9
7	1997	4	29	7.25
8	1998	8	43	5.375
9	1999	5	28	5.6
10	2000	9	106	11.78
11	2001	11	219	19.91
12	2002	11	400	36.36
13	2003	29	1513	52.17
14	2004	44	1487	33.80
15	2005	54	2417	44.76
16	2006	94	2611	27.78
17	2007	68	3350	49.26
18	2008	117	5211	44.54
19	2009	150	6049	40.33
20	2010	166	6952	41.88
21	2011	229	8872	38.74
22	2012	254	13443	52.93
23	2013	340	15204	44.72
24	2014	444	17219	38.78
25	2015	518	20507	39.59
26	2016	781	26204	33.55
27	2017	1192	34451	28.90
28	2018	1880	39484	21.00
29	2019	2913	37780	12.97
30	2020	3667	20625	5.62
	1991-2000	40	249	6.23

	2001-2010	744	30209	40.60
	2011-2020	12218	233789	19.13
		13002	**264247**	**20.32**

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.2 Annual Growth Rate (AGR) of publications:

The table 2 depicts Annual Growth Rate (AGR) and Compound Annual Growth Rate (CAGR) of publications. The highest Annual Growth Rate, i.e. 163.6364 was recorded in 2003, followed by 74.07407 in 2006. Mean while, lowest Annual Growth Rate was recorded in the year 1992 i.e. -100. The Compound Annual Growth Rate (CAGR) for the period was 0.314639.

Table- 2: Annual Growth Rate (AGR) of publications

Year	TP	Annual Growth Rate (AGR)
1991	1	0
1992	0	-100
1993	2	0
1994	3	50
1995	5	66.66667
1996	3	-40
1997	4	33.33333
1998	8	100
1999	5	-37.5
2000	9	80
2001	11	22.22
2002	11	0
2003	29	163.6364
2004	44	51.72414
2005	54	22.72727
2006	94	74.07407
2007	68	-27.6596
2008	117	72.05882
2009	150	28.20513
2010	166	10.66667
2011	229	37.95181
2012	254	10.91703
2013	340	33.85827
2014	444	30.58824
2015	518	16.66667
2016	781	50.7722
2017	1192	52.62484
2018	1880	57.71812
2019	2913	54.94681
2020	3667	25.88397
	CAGR	**0.314639**

(TP: Total Publications; AGR: Annual Growth Rate and CAGR: Compound Annual Growth Rate)

5.3 Relative Growth Rate (RGR) and Doubling Time (Dt.):

The table 3 indicates the Relative Growth Rate (RGR)and Doubling Time (Dt.) of total research output for Drone Technology publications. it shows that, the Relative Growth Rate of research output has increased from 0.0 in 1991 to 0.33 in 2020 whereas, mean value of Relative Growth Rate for the period was 0.32. Mean while, Doubling Time (Dt.) was also increased from 0.00 in 1991 to 2.09 in 2020 whereas, mean value of Doubling Time for the period was 2.24.

Table- 3: Relative Growth Rate (RGR) and Doubling Time (Dt.)

Year	TP	CTP	L1	L2	RGR	DT
1991	1	1	0.00	0.00	0.00	0.00
1992	0	1	0.00	0.00	0.00	0.00
1993	2	3	0.00	1.10	1.10	0.63
1994	3	6	1.10	1.79	0.69	1.00
1995	5	11	1.79	2.40	0.61	1.14
1996	3	14	2.40	2.64	0.24	2.87
1997	4	18	2.64	2.89	0.25	2.76
1998	8	26	2.89	3.26	0.37	1.88
1999	5	31	3.26	3.43	0.18	3.94
2000	9	40	3.43	3.69	0.25	2.72
2001	11	51	3.69	3.93	0.24	2.85
2002	11	62	3.93	4.13	0.20	3.55
2003	29	91	4.13	4.51	0.38	1.81
2004	44	135	4.51	4.91	0.39	1.76
2005	54	189	4.91	5.24	0.34	2.06
2006	94	283	5.24	5.65	0.40	1.72
2007	68	351	5.65	5.86	0.22	3.22
2008	117	468	5.86	6.15	0.29	2.41
2009	150	618	6.15	6.43	0.28	2.49
2010	166	784	6.43	6.66	0.24	2.91
2011	229	1013	6.66	6.92	0.26	2.70
2012	254	1267	6.92	7.14	0.22	3.10
2013	340	1607	7.14	7.38	0.24	2.92
2014	444	2051	7.38	7.63	0.24	2.84
2015	518	2569	7.63	7.85	0.23	3.08
2016	781	3350	7.85	8.12	0.27	2.61
2017	1192	4542	8.12	8.42	0.30	2.28
2018	1880	6422	8.42	8.77	0.35	2.00
2019	2913	9335	8.77	9.14	0.37	1.85
2020	3667	13002	9.14	9.47	0.33	2.09
Mean Value					**0.32**	**2.24**

(TP: Total Publications; CTP: Cumulative Publications; RGR: Relative Growth Rate; Dt.: Doubling Time)

5.4 Top ten Web of Science Categories of Drone Technology research

The table 4 reveals distribution of publications based on web of science categories. According to the web of science categories, highest numbers of papers were published i.e.5057 in the category of Engineering (Electrical & Electronic). This category has also received highest citations i.e. 83069 along with h-index of 116. Second highest papers were published in the category of Telecommunications i.e. 3022, the category also received second highest citations i.e. 50648 along with h-index of 96. Further, the third highest publications were published in Remote Sensing i.e. 2334,the category also received third highest citations i.e. 47392 along with h-index of 94. The highest ACPP was

recorded in category of Automation & Control Systems i.e. 25.69 followed by Imaging Science & Photographic Technology (22.27) and Geosciences(Multidisciplinary) recorded 22.00 ACPP.

Table- 4: Top ten Web of Science Categories in Drone Technology research

Sl. No	Web of Science Category	TP	TC	ACPP	H-index
1	Engineering, Electrical & Electronic	5057	83069	16.43	116
2	Telecommunications	3022	50648	16.76	96
3	Remote Sensing	2334	47392	20.31	94
4	Computer Science, Information Systems	2193	25476	11.62	62
5	Environmental Sciences	1959	34397	17.56	82
6	Imaging Science & Photographic Technology	1869	41624	22.27	92
7	Geosciences, Multidisciplinary	1851	40718	22.00	92
8	Engineering, Aerospace	1565	17226	11.01	55
9	Instruments & Instrumentation	1503	21343	14.20	66
10	Automation & Control Systems	1180	30314	25.69	80

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.5 Top ten most productive countries in the Drone Technology research:

The table 5 demonstrates top-10 countries which produced most numbers of publications in the field of Drone Technology research as per Web of Science database during 1991-2020. China was leading the research in terms of publications i.e. 5529 followed by USA (3423) and South Korea (1096). Among the top 10 countries, USA has recorded most numbers of citations i.e.75689 followed by China (63973) and Australia (23394). In terms of ACPP France was leading with 30.69 and the USA has highest h-index of 116.

Table- 5: Top ten most productive countries in the Drone Technology research

Sl. No	Countries	TP	TC	ACPP	H-index
1	China	5529	63973	11.57	92
2	USA	3423	75689	22.11	116
3	South Korea	1096	14365	13.11	51
4	England	1054	22872	21.70	68
5	Australia	882	23394	26.52	71
6	Spain	827	22436	27.13	70
7	Canada	814	16040	19.71	59
8	Italy	742	14163	19.09	58
9	Germany	635	14705	23.16	66
10	France	579	17771	30.69	63

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.6 Profiles of top ten Authors in the Drone Technology research

The table 6 shows scientometric profiles of top 10 authors (publication wise) in Drone Technology. The most productive author in world was Zhang, Y from China with 114publications followed by Wang, Y who is also from china with 97publications. Among these top 10 authors, Zhang, R. of USA was not only received the highest citations i.e.7326 from 70 publications but also the author has highest ACPP i.e. 104.66 and highest h-index i.e. 31.

Table- 6: Profiles of top ten Authors in the Drone Technology research

Sl. No	Author Name	Affiliation Institution	Country	TP	TC	ACPP	H-index
1	Zhang, Y	Tsinghua University	People's Republic of China	114	1879	16.48	20
2	Wang, Y	Nanjing University of Aeronautics	People's Republic of	97	712	7.34	17

		& Astronautics	China				
3	Li, J	Beijing Institute of Technology	People's Republic of China	88	829	9.42	16
4	Zhang J	Shanghai InstPollut Control &EcolSecur	People's Republic of China	83	954	11.49	17
5	Wang J	Embry-Riddle Aeronautical University	USA	80	519	6.49	12
6	Chen, J.	Tongji University	People's Republic of China	76	910	11.97	18
7	Kim, S	Kumoh National University Technology	South Korea	75	946	12.61	19
8	Zhang, R.	Georgia Institute of Technology	USA	70	7326	104.66	31
9	Kim, J	Korea Advanced Institute of Science & Technology (KAIST)	South Korea	68	1002	14.74	18
10	Kim, Y	Seoul National University	South Korea	60	804	13.4	17

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.7 Top ten most prolific institutions in the Drone Technology research

The table 7 lists top 10 contributing institutions in the field of the Drone Technology around the world. China's Academy of Sciences occupies top spot with 499 publications followed by Beihang University which also belong to the china with 470 publications. Among the top most published10 institutes, University of California System of USA was recorded highest citations i.e. 8404 from 776 publications followed by, Centre National de la Recherche Scientifique (France) which has 7812 citations from 253 publications. Centre National de la Recherche Scientifique also recorded the highest ACPP i.e. 30.88 and highest h-index of 45.

Table- 7: Top ten most prolific institutions in the Drone Technology research

Sl. No	Institutions	Country	TP	TC	ACPP	H-index
1	Chinese Academy of Sciences	People's Republic of China	499	5643	11.31	36
2	Beihang University	People's Republic of China	470	6695	14.24	43
3	Nanjing University of Aeronautics & Astronautics	People's Republic of China	302	3197	10.59	26
4	University of California System	USA	276	8404	30.45	42
5	Centre National de la Recherche Scientifique (CNRS)	France	253	7812	30.88	45
6	Northwestern Polytechnical University	People's Republic of China	252	1702	6.75	19
7	National University of Defence Technology-China	People's Republic of China	249	1862	7.48	22
8	Southeast University - China	People's Republic of China	207	5080	24.54	32
9	University of Chinese Academy of Sciences,	People's Republic of China	203	1612	7.94	20
10	State University System of Florida	USA	194	4453	22.95	35

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.8 Top ten Funding Agencies in the Drone Technology research:

Conducting research is often a costly affair. Hence to encourage researchers, many institutions provide financial assistance. The table 8 reveals the top 10 funding agencies which funded for Drone Technology research based on their publications. According to the web of science database, National Natural Science Foundation of China

(NSFC) has funded for highest publications i.e. 3563, received highest citations i.e. 43469 and also got highest h-index of 79. Among the top 10 funding agencies, National Science Foundation (NSF) of USA has recorded highest ACPP i.e. 31.84 followed by European Commission of United Kingdom with 30.92 ACPP.

Table- 8: Top Ten Funding Agencies in the Drone Technology research

Sl. No	Funding Agencies	Country	TP	TC	ACPP	H-index
1	National Natural Science Foundation of China (NSFC)	People's Republic of China	3563	43469	12.20	79
2	Fundamental Research Funds for the Central Universities	People's Republic of China	630	9177	14.57	40
3	European Commission	United Kingdom	593	18337	30.92	62
4	National Science Foundation (NSF)	USA	587	18690	31.84	64
5	National Key Research and Development Program of China	People's Republic of China	392	3762	9.60	28
6	UK Research & Innovation (UKRI)	England	281	7758	27.61	44
7	China Postdoctoral Science Foundation	People's Republic of China	275	2635	9.58	23
8	Natural Sciences and Engineering Research Council of Canada (NSERC)	Canada	271	5079	18.74	36
9	National Key R&D Program of China	People's Republic of China	243	1562	6.43	18
10	ConselhoNacional de Desenvolvimento Cientifico e Tecnologico (CNPQ)	Brazil	194	1978	10.20	23

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.9 Top ten most preferred Journals in the Drone Technology research:

The table 9 presents the top-10 most preferred journals by the researchers in Drone Technology. *Remote Sensing*, a journal published by MDPI, Basel, Switzerland was the most preferred journal with 1087 publications on Drone Technology, followed by *IEEE Access*a journal published by IEEE-Inst Electrical Electronics Engineers Inc, New Jersey, USA with 831 publications, whereas, *Sensors* a journal again published by MDPI, Basel has published 786 papers. Among the top-10 most preferred journals, the *Remote Sensing* has received the highest i.e. 21479 citations, followed by *Sensors*with 8762 citations; *Journal of Intelligent & Robotic Systems*a journal published by Springer has received 8392 citations from 411 papers. Further, *Remote Sensing* has recorded highest h-index i.e. 67 whereas; *Journal of Intelligent & Robotic Systems* recorded highest ACPP of 20.42.

Table- 9: Top ten most preferred Journals in the Drone Technology research

Sl. No	Source Title	Country	Publisher	TP	TC	ACPP	H-index
1	Remote Sensing	Switzerland	MDPI, Basel	1087	21479	19.76	67
2	IEEE Access	USA	IEEE-Inst Electrical Electronics Engineers Inc, New Jersey	831	7289	8.77	37
3	Sensors	Switzerland	MDPI, Basel	786	8762	11.15	43
4	Journal of Intelligent & Robotic Systems	Netherlands	Springer	411	8392	20.42	48
5	IEEE Transactions on Vehicular Technology	USA	IEEE-Inst Electrical Electronics Engineers Inc	264	4566	17.30	35
6	Applied Sciences-Basel	Switzerland	MDPI, Basel	251	910	3.63	13
7	Aerospace Science and Technology	France	Elsevier France-Editions Scientifiques Medicales Elsevier	216	3545	16.41	32
8	International Journal of Remote Sensing	England	Taylor & Francis Ltd	185	3395	18.35	30

9	Drones	Switzerland	MDPI, Basel	178	1256	7.06	19
10	IEEE Internet of Things Journal	USA	IEEE-Inst Electrical Electronics Engineers Inc.	176	3474	19.74	31

(TP: Total Publications; TC=Total Citations; ACPP: Average Citation per Publication)

5.10 Top ten highly cited publications in the Drone Technology research:

The table 10 depicts the top 10 highly cited papers in Drone Technology research The paper titled, "Unmanned aerial systems for photogrammetry and remote sensing: A review" by Colomina, I &Molina, P (2014) published in *ISPRS Journal of Photogrammetry and Remote Sensing,* has received the highest citatonsi.e. 1351. Second highly cited paper was "The flying sidekick travelling salesman problem: Optimization of drone-assisted parcel delivery" by Murray, C.C &Chu, A.G. (2015) received 321 citations published in *Transportation Research Part C-Emerging Technologies.* Third highly cited papers was "Classifications, applications, and design challenges of drones: A review" by Hassanalian, M & Abdelkefi, A (2017) received 294 citations published in *Progress in Aerospace Science.*

Table-10 Top ten highly cited publications in the Drone Technology research

Sl. No	Title of the Paper	Total Citations	Authors	Publisher
1	Unmanned aerial systems for photogrammetry and remote sensing: A review	1351	Colomina, I &Molina, P.	2014,*ISPRS JOURNAL OF PHOTOGRAMMETRY AND REMOTE SENSING*, 92.pp.79-97
2	The flying sidekick travelling salesman problem: Optimization of drone-assisted parcel delivery	321	Murray, C.C &Chu, A.G.	2015,*TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES*, 54, pp.86-109
3	Classifications, applications, and design challenges of drones: A review	294	Hassanalian, M &Abdelkefi, A	2017, *PROGRESS IN AEROSPACE SCIENCES*, 91, pp.99-131.
4	Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges	197	Linchant, J et.al	2015, *MAMMAL REVIEW*, 45 (4). pp.239-252.
5	Drones count wildlife more accurately and precisely than humans	143	Hodgson, J.C and et.al	2018, *METHODS IN ECOLOGY AND EVOLUTION*, 9(5), pp.1160-1167.
6	Approaching birds with drones: first experiments and ethical guidelines	141	Vas, E and et.al	2015,*BIOLOGY LETTERS*, 11(2).
7	Airborne Optical and Thermal Remote Sensing for Wildfire Detection and Monitoring	82	Allison, R.S and et.al	2016, *SENSORS*, 16(8).
8	The potential for unmanned aerial vehicles (UAVs) to conduct marine fauna surveys in place of manned aircraft	72	Colefax, A.P.,Butcher, P.A &Kelaher, B.P	2018, ICES JOURNAL OF MARINE SCIENCE, 75(1), pp.1-8.
9	Principles and practice of acquiring drone-based image data in marine environments	69	Joyce, K.E and et.al	2019, MARINE AND FRESHWATER RESEARCH, 70(7), pp.952-963.
10	A Grassroots Remote Sensing Toolkit Using Live Coding, Smartphones, Kites and Lightweight Drones	59	Anderson, K and et.al	2016, PLOS ONE, 11(5).

6. DISCUSSION:

The study indicates significant increase in publications on Drone Technology during 1991-2020, particularly in the third decade (2011-2020). Citations also significantly increased, although drastic decrease in ACPP can be noticed in recent years (after 2015-16) (See table 1). Annual Growth Rate of publications was never in negative zone after the first decade apart from the year 2007 It is evident from the study that the research in the field of Drone Technology has steadily increasing (See table 2). Relative Growth Rate and Doubling Time suggest that, there was steady increase in the publications of Drone Technology (See table 3). Research related to Technical aspect of drone was dominated in majority of the publications (See table 4). China was the most productive country in the field but, USA was the most cited country and France received highest ACPP (See table 5).

In the top 10 most prolific authors five authors belongs to China and remaining five authors belong to South Korea (3) and USA (2) (See table 6). The dominance of China can also be noticed in the top 10 institutions and funding agencies. In the top to most productive institutes, seven were from China and in the top 10 funding agencies five were from China (See tables 7 & 8). As for as top 10 most preferred journals are concerned, European countries were in forefront as majority i.e. 7 journals were published from there and remaining three were published from USA. It is interesting to note that, in spite high productivity of publications, not a single journal from China can be seen (See table 9). Further, a huge citation gap can be noticed in citations from first highly cited paper to remaining nine papers (See table 10).

7. CONCLUSION:

Study found that the global research output on Drone Technology has increased during the study period and the developing countries like China and South Korea have played a significant part in it also the impact of USA and European countries on research cannot be ignored. Other developing countries can take inspiration from China and South Korea and conduct research in this field since, the future of drone technology research looking very promising and limitless. This study can help the researchers and policy makers in this endeavour.

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