Sri Lanka S &T output during 2001-2010: A scientometric asssessment

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ABSTRACT

This study analyses the research output of Sri Lanka in S&T during 2001-2010 on several parameters including its growth and global publications share, citation impact, share of international collaborative papers, contribution of major collaborative partner countries, contribution to various subject fields, geographical distribution of its papers, evaluation of the characteristics on its high productive institutions, authors and papers and the journals publishing the research output. The Scopus Citation Database has been used to retrieve the publication data for 10 years. The study concludes that Sri Lanka needs to increase its output and bring about improvement in the quality of its research efforts. This can be done by investing much more in research and development (R&D) expenditure, increase in the deployment of more qualified manpower and international collaboration; and by modernizing and strengthening its research infrastructure.

Keywords: Research productivity; Science; Technology; Scientometrics; Citation study; Sri Lanka.

INTRODUCTION

Democratic Socialist Republic of Sri Lanka, known as Ceylon before 1972, is an island in South Asia. It has a total land area of 65,610 square km and a population of 20.2 million in 2008. The average literacy rate is 91.3%. Its Gross Domestic Product (GDP) has increased from USD16.33 billion in 2000 to USD40.56 billion in 2008.

Over the past 30 years, Sri Lanka's annual economic growth has averaged 5%, with an upward trend since 2003. Economic and structural reforms that began in 1977, when the government switched from import substitution and nationalization to policies supporting deregulation, international trade and privatization, were largely responsible for the income growth. The structure of the economy indicates that 43.0% of the contribution comes from services, 29.2% from industry and 12.8% from agriculture during 2009. In the 1990's, growth was driven by manufacturing, especially garments, which now represent 45% of exports. Since 2001, services, especially in telecommunications, transport and finance, have led economic growth. Agriculture and rural industries have remained stagnant, a condition associated with falling agricultural productivity (ADB 2008).

Its merchandise exports have increased from USD5.43 billion in 2000 to USD8.37 billion in 2008. Its share of high technology exports in manufacturing exports has decreased from 2.2% in 2000 to 2.0% in 2008. The Foreign Direct Investment (FDI) net inflows in the country have increased from USD173 million in 2000 to USD752 million in 2008.

Sri Lanka has 31 research institutes under the 9 ministries and 38 higher education institutes. More than 50% of the research and development institutes are in the western province, while the second highest number is in central provenance. More than 50% of state research institutes are dedicated to agricultural research and development, while only five are devoted to industrial research and development and two for health research. The country's university system consists of 15 public universities, besides 7 post graduates institutes. In addition there are nine higher education institutes and seven other degree awarding institutes. Besides universities, other institutes of higher education include medical schools, engineering schools, schools of law, technical and vocational training schools and National College of Education (Sirimana 2011). Under the Ministry of Technology and Research, the research institutes are: (i) The National Science and Technology Commission (NASTEC), (ii) National Science Foundation (NSF), (iii) Industry Technology Institute (ITI), (iv) Arthur C. Clarke Center for Modern Technologies, (v) National Engineering Research and Development Center (NERD), (vi) Institute of Fundamental Studies (IFS), (vii) National Research Council (NRC), (viii) Sri Lanka Standards Institute (SLSI), (ix) Sri Lanka Accreditation Board for Conformity Assessment (SLAB) and (x) Sri Lanka Inventors Commission (Sirimana 2011).

The Gross Expenditure on R&D (GERD) in the country has increased from USD4.2 million in 1966 to USD46.1 million in 2008. GERD as a percentage of GDP has decreased from 0.30 in 1966 to 0.11 in 2008. GERD per million populations has increased from 1.7 in 1966 to 249.9 in 2008. In terms of source of funds in R&D in 2008, 71.8% comes from government, 19.9% from private sector, 4.3% from foreign sources and 4.0% from other sources (Dilrukshi 2010). Currently there are about 46,000 research scientists and the government has plans to increase research scientists to 7200 by 2016 (Sirimana 2011).

Only few scientometrics studies have been carried out on the research output of Sri Lanka. Among these studies, Mehbuba and Rousseau (2010) have compared Bangladesh, Pakistan and Sri Lanka research output with India using three indicators, such as percentage of uncited articles, number of citations per document and h-index. Gupta, Munshi and Mishra (2002) analysed India's collaboration with South Asian countries during 1992-1999 using Science Citation Index (SCI) database. Geethika Yapa, de Silva and de Silva (2004) have analyzed institutional research productivity in nine Sri Lankan research laboratories in the field of natural products chemistry research from 1975 to 1998. Wickremasinghe (2008) evaluated and compared research productivity of rice scientists using publications and other research output at one institute each in India and Sri Lanka.

OBJECTIVES

The objectives of the present study are to analyze the performance of Sri Lanka's science and technology, as reflected in their publications output during 2001-2010. In particular, it analyses:

a) publications growth rate and global publication share;
b) the most productive, medium productive, low productive and least productive areas of research;
c) share of international collaborative papers and identification of major collaborative partners;
d) publication productivity of the geographical regions;
e) characteristics of its high productive institutions, authors and high cited papers;
f) leading journals that publish Sri Lanka's S&T research.

MATERIALS AND METHOD

This publications data from 2001-2010 on Sri Lanka in science and technology forms the basis of this study and they are derived from the Scopus citation database, which is an international multi-disciplinary database indexing over 18000 titles from more than 5000 publishers, including 16500 peers reviewed journals, 600 trade publications, 350 book series and 3.6 million international conference/seminar papers. Scopus has a world wide coverage, of which more than half of the Scopus contents originate from Europe, Latin America, Asia and the Pacific Region. Scopus' coverage of journals from developing countries including Sri Lanka is much higher, compared to the Web of Science database. Given its wider coverage of journals and conference/seminar proceedings from developed and developing countries, the use of Scopus is expected to generate a better picture of Sri Lanka's S&T indicators and hence its selection for this study.

The study has purposely used larger data set covering 10 publication years in order to ensure that the study reflects a more accurate and reliable results as possible. In addition, it used citations data for measuring quality and visibility of Sri Lanka's research output. For this purpose, a three-year citation window has been used for counting the citations received and to access the impact of the research output The study has used a number of absolute publications, citation and collaborative measures for developing S&T indicators as needed for depicting Sri Lanka's status in science and technology from 2001 to 2010.

The Scopus database classifies each item covered under 20 subject categories of S&T and four broad subject categories, such as physical sciences, engineering sciences, life sciences and health sciences. The physical sciences include subjects such as physics, chemistry, mathematics, earth & planetary sciences and environmental sciences. Life sciences include subjects such as agricultural & biological sciences, biochemistry, genetics & molecular biology, pharmacology, toxicology and pharmaceutics, immunology & microbiology and neurosciences. Engineering sciences include subjects such as engineering, materials science, computer science, chemical engineering and energy. Health sciences include subjects such as medicine, veterinary science, public health, dentistry and nursing. The Scopus database classifies each item on the basis of source subject title.

FINDINGS

Science and Technology (S&T) Publications Output

Sri Lanka has produced 5301 papers during the last ten years (2001-2010), which are increasing at an annual average growth rate of 13.20%. In terms of cumulative publications growth, the cumulative S&T publications output of Sri Lanka had increased from 1816 publications during 2001-2005 to 3385 publications during 2006-2010, experiencing a growth rate of 91.90% (Table 1). The h-index of its total publications during 2001-2010 was 60 and the number of high-cited papers (receiving 100 or more citations till today from the date of their publication) recorded was 17. Its average citation impact on a three year citation window for its total publications during 2001-2010 was 3.06. The global publications share of Sri Lanka during 2001-2010 was 0.030, which has increased from 0.024 in 2001-2005 to 0.035 in 2006-2010 (Table 2).

Table 1: Annual Publication Growth, Citation Impact & ICP Share of Sri Lanka, 2001-2010

Year	Sri Lanka			
	TP	ACPP	ICP	ICP Share
2001	240	2.61	102	42.50
2002	271	3.26	94	34.69
2003	396	4.39	214	54.04
2004	417	4.18	227	54.44
2005	492	3.90	252	51.22
2006	583	4.09	293	50.26
2007	667	4.01	353	52.92
2008	702	3.35	349	49.72
2009	746	1.74	362	48.53
2010	687	0.80	377	54.88
2001-05	1816	3.80	889	48.95
2006-10	3485	2.66	1734	51.23
2001-10	5301	3.06	2623	50.43
TP=Total Papers; ACPP=Average Citations per Paper; ICP=International Collaborative Papers				

Table 2: Global Publication Share of Sri Lanka during 2001-2010

Year	Count of Papers		
	Sri Lanka	World	Sri Lanka World Share
2001	240	1326979	0.018
2002	271	1371936	0.020
2003	396	1426444	0.028
2004	417	1579618	0.026
2005	492	1749574	0.028
2006	583	1832242	0.032
2007	667	1927447	0.035
2008	702	2006228	0.035
2009	746	2087381	0.036
2010	687	2175243	0.032
2001-05	1816	7454551	0.024
2006-10	3485	10028541	0.035
2001-10	5301	17483092	0.030

Subject Profile in Science & Technology

As per the publications data for 2001-2010, Sri Lanka's research profile by broad disciplines emerges as follows. Health sciences subjects together contributed the highest publications share (34.16%), followed by life sciences (33.43%), physical sciences (25.73%) and engineering sciences (22.90%). Its publications share has increased in engineering sciences from 18.06% to 26.17% and health sciences from 32.65% to 35.98%, as against decrease in physical sciences from 31.55% to 23.37% and in life sciences from 39.21% to 31.31% from 2001-2005 to 2006-2010 (Table 3).

High Productivity Subject Areas

Medicine, agricultural & biological sciences, engineering and environmental science are considered as the four high priority areas of Sri Lanka in S&T, each contributing publication share between 12.22% and 31.50% in the cumulative national publication output of Sri Lanka during 2001-10.

The highest national publication share of Sri Lanka in medicine was 31.50%, followed by agricultural & biological sciences (19.50%), engineering (13.96%) and environmental science (12.22%) during 2001-10. The national publication share of Sri Lanka has witnessed the largest increase in medicine by 17.86% (from 20.48% to 38.35%), followed by engineering by 8.58% (from 8.65% to 17.22%), as against decrease in agricultural & biological sciences by 6.23% (from 24.28% to 18.05%) and in environmental sciences by 4.80% (from 15.58% to 10.78%) from 2001-2005 to 2006-2010 (Table 4).

Table 3: Distribution of Papers in Sri Lanka by Broad Subject, 2001-10

Broad Subject	Number of Papers			Publications Share		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
Physical Sciences	573	791	1364	31.55	23.37	25.73
Engineering Sciences	328	886	1214	18.06	26.17	22.90
Life Sciences	712	1060	1772	39.21	31.31	33.43
Health Sciences	593	1218	1811	32.65	35.98	34.16

Table 4: World & National Publication Share, ICP Share, ACPP, H-Index and HCP in High Productivity Subject Areas, 2001-2010

Subject	National Publication Share (%)			World Publication Share (%)	ICP Share (%)	ACPP	h-Index	HCP
	2001-05	2006-10	2001-10	2001-10				
Medicine	20.48	38.35	31.50	0.035	43.83	3.34	38	9
Agricultural & Biological Sciences	24.28	18.05	19.50	0.089	61.03	3.08	29	1
Engineering	8.65	17.22	13.96	0.023	42.84	1.11	18	2
Environmental Science	15.58	10.78	12.22	0.092	66.20	4.04	33	3
ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=High Cited Papers								

The highest global publications share (0.092) of Sri Lanka in these high productivity subject areas was observed in environmental sciences, followed by agricultural & biological sciences (0.089), medicine (0.035) and engineering (0.023) during 2001-2010. The largest international collaborative publications share (66.20%) of Sri Lanka was observed in environmental science, followed by agricultural & biological sciences (61.03%), medicine (43.83%) and engineering (42.84%) during 2001-2010 (Table 4).

The highest average citation impact per paper (4.04) for all its publications in high productivity subject areas was observed in environmental science, followed by medicine (3.34), agricultural & biological sciences (3.08) and engineering (1.11) during 2001-10. The highest h-index (38) of Sri Lanka publications during 2001-2010 was achieved by medicine, followed by environmental science (33), agricultural & biological sciences (29) and engineering (18) during 2001-10. The largest number of high-cited papers (9) was recorded by Sri Lanka in medicine, followed by environmental science (3), engineering (2) and agricultural & biological sciences (1) during 2001-2010 (Table 4).

Medium Productivity Subject Areas

Computer science, biochemistry, genetics & molecular biology, immunology & microbiology, chemistry, earth & planetary sciences, physics, materials science and

pharmacology, toxicology & pharmaceutics are considered as the eight medium priority areas of Sri Lanka in S&T, each contributing publication share between 3.79% and 8.58% in the cumulative national publication output of Sri Lanka during 2001-2010.

The highest national publication share (8.58%) of Sri Lanka was recorded in computer science, followed by biochemistry, genetics & molecular biology (7.70%), immunology & microbiology (6.02%), chemistry (5.56%), earth & planetary sciences (4.94%), physics (4.73%), materials science (4.64%) and pharmacology, toxicology & pharmaceutics (3.79%) during 2001-10. The national publication share of Sri Lanka has witnessed the largest increase in computer science by 10.14% (from 2.15% to 12.29%), followed by materials science by 0.24% (from 4.57% to 4.82%), as against decrease in chemistry by 1.61% (from 6.72% to 5.11%), physics by 1.38% (from 5.73% to 4.34%), immunology & microbiology by 1.07% (from 6.83% to 5.76%), in pharmacology, toxicology & pharmaceutics by 0.75% (from 4.35% to 3.60%), in biochemistry, genetics & molecular biology by 0.55% (from 8.20% to 7.65%) and earth & planetary sciences by 0.04% (from 5.07% to 5.02%) from 2001-2005 to 2006-2010 (Table 5).

Table 5: World & National Publication Share, ICP Share, ACPP, H-Index and HCP in Medium Productivity Subject Areas, 2001-10

Subject	National Publication Share (%)			World Publication Share (%)	ICP Share (%)	ACPP	h-index	HCP
	2001-05	2006-10	2001-10	2001-10				
Computer Science	2.15	12.29	8.58	0.032	31.21	0.52	10	0
Biochemistry, Genetics & Molecular Biology	8.20	7.65	7.70	0.019	67.40	4.52	25	0
Immunology & Microbiology	6.83	5.76	6.02	0.057	61.76	5.01	27	1
Chemistry	6.72	5.11	5.56	0.023	61.36	5.15	29	2
Earth & Planetary Science	5.07	5.02	4.94	0.035	76.72	3.87	20	0
Physics	5.73	4.34	4.73	0.013	58.96	4.37	25	0
Materials Science	4.57	4.82	4.64	0.017	56.10	4.57	25	2
Pharmacology, Toxicology & Pharmaceutics	4.35	3.60	3.79	0.032	48.76	3.42	20	0

ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=High Cited Papers

The highest global publications share (0.057) of Sri Lanka in these medium productivity subject areas was observed in immunology & microbiology, followed by earth & planetary science (0.035), pharmacology, toxicology & pharmaceutics (0.032), computer science (0.032), chemistry (0.023, biochemistry, genetics & molecular biology (0.019), materials science (0.017) and physics (0.013) during 2001-10. The largest international collaborative publications share (76.72%) of Sri Lanka was observed in earth & planetary science, followed by biochemistry, genetics & molecular biology (67.40%), immunology & microbiology (61.76%), chemistry (61.36%), physics (58.96%), materials science (56.10%), pharmacology, toxicology & pharmaceutics (48.76%) and computer science (31.21%) during 2001-2010 (Table 5).

The highest average citation impact per paper (5.15) for all its publications in medium productivity subject areas was observed in chemistry, followed by immunology & microbiology (5.01), materials science (4.57), biochemistry, genetics & molecular biology

(4.52), physics (4.37), earth & planetary sciences (3.87), pharmacology, toxicology & pharmaceutics (3.42) and computer science (0.52) during 2001-10. The highest h-index (29) of Sri Lanka publications was achieved by chemistry, followed by immunology & microbiology (27), biochemistry, genetics & molecular biology (25), physics (25), materials science (25), earth & planetary science (20), pharmacology, toxicology & pharmaceutics (20) and computer science (10) during 2001-2010. The largest number of high-cited papers (2) was recorded by Sri Lanka in chemistry and materials science, followed by immunology & microbiology (1) and zero in other subjects during 2001-2010 (Table 5).

Low Productivity Subject Areas

Energy, chemical engineering, dentistry, mathematics, nursing, neurosciences and veterinary science are considered as the seven low priority areas of Sri Lanka in S&T, each contributing publication share between 1.11% and 2.66% in the cumulative national publication output of Sri Lanka during 2001-2010.

The highest national publication share (2.66%) of Sri Lanka was recorded in energy, followed by chemical engineering (2.32), dentistry (1.91), mathematics (1.77), nursing (1.41), neurosciences (1.17) and veterinary science (1.11) during 2001-10. The national publication share of Sri Lanka has witnessed the largest increase (1.28) in nursing, followed by mathematics (0.41%), as against decrease by 1.50% in energy, 0.91% in dentistry, 0.71% in neurosciences, 0.38% in veterinary science and 0.34% in chemical engineering from 2001-05 to 2006-10. The highest global publications share (0.107) of Sri Lanka in these low productivity subject areas was observed in dentistry, followed by energy (0.036), veterinary science (0.034), nursing (0.028), chemical engineering (0.016), neurosciences (0.013) and mathematics (0.011) during 2001-2010 (Table 6).

Table 6: World & National Publication Share, ICP Share, ACPP, H-Index and HCP in Low Productivity Subject Areas, 2001-2010

Subject	National Publication Share (%)			World Publication Share (%)	ICP Share (%)	ACPP	h-Index	HCP
	2001-05	2006-10	2001-10	2001-10				
Energy	3.69	2.19	2.66	0.036	46.81	4.30	21	0
Chemical Engineering	2.59	2.25	2.32	0.016	60.16	5.42	18	1
Dentistry	2.53	1.62	1.91	0.107	48.51	4.49	10	0
Mathematics	1.54	1.95	1.77	0.011	68.09	2.48	10	0
Nursing	0.61	1.89	1.41	0.028	54.67	2.24	8	0
Neurosciences	1.65	0.95	1.17	0.013	62.90	4.15	11	0
Veterinary science	1.38	1.00	1.11	0.034	61.02	3.59	10	0
ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=High Cited Papers								

The highest average citation impact per paper (5.42) for all its publications in low productivity subject areas was observed in chemical engineering, followed by dentistry (4.49), energy (4.30), neurosciences (4.15), veterinary science (3.59), mathematics (2.48) and nursing (2.24) during 2001-10. The highest h-index (21) of Sri Lanka publications was achieved by energy, followed by chemical engineering (18), neurosciences (11), mathematics (10), dentistry (10), veterinary science (10) and nursing (8) during 2001-2010. The largest number of high-cited papers (1) was recorded by Sri Lanka in chemical engineering and zero papers in all other subjects during 2001-2010 (Table 6).

The Least Productivity Subject Areas of Research

Public health is considered as the only least priority subject area of Sri Lanka in S&T, contributing publication share of 0.66% in the cumulative national publication output of Sri Lanka during 2001-2010. The national publication share of Sri Lanka has witnessed decrease by 0.24% (from 0.83% to 0.59%) in public health from 2001-2005 to 2006-2010. The global publications share (0.14) of Sri Lanka was observed in public health. The international collaborative publications share (45.71%) of Sri Lanka was observed public health during 2001-2010.

The average citation impact per paper for all its publications in public health was 2.14 during 2001-2010. The h-index (6) of Sri Lanka publications was achieved in public health in 2001-2010. The number of high-cited papers recorded by Sri Lanka in public health was zero during 2001-2010 (Table 7).

Table 7: World & National Publication Share, ICP Share, ACPP, H-Index and HCP in Least Productivity Subject Areas, 2001-2010

Subject	National Publication Share (%)			World Publication Share (%)	ICP Share (%)	ACPP	h-Index	HCP
	2001-05	2006-10	2001-10	2001-10				
Public Health	0.83	0.59	0.66	0.014	45.71	2.14	6	0
ACPP=Average Citations per Paper; ICP=International Collaborative Papers; HCP=High Cited Papers								

International Collaboration

The share of international collaborative papers in the Sri Lanka research output was 50.43% during 2001-2010. Its share of internationally collaborative papers has increased from 48.95% during 2001-2005 to 51.23% during 2006-10. In terms of citation impact of international collaborative papers, Sri Lanka achieved a citation impact of 4.74 per paper during 2001-2010.

Table 8 depicts the international collaborative linkages of Sri Lanka with top 45 countries during 2001-2010. The largest number of collaborative linkages (664) of Sri Lanka was with United Kingdom with 25.60% share, followed by United States (21.63% share), Australia (16.10% share), Japan (15.38% share), India, Canada, Germany, Sweden, Switzerland, Thailand and China (varying from 4.01% to 10.26% share), Netherlands, France, Pakistan, Malaysia, South Africa, Singapore, South Korea, Belgium, Nepal, Bangladesh, New Zealand, Italy, Columbia, Philippines, Brazil and Iran (varying from 1.11% to 3.74% share) and with other countries (less than 1% share) during 2001-2010.

Of the top 45 international collaborating countries, Sri Lanka collaborative linkages have decreased with 7 countries, with largest decrease (5.34%) with United Kingdom, followed by Japan (1.76%), Germany (1.06%), Belgium (0.69%), Switzerland (0.16), Turkey (0.05%) and Pakistan (0.04%) from 2001-05 to 2006-10. In contrast, Sri Lanka collaborative linkages have increased with 38 other countries, with maximum increase of 3.94% was observed with Australia, followed by India (2.94%), China (2.66%), USA (2.61%), Bangladesh (1.58%), Canada (1.47%), South Korea (1.24%), Sweden (1.04%), Brazil (1.0%), and other countries less than 1%. from 2001-2005 to 2006-2010 (Table 8).

Table 8: Sri Lanka Collaborative Linkages with Top 45 Countries, 2001-2010

Collaborating Country	Number of International Collaborative Papers			Share of International Collaborative Papers		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
UK	259	412	671	29.13	23.79	25.60
USA	177	390	567	19.91	22.52	21.63
Australia	120	302	422	13.50	17.44	16.10
Japan	147	256	403	16.54	14.78	15.38
India	74	195	269	8.32	11.26	10.26
Canada	47	117	164	5.29	6.76	6.26
Germany	49	77	126	5.51	4.45	4.81
Sweden	37	90	127	4.16	5.20	4.85
Switzerland	41	77	118	4.61	4.45	4.50
Thailand	34	78	112	3.82	4.50	4.27
China	20	85	105	2.25	4.91	4.01
Netherlands	31	67	98	3.49	3.87	3.74
France	23	60	83	2.59	3.46	3.17
Pakistan	26	50	76	2.92	2.89	2.90
Malaysia	18	50	68	2.02	2.89	2.59
S.Africa	20	42	62	2.25	2.42	2.37
Singapore	17	45	62	1.91	2.60	2.37
S.Korea	9	39	48	1.01	2.25	1.83
Belgium	20	27	47	2.25	1.56	1.79
Nepal	14	32	46	1.57	1.85	1.76
Bangladesh	6	39	45	0.67	2.25	1.72
New Zealand	13	27	40	1.46	1.56	1.53
Italy	12	27	39	1.35	1.56	1.49
Columbia	12	27	39	1.35	1.56	1.49
Philippines	8	30	38	0.90	1.73	1.45
Brazil	7	31	38	0.79	1.79	1.45
Iran	7	22	29	0.79	1.27	1.11
Taiwan	4	22	26	0.45	1.27	0.99
Austria	6	19	25	0.67	1.10	0.95
Spain	2	17	19	0.22	0.98	0.72
Mexico	2	17	19	0.22	0.98	0.72
Nigeria	5	10	15	0.56	0.58	0.57
Finland	3	11	14	0.34	0.64	0.53
Czech Republic	4	10	14	0.45	0.58	0.53
Poland	3	10	13	0.34	0.58	0.50
Turkey	4	7	11	0.45	0.40	0.42
Russia	1	8	9	0.11	0.46	0.34
Romania	0	5	5	0.00	0.29	0.19
Kuwait	1	4	5	0.11	0.23	0.19
Argentina	1	4	5	0.11	0.23	0.19
Ukraine	0	4	4	0.00	0.23	0.15
Jordan	0	4	4	0.00	0.23	0.15
Saudi Arabia	1	2	3	0.11	0.12	0.11
Slovenia	0	3	3	0.00	0.17	0.11
Total	889	1732	2621	100.00	100.00	100.00

On further grouping 45 collaborating countries, it was found that Sri Lanka's combined collaborating papers share was highest (67.46%) with G-8 countries, followed by 18 developing countries (17.47% share), 4 South Asian countries (17.25% share), 13 European countries (15.76% share) and 2 Pacific countries (13.05%) during 2001-10. Among these five group of countries, Sri Lanka's combined collaborating papers share has decreased by 3.63% in G-8 countries, as against increase by 8.40% in developing countries, 6.85% in

Pacific countries, 2.55% in South Asian countries and 1.21% in European countries from 2001-2005 to 2006-2010 (Table 8).

Geographical Distribution of Papers

Colombo is the only most productive geographical area in Sri Lanka which has individually contributed 36.80% share to the total research output of Sri Lanka during 2001-2010. Its publications share has, however, decreased from 37.61% to 36.38% from 2001-2005 to 2006-2010 (Table 9).

Kelaniya, Moratuwa, Kandy, and Nugegoda are the medium productive geographical areas of Sri Lanka with their individual publication share between 5.0% and 8.09% (together 29.18%) to the total research output of Sri Lanka during 2001-10. The publication share has increased from 7.60% to 8.35% in case of Kelaniya and from 4.90% to 9.73% in Moratuwa, as against decreased from 11.62% to 6.14% in Kandy and from 5.07% to 4.96% in Nugegoda from 2001-2005 to 2006-2010 (Table 9).

Galle, Jaffna and Battaramulla are the low productive geographical areas of Sri Lanka with their individual publication share between 1.06% and 2.60% (together 5.43%) to the total research output of Sri Lanka during 2001-2010. The research contribution of all the three cities has increased from 2.09% to 2.87% in Galle, 1.43% to 1.95% in Jaffna and 0.72% to 1.23% in Battarmulla from 2001-2005 to 2006-2010 (Table 9).

Table 9: Geographical Distribution of Papers of Sri Lanka, 2001-10

Sri Lanka Cities	Number of Papers			Share of Papers		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
Colombo	683	1268	1951	37.61	36.38	36.80
Kelaniya	138	291	429	7.60	8.35	8.09
Moratuwa	89	339	428	4.90	9.73	8.07
Kandy	211	214	425	11.62	6.14	8.02
Nugegoda	92	173	265	5.07	4.96	5.00
Galle	38	100	138	2.09	2.87	2.60
Jaffna	26	68	94	1.43	1.95	1.77
Battaramulla	13	43	56	0.72	1.23	1.06
Anuradhapura	18	32	50	0.99	0.92	0.94
Lunuwila	14	30	44	0.77	0.86	0.83
Agalawatta	17	16	33	0.94	0.46	0.62
Talawakelle	10	19	29	0.55	0.55	0.55
Dehiwala	5	16	21	0.28	0.46	0.40
Belihuloya	2	15	17	0.11	0.43	0.32
Batalagoda	2	10	12	0.11	0.29	0.23
Mihintale	2	6	8	0.11	0.17	0.15
Ekala	0	5	5	0.00	0.14	0.09
Peredeniya	1	1	2	0.06	0.03	0.04
	1816	3485	5301	100.00	100.00	100.00

Institutional Profile

a) Universities

The top 10 universities in Sri Lanka together have published 3852 papers, which account for 72.66% share of the total research output of Sri Lanka during 2001-2010. The output of individual universities however varied from 14 to 1198, with average productivity of 385.2 papers per university. The international collaborative share of these 10 universities account for 41.28% share (varying from 32.38% to 75.00%) of their total output during

2001-10. These 10 universities have achieved an h-index of 50 (varying from 3 to 36) and number of high-cited papers published was only 13 (varying from 0 to 6). A complete profile of these 10 universities is given in Table 10**.**

Table 10: Sri Lanka: Top 10 Most Productive Universities, 2001-2010

S.No	Name of the University	TP	H-Index	HCP	ICP	%ICP
1	University of Peradeniya, Kandy	1198	36	4	684	57.10
2	University of Colombo	948	33	6	410	43.25
3	University of Kelaniya	426	22	1	151	35.45
4	University of Moratuwa	420	13	1	136	32.38
5	University of Rahuna, Galle	267	19	0	137	51.31
6	University of Shri Jayewardenepura, Nugegoda	230	16	0	89	38.70
7	University of Jaffna	89	13	3	45	50.56
8	Open University of Sri Lanka, Nugegoda	74	7	0	39	52.70
9	Sabaragamuwa University of Sri Lanka, Belihuloya	24	5	0	18	75.00
10	University of Rajarata, Mihintale	14	3	0	5	35.71
TP=Total Papers; ICP=International Collaborative Papers; HCP=High Cited Papers						

b) Research Institutes

The top 17 research institutes in Sri Lanka together have published 1078 papers, which account for 20.33% share of the total research output of Sri Lanka during 2001-2010. The output of individual research institutes, however, varied from 2 to 401, with an average productivity of 63.41 papers per institution. The international collaborative share of these 17 research institutes account for 20.33% share (varying from 0.00% to 74.56%) of their total output during 2001-2010. These 17 research institutes have achieved an h-index of 39 (varying from 2 to 31) and number of high-cited papers published was only 4 (varying from 0 to 2). A complete profile of these 17 research institutes is given in Table 11**.**

Table 11: Sri Lanka - Top 17 Most Productive Research Institutes, 2001-2010

S.No	Name of Research Institute	TP	H-Index	HCP	ICP	% ICP
1	International Water Management Institute (IWMI)	401	31	2	299	74.56
2	Institute of Fundamental Studies, Kandy	325	28	1	181	55.69
3	Medical Research Institute, Colombo	45	9	1	18	40.0
4	Industrial Technology Institute, Colombo	73	13	0	21	28.8
5	Ministry of Health, Colombo	58	8	0	34	58.6
6	Rubber Research Institute of Sri Lanka, Agalawatta	41	9	0	18	43.9
7	Tea Research Institute of Sri Lanka, Talawakelle	33	6	0	8	24.2
8	Coconut Research Institute of Sri Lanka, Lunuwila	26	7	0	15	57.7
9	Veterinary Research Institute, Peradeniya	24	8	0	10	41.7
10	Department of Agriculture, Colombo	13	4	0	4	30.8
11	Rice Research & Development Institute, Batalagoda	13	3	0	2	15.4
12	National Aquatic Resources Research & Development Agency, Colombo	11	5	0	3	27.3
13	Institute of Policy Studies, Colombo	7	3	0	2	28.6
14	National Engineering Research & Development Center, Ekala	6	3	0	3	50.0
15	Institute for Research & Development, Baattaramula	5	4	0	3	60.0
16	Marga Institute, Colombo	4	2	0	0	0.0
17	Geological Survey & Mines Bureau, Dehiwala	2	2	0	1	50.0
TP=Total Papers; ICP=International Collaborative Papers; HCP=High Cited Papers						

c) Medical Colleges and Hospitals

The top 5 medical colleges and hospitals in Sri Lanka together have published 207 papers, which account for 3.90% share of the total research output of Sri Lanka during 2001-2010. The output of individual medical colleges and hospitals, however, varied from 16 to 129, with an average productivity of 41.40 papers per organization. The international collaborative share of these 5 medical colleges & hospitals account for 25.60% share (varying from 18.60% to 41.18%) of their total output during 2001-2010. These 5 medical colleges and hospitals have achieved an h-index of 14 (varying from 4 to 11) and number of high-cited papers published was only 2 (varying from 0 to 1). A complete profile of these 5 medical colleges and hospitals is given in Table 12**.**

Table 12: Sri Lanka - Top 5 Most Productive Medical Colleges & Hospitals, 2001-2010

S.No	Medical Colleges & Hospitals	TP	H-Index	HCP	ICP	% ICP
1	National Hospital of Sri Lanka, Colombo	129	11	1	24	18.60
2	Lady Ridgeway Hospital for Children, Colombo	29	6	0	10	34.48
3	Apollo Hospital, Colombo	18	4	0	7	38.89
4	Sri Jayewardenepura General Hospital, Nugegoda	17	4	0	7	41.18
5	Anuradhapura General Hospital	16	8	1	6	37.50
TP=Total Papers; ICP=International Collaborative Papers; HCP=High Cited Papers						

Contribution and Citation Impact of Most Productive Authors

Fifteen authors have been identified as productive authors who have published 24 and above papers in science and technology from Sri Lanka (Table 13). They have contributed 496 papers with an average of 33.07 papers per author and account for 9.36% share in the cumulative publications output of Sri Lanka during 2001-2010. Five authors have published higher number of papers than the group average (33.07). These are: H.J.De Silva with 69 papers, followed by K.Tennakone (60 papers), N.D Karunaweera (41 papers), R.P.V.J. Rajapaske (35 papers) and H.Turral (34 papers). Considering the citation/impact of these papers, these most productive authors have received a total of 2171 citations for these 496 papers with an average of 4.38 citations per paper (varying from 0.50 to 9.74). Six authors have registered higher citation impact than the average impact of papers of all authors. These are M.H.R. Sheriff with average citation per paper of 9.74, followed by K.Tennakone (6.93), M.F.Giordano (6.88), N.D.Karunaweera (6.00), H.Turral (5.47) and A.R.Wickremesimghe (5.22). These 15 authors have received an average h-index of 8.33 (varying from 2 to 18). Eight authors have achieved the higher h-index value than the group average of 8.33. These are K. Tannakone with an h-index of 18, followed by H.J.De Silva (11), M.H.R.Sheriff (11), M.F.Giordano (10), N.D. Karunaweera (9), R.P.V.J.Rajapaske (9), H.Turral (9) and A.R.Wickremasinghe (9).

Journals Publishing Sri Lanka's Research

The top 25 most productive national and international journals publishing Sri Lanka's research papers in science and technology together contributed 1016 papers, which accounts for 19.17% share in the cumulative publications output of Sri Lanka during 2001-10. The cumulative publications share of these 25 most productive domestic journals showed decrease in Sri Lanka's publications output from 20.54% during 2001-2005 to 18.45% during 2006-1200 (Table 14).

Table 13: Productivity & Impact of 15 Most Productive Sri Lanka Authors in S&T, 2001-2010

S. No.	Name of Authors	Affiliation of Authors	TP	TC	ACPP	H-index
1.	H.J De Silva	Univ. of Kelaniya, Faculty of Medicine, Kelaniya	64	272	4.25	11
2.	K. Tennakone	Univ. of Colombo, Colombo	60	416	6.93	18
3.	N.D. Karunaweera	Univ. of Colombo, Dept. of Parasitology, Colombo	41	246	6.00	9
4.	R.P.V.J Rajapaske	Univ. of Colombo, Dept. of Zoology, Colombo	35	128	3.66	9
5.	H. Turral	International Water Management Institute, Colombo	34	186	5.47	9
6.	W.D.Ratnosooriya	Univ. of Colombo, Dept. of Zoology, Colombo	31	66	2.13	8
7.	A. Pathmeswaron	Univ. of Kelaniya, Faculty of Medicine, Kelaniya	28	103	3.68	6
8.	A.R. Wickremasinghe	Univ. of Kelaniya, Dept. of Public Health, Kelaniya	27	141	5.22	9
9.	M.H.R Sheriff	Univ. of Colombo, Faculty of Medicine, Colombo	27	263	9.74	11
10.	R.L.C. Wijesundera	Univ. of Colombo, Dept. of Plant Sc., Colombo	26	39	1.50	7
11.	G.Seneviratne	Institute of Fundamental Studies, Kandy	26	62	2.38	8
12.	M.F. Giordano	International Water Management Institute, Colombo	25	172	6.88	10
13.	P.L.N.Lakshman	Univ. of Rahuna, Dept. of Food Science & Tech. Mapalana	24	18	0.75	2
14.	E.R.Jansz	Univ. of Jayewardenepura, Dept. of Biochemistry, Nugegoda	24	47	1.96	6
15.	J.P.Marasinghe	De Soyza Hospital for Women, Univ. Obstetrics, Colombo	24	12	0.50	2
		Total	496	2171	4.38	8.33
		Total of the Country	5301			
		Share of 15 authors in country output	9.36			
TP=Total Papers; ACPP=Average Citations per Paper; ICP=International Collaborative Papers						

Table 14: Productivity of the Top 25 Most Productive National & International Journals, 2001-2010

S.No	Journal Title	Number of Papers		
		2001-2005	2006-2010	2001-2010
1	Ceylon Medical Journal	116	148	264
2	Journal of the National Foundation of Sri Lanka	13	153	166
3	Trans. Of the Royal Society of Tropical Medicine & Hygiene	16	36	52
4	Current Science	20	22	42
5	Lancet	16	25	41
6	Agricultural Water Management	16	22	38
7	Water Policy	20	14	34
8	Southeast Asian Journal of Tropical Medicine & Public Health	16	15	31
9	Irrigarion & Drainage	16	15	31
10	British Medical Journal	19	7	26
11	Acta Crstalllographica Section E. Structura Reports Online	0	25	25
12	Clinical Toxicology	2	22	24
13	Solar Energy Materials & Solar Cells	16	7	23
14	Annals of the Tropical Medicine & Parasitology	11	10	21
15	Acta Horticulturae	0	20	20
16	Energy for Sustainable Development	15	4	19
17	Pharmaceutical Biology	11	8	19
18	Zootaxa	0	19	19
19	Water International	6	12	18
20	Journal of Oral Pathology & Medicine	4	14	18
21	British Journal of Psychiatry	10	8	18
22	Tropical Medicine & International Health	8	10	18
23	Irrigation & Drainage Systems	10	7	17
24	Chemoshere	9	7	16
25	Malaria Journal	3	13	16
	Total Papers	373	643	1016
	Country's Total Papers	1816	3485	5301
	Share of Top 20 National Journals in Country Output	20.54	18.45	19.17

Sri Lanka's High-Cited Papers

Sri Lanka has published 17 high-cited papers (receiving 100 or more citations since their publications till November 2011) in science and technology in last 10 years (2001-2010) and these have received between 101 and 250 citations per paper. Of these 17 high-cited papers, all were international collaborative (10 bilateral and 7 multilateral). Of the international collaborative papers, Sri Lanka institutions were first author in only 4 papers and foreign institutions in 13 papers. Of the 17 high cited papers, 11 appeared as articles, 5 as review papers and 1 as editorial. In overall, Sri Lanka participation in these 17 papers was confined to 13 institutions, which includes 6 papers from University of Colombo , 4 papers from University of Peradeniya, 3 papers from University of Jaffna, 2 papers from International Water Management Institute, Colombo and 1 paper each from 9 other institutions. These 17 high cited papers appeared in 16 journals, including 2 papers in *Lancet* and 1 paper each in 15 other journals. The list of high cited papers is given in Table 15.

Table 15: List of High-Cited Papers of Sri Lanka, 2001-2010

S.No	Authors	Title	Source title	No of citations
1	De Silva N.R., Brooker S., et al	Soil-transmitted helminth infections: Updating the global picture (Review)	Trends in Parasitology 2003, 19(12), 547-51	250
2	Ekanayake J.B., Holdsworth L., et al	Dynamic modeling of doubly fed induction generator wind turbines (Article)	IEEE Transactions on Power Systems 2003, 18(2), 803-09	237
3	De Jong J.T.V.M., Komproe I.H., et al	Lifetime events and posttraumatic stress disorder in 4 postconflict settings (Article)	Journal of the American Medical Association 2001, 286(5), 555-62	210
4	Ravirajan P., Peiro A.M., et al	Hybrid polymer/zinc oxide photovoltaic devices with vertically oriented ZnO nanorods and an amphiphilic molecular interface layer(Article)	Journal of Physical Chemistry B 2006, 110(15), 7635-39	192
5	Kumara G.R.A., Konno A., et al	Dye-sensitized solid-state solar cells: Use of crystal growth inhibitors for deposition of the hole collector(Article)	Chemistry of Materials 2002, 14(3), 954-55	149
6	Holdsworth L., Wu X.G., et al	Comparison of fixed speed and doubly-fed induction wind turbines during power system disturbances(Article)	IEE Proceedings: Communications 2003, 150(3), 343-52	140
7	Harrad S., Wijesekera R., et al	Preliminary Assessment of U.K. Human Dietary and Inhalation Exposure to Polybrominated Diphenyl Ethers(Article)	Environmental Science and Technology 2004, 38(8), 235-50	128
8	Messer W.B., Gubler D.J., et al	Emergence and global spread of a dengue serotype 3, subtype III virus(Article)	Emerging Infectious Diseases 2003, 9(7), 800-809	128
9	Eddleston M., Phillips M.R.	Self poisoning with pesticides(Review)	British Medical Journal 2004, 328(7430), 42-44	125
10	Eddleston M., Karalliedde L., et al	Pesticide poisoning in the developing world - A minimum pesticides list(Review)	Lancet 2002, 360(9340), 1163-67	125
11	Boucle J., Ravirajan P., Nelson J.	Hybrid polymer-metal oxide thin films for photovoltaic applications(Article)	Journal of Materials Chemistry 2007, 17(30), 3141-53	116
12	Amarasinghe B.M.W.P.K., Williams R.A.	Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater(Article)	Chemical Engineering Journal 3 January 2007, 17, 3141-53	113
13	Song J.-H., Jung S.-I., et al	High prevalence of antimicrobial resistance among clinical Streptococcus pneumoniae isolates in Asia (an ANSORP study)(Article)	Antimicrobial Agents and Chemotherapy 2004, 48(6), 2101-2107	113
14	Gunnell D.J., Eddleston M.	Suicide by intentional ingestion of pesticides: A continuing tragedy in developing countries (Editorial)	International Journal of Epidemiology 2003, 32(6), 902-909	113
15	Eddleston M., Eyer P., et al	Differences between organophosphorus insecticides in human self-poisoning: A prospective cohort study(Article)	Lancet 2005, 366(9495), 1452-59	109
16	Spalding M.D., Fox H.E., et al	Marine ecoregions of the world: A bioregionalization of coastal and shelf areas(Review)	BioScience 2007, 57(7), 573-83	107
17	Malavige G.N., Fernando S., et al	Dengue viral infections(Review)	Postgraduate Medical Journal 2004, 80(948), 588-601	101

SUMMARY

Sri Lanka has produced 5301 papers during the last ten years (2001-2010), which are increasing at an annual average growth rate of 13.20%. The average citation impact of Sri Lankan papers on a three year citation window for its total publications during 2001-2010 was 3.06. The global publications share of Sri Lanka during 2001-2010 was 0.030, which has increased from 0.024 in 2001-05 to 0.035 in 2006-2010.

In terms of broad subjects, health sciences subjects together contributed the highest publications share (34.16%) during 2001-2010, followed by life sciences (33.43%), physical sciences (25.73%) and engineering sciences (22.90%). Its publications share in engineering sciences has increased from 18.06% to 26.17% and health sciences from 32.65% to 35.98%, as against decrease in physical sciences from 31.55% to 23.37% and in life sciences from 39.21% to 31.31% from 2001-2005 to 2006-2010.

Medicine, agricultural & biological sciences, engineering and environmental science are the four high priority areas of Sri Lanka in S&T, each contributing publication share between 12.22% and 31.50% in the cumulative national publication output of Sri Lanka during 2001-2010. Computer science, biochemistry, genetics & molecular biology, immunology & microbiology, chemistry, earth & planetary sciences, physics, materials science and pharmacology, toxicology & pharmaceutics are the eight medium priority areas of Sri Lanka in S&T, each contributing publication share between 3.79% and 8.58% in the cumulative national publication output of Sri Lanka during 2001-2010. Energy, chemical engineering, dentistry, mathematics, nursing, neurosciences and veterinary science are the seven low priority areas of Sri Lanka in S&T, each contributing publication share between 1.11% and 2.66% in the cumulative national publication output of Sri Lanka during 2001-2010.

The national publication share increased in medicine by 17.87%, followed by computer science (10.14%), engineering (8.57%), nursing (1.28%), mathematics (0.41%), materials science (0.25%) from 2001-05 to 2006-10, as against decrease in agricultural & biological sciences by 6.23%, followed by environmental science (4.8%), chemistry (1.61%), energy (1.50%), physics (1.39%), and immunology & microbiology (1.07%).

The world share of various subjects varied from 0.011 to 0.107 during 2001-2010, with maximum share (0.107) in dentistry, followed by environmental science (0.092%), agricultural & biological sciences (0.089), immunology & microbiology (0.057), energy (0.036), medicine (0.035), earth & planetary sciences (0.035), veterinary science (0.034), computer science (0.32), pharmacology, and toxicology & pharmaceutics (0.032).

The international collaborative publications share of various subjects varied from 31.21% to 76.72%, with maximum share (76.72%) in earth & planetary sciences during 2001-2010, followed by mathematics (68.09%), biochemistry, genetics & molecular biology (67.40%), environmental science (66.20%), neurosciences (62.90%), immunology & microbiology (61.76%), chemistry (61.36%), agricultural & biological sciences (61.03%), veterinary science (61.02%), and chemical engineering (60.16%).

The average citation impact per paper of various subjects varied from 0.52 to 5.42, with maximum citation impact (5.42) in chemical engineering during 2001-2010, followed by chemistry (5.15), immunology & microbiology (5.01), materials science (4.57),

biochemistry, genetics & molecular biology (4.52), dentistry (4.49), physics (4.37), energy (4.30), neurosciences (4.15), and environmental sciences (4.04).

The h-index of various subjects varied from 6 to 38, with maximum h-index (38) in medicine during 2001-2010, followed by environmental sciences (33), chemistry (29), agricultural & biological sciences (29), immunology & microbiology (27), materials science (25), biochemistry, genetics & molecular biology (25), physics (25), energy (21), earth & planetary sciences (20), and pharmacology, toxicology & pharmaceutics (20).

The number of high cited papers of various subjects varied from 0 to 9 during 2001-2010, with maximum papers (9) in medicine, followed by environmental sciences (3), chemistry (2), materials science (2), engineering (2), agricultural & biological sciences (1), immunology & microbiology (1) and chemical engineering (1).

The share of international collaborative papers in the Sri Lanka research output was 50.43% during 2001-2010, which increased from 48.95% during 2001-2005 to 51.23% during 2006-10. In terms of citation impact of international collaborative papers, Sri Lanka achieved a citation impact of 4.74 per paper during 2001-2010.

The largest number of collaborative linkages (664) of Sri Lanka was with United Kingdom with 25.60% share, followed with United States, Australia, Japan, India, Canada, Germany, Sweden, Switzerland, Thailand and China during 2001-2010. Sri Lanka's combined collaborating papers share was highest (67.46%) with G-8 countries, followed by 18 developing countries (17.47% share), 4 South Asian countries (17.25% share), 13 European countries (15.76% share) and 2 Pacific countries (13.05%) during 2001-2010.

In terms of geographical distribution of papers in Sri Lanka, Colombo is the only most productive geographical area who have contributed 36.80% share, Kelaniya, Moratuwa, Kandy, and Nugegoda are the four medium productive geographical areas with their publication share between 5.0% and 8.09% and Galle, Jaffna and Battaramulla are the three low productive geographical areas with their publication share between 1.06% and 2.60% to the total research output of Sri Lanka during 2001-2010.

The top 10 universities, 17 research institutes and 5 medical colleges and hospitals (32 organizations) in Sri Lanka together contributed 72.66%, 20.33% and 3.90% share respectively to the total research output of Sri Lanka during 2001-2010. These top 15 authors together contributed 496 papers with an average productivity of 33.07 papers per author. These authors together account for 9.36% share in the cumulative publications output of Sri Lanka, an average citation impact per paper of 4.38 and an average h-index of 8.33 during 2001-2010.

The top 25 most productive journals publishing Sri Lanka's research papers accounted for 19.17% share in the cumulative publications output of Sri Lanka during 2001-2010, which decreased from 20.54% during 2001-2005 to 18.45% during 2006-2010. Sri Lanka has published 17 high-cited papers in science and technology in last 10 years (2001-2010) and these have received between 101 and 250 citations per paper. Of these 17 high-cited papers, all were international collaborative (10 bilateral and 7 multilateral).

This paper concludes that Sri Lanka's output can be further increased by expanding and modernization of S&T infrastructure, investing more in R&D and deployment of more qualified manpower.

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