JSCIRES RESEARCH ARTICLE

Research trends in agricultural science: A global perspective

Anil Sagar*, Basavaraj Shivappa Kademani and Karanam Bhanumurthy

Scientific Information Resource Division , Bhabha Atomic Research Centre, Mumbai, India

ABSTRACT

This paper attempts to highlight quantitatively and qualitatively the growth and development of global agricultural science publication output and citations as per *Web of science* during 1993-2012. The objective of this study was to perform a scientometric analysis of all agricultural science research publications in the world. The parameters studied include growth of publications and citations, continent-wise distribution of publications and citations, country-wise distribution of publications, publication efficiency index, domain-wise distribution of publications and citations, specialization index, variation of average impact factor in agricultural science sub-domains, language-wise distribution of publications, distribution of high frequency keywords, identification of highly cited publications and highly preferred journals.

Keywords: Agricultural economics and policy, agricultural engineering, agricultural science, agriculture-multidisciplinary, Agronomy, dairy and animal sciences, publication efficiency index, publication productivity, quality research, R and D trend, scientometrics

INTRODUCTION

The human civilization began with agriculture. Our nomadic ancestors who depended on hunting and fishing for living slowly learnt to grow their own food. This metamorphosed the human society forever. Villages, towns and cities begin to flourish. This led man to advance in several branches of knowledge. In spite of several advancements in identifying several high yield crops and record production of agricultural produce, a significant portion of the population continue to suffer from hunger and malnutrition. The rate of growth in agricultural production is declining; world grain reserves have fallen to record lows; the demand for imported grain is increasing; and commitments of aid to agricultural development have decreased. This against a backdrop of expanding world population, intensifying demands on agricultural resources, and a growing recognition that the agri-food system is not sustainable. In addition, there is a lot of food is wasted because of lack of proper storage, preservation and distribution system in many countries. Therefore, it is high time that immediate necessary action has to be initiated at the national and international level to tackle this serious problem of food insecurity and make the world free from hunger.

Nearly 1 billion people-one out of six globally-lack access to adequate food and nutrition. By 2050, the global population will surpass 9 billion people, and demand for agricultural products is expected to double. Simultaneously, the world's agricultural systems will be increasingly challenged by water scarcity, climate change and volatility, raising the risk of production shortfalls. Substantial gains in agricultural productivity can be realized through investment, innovation, policy and other improvements. However, realizing these gains will require an exceptional level of collaboration among stakeholders in the agricultural value chain, including governments, companies, multilateral

***Address for correspondence:**
E-mail: asagar@barc.gov.in

Access this article online

Quick Response Code:

Website: www.jscires.org

DOI: 10.4103/2320-0057.135409

and civil-society organizations, farmers, scientists, consumers and entrepreneurs. There is a lot of research is being conducted all over the world in various areas of agriculture to overcome the food security problem and to evolve sustainable agricultural systems.

Scientometrics is a discipline which analyses scientific publications and citations appended to the papers to gain an understanding of the structure of science, growth of science at the global level, performance of a country in a particular domain, performance of institutions and scientific eminence of an individual scientist. It also helps in knowing the information seeking behavior of scientists and engineers by way of identifying where they publish and what they cite.

Balasubramanian and Ravanan[1] have studied the global agriculture literature and highlighted the scientific output during 1945-2010 and focused on the growth of literature, highly productive countries and most preferred journals. A few scientometric studies in various countries in agricultural science have been carried out.[2-8]

Many scientometric studies have appeared in the literature to focus on the performance of nuclear science and technology.[9-23] Scientometric studies are useful in understanding the growth of literature, identifying strengths and weaknesses of a country, organization and an individual in various domains of scientific endeavors. These studies will help the policy makers and science administrators to have better insights in framing science policy and guiding the researchers.

Objectives

The main objective of this study is to analyze the global research performance in the field of agricultural science as reflected in the publication and citation output during 1993-2012. In particular, the study focuses on the following aspects:

- To study the year-wise growth of publications and citations
- To study the continent-wise distribution of publications and citations
- To study the share of publications of highly productive countries
- To study the publication efficiency index (PEI) of highly productive countries
- To study the average citations per publication (ACP) of highly productive countries
- To study the distribution of publications and citations in various agricultural science sub-domains
- To study the specialization index (SI) of various countries in different agricultural sub-domains
- To study the variation of average impact factor (AIF) in agricultural science sub-domains
- To study the distribution of publications and citations of top ten countries in various agricultural science sub-domains
- To study the language-wise distribution of publications
- To study the highly cited publications in agricultural science
- To study the highly preferred journals for publication in the field, and
- To study the Quality of Research Output.

MATERIALS AND METHODS

Data were collected from Web of Science for the period 1993-2012. It is very difficult to define the scope of agricultural science using keywords and combination of keywords which may not always cover the entire gamut of literature on agricultural science and there is always every possibility of missing some percentage of literature. Therefore, it was decided to select all the journals on agricultural science and was identified from the subject categories provided by the Journal Citation Reports (JCR-2011). A list of 210 journals were identified falling within the scope of agricultural science as per JCR subject categories and all the bibliographic details of publications from these journals and citations to these publications were downloaded for the period 1993-2012. A total of 284,103 publications and 2,988,275 citations received to these publications were transferred to spread sheet application and analyzed the data as per objectives of the study. The bibliographic fields were analyzed by normal count procedure for continents, countries, sub-domain-wise, authorships and journals. Full credit was given to each continent, country regardless of whether it appears first or last in the author byline.

RESULTS AND DISCUSSION

Year-wise Distribution of Publications and Citations

A total of 284103 publications were published in Agricultural Science during 1993-2012 and these publications received 2,988,275 citations. Year-wise distribution of publications and citations is given in Figure 1 and Table 1. The highest number of publications 22,788 were published in 2011. The highest number of citations 205,098 were received

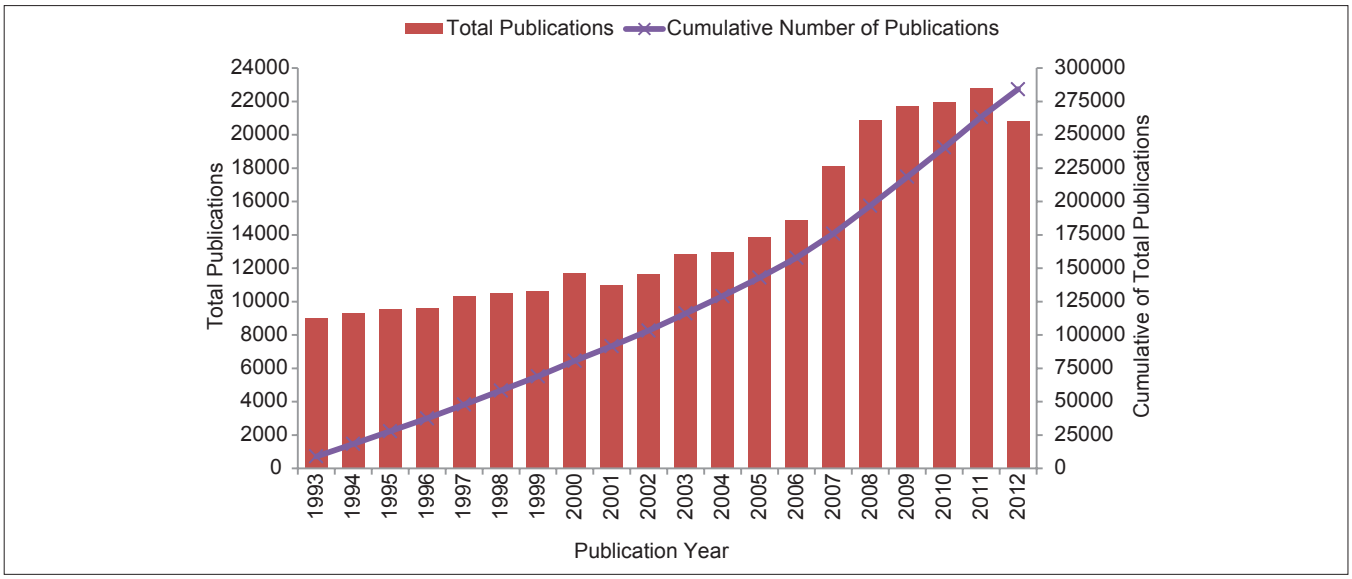

Figure 1: Year-wise distribution of publications in agricultural science (1993-2012)

Table 1: Year-wise distribution of publications and citations

Year	TP	Percentage of TP	TC	Percentage of TC	ACP	TIF	AIF	CR
1993	8990	3.16	142914	4.78	15.90	15304.00	1.70	0.85
1994	9332	3.28	141968	4.75	15.21	15717.91	1.68	0.85
1995	9536	3.36	159036	5.32	16.68	16143.36	1.69	0.87
1996	9608	3.38	164957	5.52	17.17	16466.02	1.71	0.87
1997	10361	3.65	176383	5.90	17.02	17504.24	1.69	0.88
1998	10500	3.70	176591	5.91	16.82	17673.89	1.68	0.89
1999	10619	3.74	184386	6.17	17.36	17658.72	1.66	0.89
2000	11687	4.11	205661	6.88	17.60	19331.93	1.65	0.90
2001	11018	3.88	188281	6.30	17.09	18310.46	1.66	0.91
2002	11635	4.10	205098	6.86	17.63	20110.76	1.73	0.92
2003	12829	4.52	203891	6.82	15.89	21737.72	1.69	0.93
2004	12984	4.57	182311	6.10	14.04	21791.79	1.68	0.92
2005	13847	4.87	175798	5.88	12.70	23283.07	1.68	0.93
2006	14862	5.23	163867	5.48	11.03	24828.33	1.67	0.93
2007	18147	6.39	152562	5.11	8.41	27821.93	1.53	0.93
2008	20861	7.34	140876	4.71	6.75	32977.85	1.58	0.94
2009	21740	7.65	107703	3.60	4.95	33623.55	1.55	0.94
2010	21937	7.72	74343	2.49	3.39	36734.85	1.67	0.95
2011	22788	8.02	35486	1.19	1.56	39110.08	1.72	0.95
2012	20822	7.33	6163	0.21	0.30	36909.87	1.77	0.96
Total	284103	100.00	2988275	100.00	10.52	473040.33	1.67	0.92

TP=Total publications, TC=Total citations, ACP=Average citations per publication, TIF=Total impact factor, AIF=Average impact factor per publication, CR=Collaboration rate

in 2002. The highest ACP 17.63 was in 2002. There were 63,623 (22.39%) publications with no citations during the period under study. The highest total impact factor (39,110.08) was in 2011. The highest AIF 1.77 was in 2012. Overall collaboration rate was very high (0.92) as 261,525 publications of the total documents were multi-authored and the highest CR (0.96) was in 2012. An average 6.55% annual growth of publications was observed. An exponential growth of publications was observed except in 2012 which may be attributed to the input time-lag in the database.

Continent-wise Distribution of Publications and Citations

The number and growth of Agricultural Science literature

in six continents of the world during 1993-2012 is illustrated in Table 2. It was observed that Europe is the most productive continent with 114,504 publications and 1,476,455 citations followed by North America with 89,881 publications and 1,241,421 citations and Asia with 83,454 publications and 610,791 citations.

Table 2: Continents-wise distribution of publications and citations in agricultural science (1993-2012)

Rank	Continents	Total countries	TP	Percentage of TP	TC	Percentage of TC	ACP	AIF	Publication trend
1	Europe	47	114504	40.30	1476455	49.41	12.89	1.86	
2	North America	16	89881	31.64	1241421	41.54	13.81	1.85	
3	Asia	45	83454	29.37	610791	20.44	7.32	1.56	
4	South America	12	22883	8.05	126361	4.23	5.52	1.16	
5	Australia/Oceania	7	15324	5.39	191361	6.40	12.49	1.79	
6	Africa	45	12442	4.38	92716	3.10	7.45	1.57	
7	Without Affiliation	-	2504	0.88	4253	0.14	1.70	0.76	

TP=Total publications, TC=Total citations, ACP=Average citations per publication, AIF=Average impact factor per publication

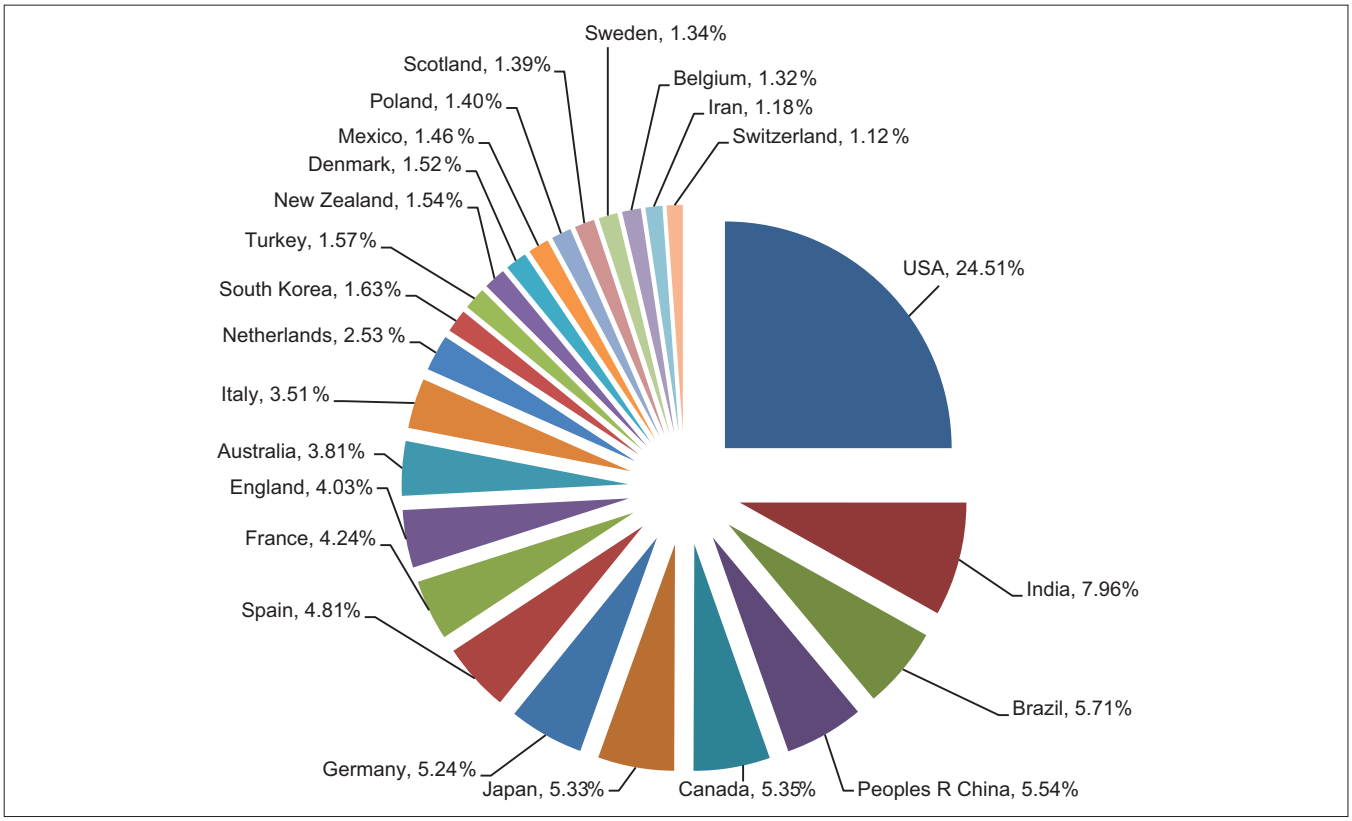

Figure 2: Countries share of publications in agricultural science (≥3000 publications)

Publications from North America received the highest average number of citations (13.81) per publication followed by Europe with 12.89 ACP, Australia/Oceania with 12.49 ACP, Africa with 7.45 and Asia with 7.32 ACP.

Germany is the highly productive country in Europe with 14,882 publications, 164,951 citations and 11.08 ACP. USA is the highly productive country in North America with 69,636 publications, 1,005,304 citations and 14.44 ACP India is the highly productive country in Asia with 22,615 publications, 98,954 citations and 4.38 ACP Brazil is the highly productive country in South America with 16,221 publications, 66,638 citations and 4.11 ACP. Australia is the highly productive country in Australia/Oceania with 10,814 publications, 135,635 citations and 12.54 ACP. South Africa is the highly productive country in Africa with 2404 publications, 17,139 citations and 7.13 ACP [Table 3].

Share of Publications of Highly Productive Countries

In all, there were 172 countries involved in research in agricultural science which published at least one publication. The publication share of highly productive countries (≥3000 publications) in agricultural science varies from 1.12% to 24.51% during 1993-2012 [Figure 2]. USA topped the list with highest share (24.51%) of publications. India ranked second with 7.96% share of publications followed by Brazil with 5.71%, Peoples R China with 5.54%, Canada with 5.35%, Japan with 5.33%, Germany with 5.24%, Spain with 4.81%, France with 4.24% and England with 4.03% share of publications. Table 4 provides distribution of publications and citations of highly productive countries with ≥ 3000 publications.

Publication Efficiency Index

PEI was used by Guan and Ma[24] in their studies as a

Table 3: Highly productive countries in six continents (1993-2012)

Continent	Rank	Country	TP	Percentage of TP	TC	Percentage of TC	ACP	*h-index*
Europe	1	Germany	14882	5.24	164951	5.52	11.08	105
	2	Spain	13663	4.81	176754	5.91	12.94	104
	3	France	12043	4.24	182169	6.10	15.13	109
	4	England	11451	4.03	186493	6.24	16.29	119
	5	Italy	9965	3.51	115833	3.88	11.62	95
North America	1	USA	69636	24.51	1005304	33.64	14.44	201
	2	Canada	15206	5.35	192526	6.44	12.66	107
	3	Mexico	4150	1.46	36061	1.21	8.69	61
	4	Costa Rica	291	0.10	2808	0.09	9.65	24
	5	Cuba	270	0.10	1863	0.06	6.90	22
Asia	1	India	22615	7.96	98954	3.31	4.38	83
	2	Peoples R China	15751	5.54	117594	3.94	7.47	82
	3	Japan	15150	5.33	137415	4.60	9.07	92
	4	South Korea	4619	1.63	36315	1.22	7.86	60
	5	Turkey	4462	1.57	31226	1.04	7.00	63
South America	1	Brazil	16221	5.71	66638	2.23	4.11	64
	2	Argentina	2922	1.03	28949	0.97	9.91	57
	3	Colombia	1195	0.42	11611	0.39	9.72	48
	4	Chile	1107	0.39	7680	0.26	6.94	36
	5	Venezuela	450	0.16	2936	0.10	6.52	25
Australia/Oceania	1	Australia	10814	3.81	135635	4.54	12.54	106
	2	New Zealand	4383	1.54	54889	1.84	12.52	77
	3	Papua N Guinea	49	0.02	271	0.01	5.53	9
	4	Fiji	47	0.02	275	0.01	5.85	9
	5	Vanuatu	27	0.01	256	0.01	9.48	10
AFRICA	1	South Africa	2404	0.85	17139	0.57	7.13	42
	2	Nigeria	1972	0.69	11225	0.38	5.69	37
	3	Kenya	1235	0.43	13299	0.45	10.77	45
	4	Egypt	1223	0.43	7766	0.26	6.35	33
	5	Ethiopia	788	0.28	5064	0.17	6.43	27

TP=Total publications, TC=Total citations, ACP=Average citations per publication

Table 4: Trends of publications of highly productive countries in agricultural science (1993-2012)

Country	TP	Percentage of TP	TC	Percentage of TC	AIF	ACP	Publication trend
USA	69636	24.51	1005304	33.64	1.91	14.44	
India	22615	7.96	98954	3.31	0.96	4.38	
Brazil	16221	5.71	66638	2.23	0.99	4.11	
Peoples R China	15751	5.54	117594	3.94	2.18	7.47	
Canada	15206	5.35	192526	6.44	1.71	12.66	
Japan	15150	5.33	137415	4.60	1.62	9.07	
Germany	14882	5.24	164951	5.52	1.65	11.08	
Spain	13663	4.81	176754	5.91	2.10	12.94	
France	12043	4.24	182169	6.10	2.06	15.13	
England	11451	4.03	186493	6.24	2.01	16.29	
Australia	10814	3.81	135635	4.54	1.85	12.54	
Italy	9965	3.51	115833	3.88	1.81	11.62	
Netherlands	7194	2.53	118872	3.98	2.05	16.52	
South Korea	4619	1.63	36315	1.22	1.75	7.86	
Turkey	4462	1.57	31226	1.04	1.32	7.00	

Contd...

Table 4: Contd...

Country	TP	Percentage of TP	TC	Percentage of TC	AIF	ACP	Publication trend
New Zealand	4383	1.54	54889	1.84	1.64	12.52	
Denmark	4313	1.52	61606	2.06	1.98	14.28	
Mexico	4150	1.46	36061	1.21	1.53	8.69	
Poland	3967	1.40	23847	0.80	1.28	6.01	
Scotland	3961	1.39	67594	2.26	1.94	17.06	
Sweden	3799	1.34	56194	1.88	2.08	14.79	
Belgium	3744	1.32	49703	1.66	1.95	13.28	
Iran	3351	1.18	10913	0.37	1.14	3.26	
Switzerland	3191	1.12	42674	1.43	1.75	13.37	

TP=Total publications, TC=Total citations, AIF=Average impact factor per publication, ACP=Average citations per publication

measure of research quality. It indicates whether the impact of publications in a country in a research field is compatible with the research efforts. The value of PEI ≥ 1 for a country indicates that the impact of publications is more than the research effort devoted to it for that particular country and vice versa. The PEI for top 30 countries is shown in Figure 3.

The PEI indicates that in general the impact of research in Asian countries (region) is very weak despite their devoted research efforts as compared to, USA (1.37), Canada (1.20), Germany (1.05), Spain (1.23), France (1.44), England (1.55), Australia (1.19), Italy (1.11), Netherlands (1.57), New Zealand (1.19), Denmark (1.36), Scotland (1.62), Sweden (1.41), Belgium (1.26), Switzerland (1.27), Taiwan (1.07), Israel (1.62) and Finland (1.51), while Taiwan (1.07) is an exception. In other words, the Asian publications have not received enough citations in comparison to their large number of publications. Therefore, it is suggested that the Asian countries have to make efforts to publish their publications in high IF journals. In addition, the major countries in Asia like Peoples Republic of China, Japan, South Korea and Taiwan publish in Chinese, Japanese, Korean and Taiwanese are not easily understood by the scientific community in the rest of the world.

Distribution of Countries According to Average Citations per Publication of Highly Productive Countries

The ACP is one of the important indicators to know the quality of publications. Distribution of the top 30 countries according to ACP is given in Figure 4. Israel had the highest ACP (17.09) per publication followed by Scotland with

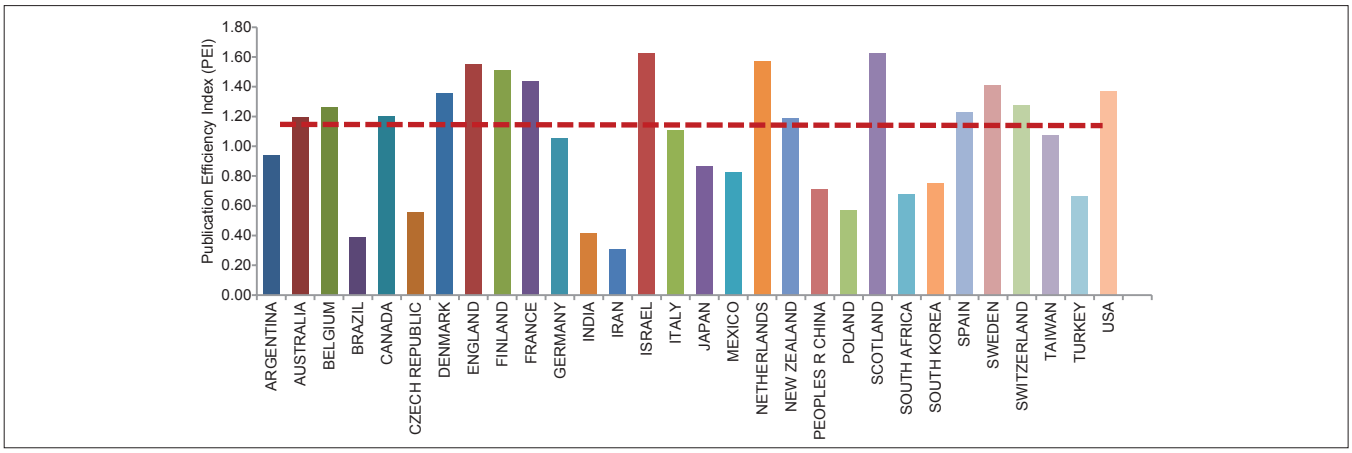

Figure 3: Publication efficiency index of highly productive countries in agricultural science

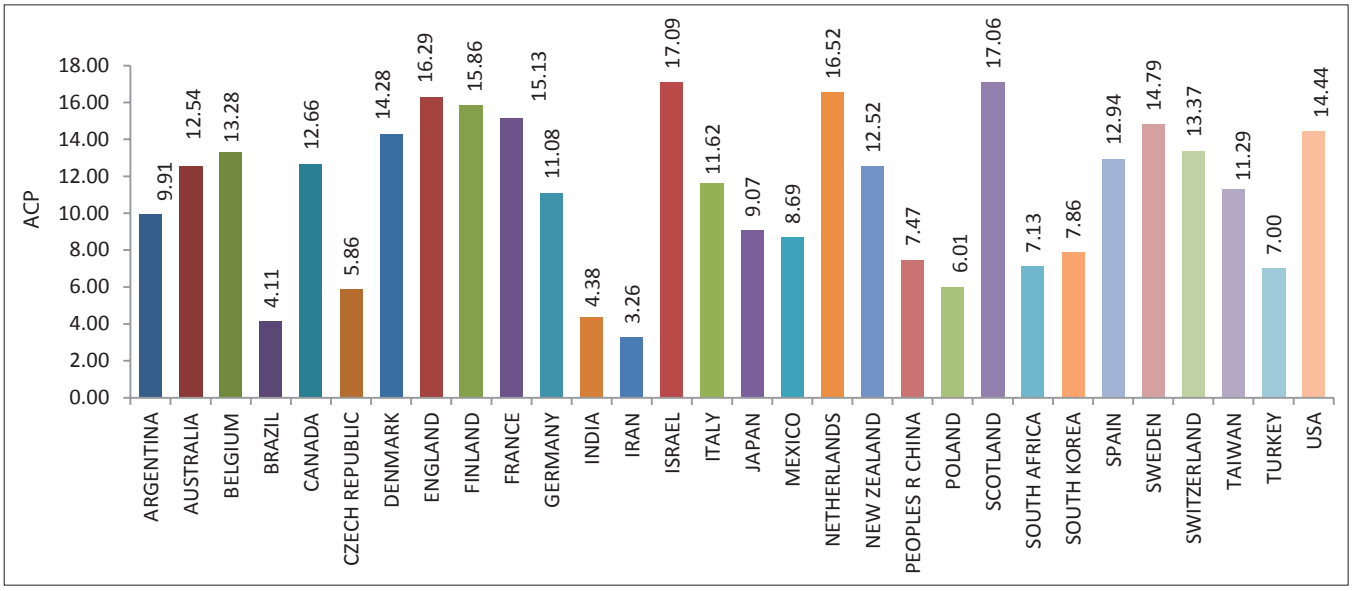

Figure 4: Average citations per publication of highly productive countries in agricultural science

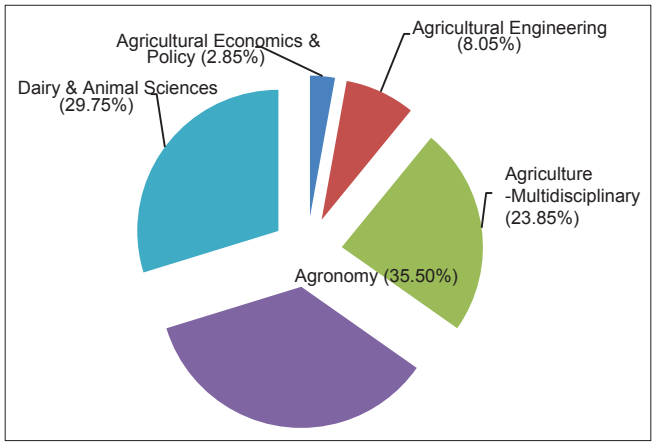

Figure 5: Distribution of publications in agricultural science sub-domains (1993-2012)

17.06 ACP, Netherlands with 16.52 ACP, England with 16.29 ACP, Finland with 15.86 ACP, France with 15.13 ACP, Sweden with 14.79 ACP, USA with 14.44 ACP, Denmark with 14.28 ACP, Switzerland with 13.37 ACP, Belgium with 13.28 ACP, Spain with 12.94 ACP, Canada with 12.66 ACP and Australia with 12.54 citations per publication.

Distribution of Publications and Citations in Agricultural Science Sub-Domains

Based on the classification of subject-categories in JCR of Thomson Reuters, the publication output data of agricultural science research was classified into five sub-domains [Figure 5] during 1993-2012. Agronomy accounts for the largest share 100,845 of publications in the total worldwide output in agricultural science which received 1,109,679 citations followed by Dairy and Animal Sciences with 84,533 publications and 805,854 citations, Agriculture-Multidisciplinary with 67,760 publications

and 743,078 citations, Agricultural Engineering with 22,870 publications and 271,427 citations and Agricultural Economics and Policy with 8095 publications and 58,237 citations [Table 5].

Specialization Index

Specialization index is the relationship between a country's share of global publications for a field of research and its world share of publications in all disciplines. If they are higher than 1 that indicates subjects in which research is especially active, and thus supported as priorities by the research policy decision-makers. Conversely, an index of <1 indicates the research areas which are not given emphasis.[25]

Agricultural Economics and Policy

For the period of 1993-2012, USA obtained the highest SI of 2.19 in the area of Agricultural Economics and Policy followed by Kenya with 1.85, South Africa with 1.75, England with 1.72, Australia with 1.63, Canada with 1.53, Norway with 1.53, Germany with 1.48 and Netherlands with 1.17 [Figure 6].

Table 5: Distribution of publications and citations in agricultural science sub-domains

Sub-domains	TP	Percentage of TP	TC	Percentage of TC	ACP	Publication trend
Agronomy	100845	35.50	1109679	37.13	11.00	
Dairy and animal sciences	84533	29.75	805854	26.97	9.53	
Agriculture-multidisciplinary	67760	23.85	743078	24.87	10.97	
Agricultural engineering	22870	8.05	271427	9.08	11.87	
Agricultural economics and policy	8095	2.85	58237	1.95	7.19	
Total	284103	100.00	2988275	100.00	10.52	

TP=Total publications, TC=Total citations, ACP=Average citations per publication

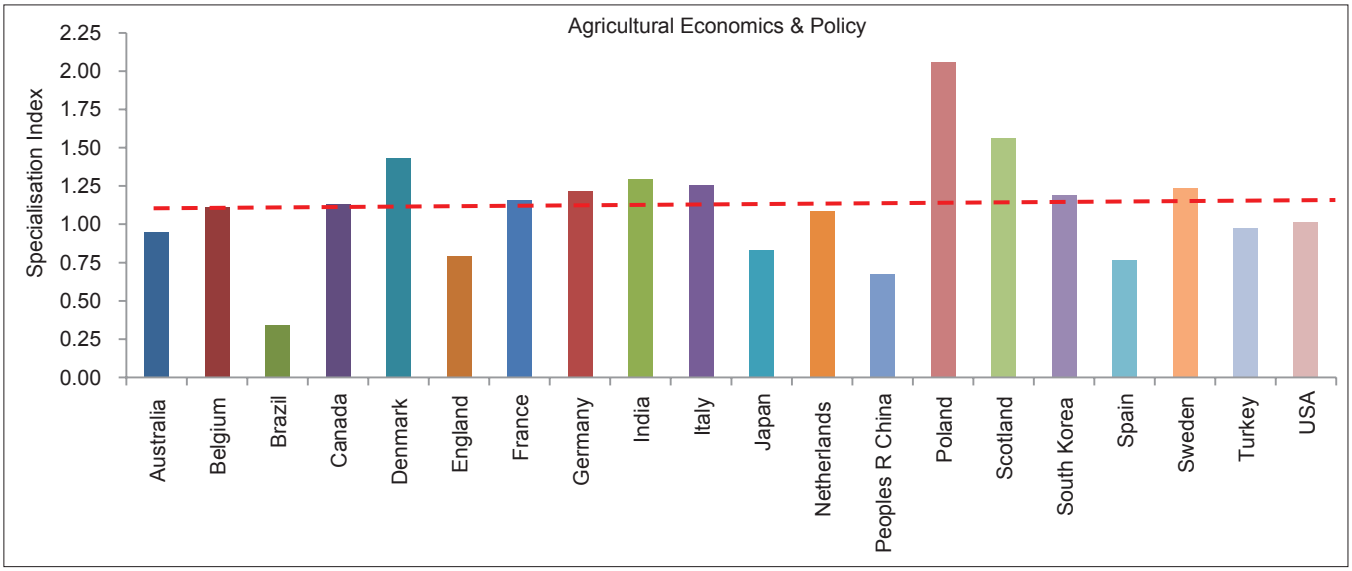

Figure 6: Specialization index for top 20 countries in agricultural economics and policy sub-domain (1993-2012)

Agricultural Engineering

For the period of 1993-2012, South Korea obtained the highest SI of 3.22 in the area of Agricultural Engineering followed by Taiwan with 2.40, Peoples R China with 2.06, Greece with 1.72, Sweden with 1.71, Turkey with 1.52, India with 1.24, Spain with 1.19, USA with 1.09 and Belgium with 1.00 [Figure 7].

Agriculture-Multidisciplinary

For the period of 1993-2012, Brazil obtained the highest SI of 2.07 in the area of Agriculture-Multidisciplinary followed by Taiwan with 2.05, Switzerland with 1.54, Spain with 1.53, New Zealand with 1.50, Japan with 1.20, England with 1.16, India with 1.14, Turkey with 1.08, Peoples R China with 1.01, Italy with 1.00 and Mexico with 1.00 [Figure 8].

Agronomy

For the period of 1993-2012, Hungary obtained the highest SI of 1.93 in the area of Agronomy followed by Argentina with 1.29, Iran with 1.23, Mexico with 1.22, Australia with 1.21, Canada with 1.19, Japan with 1.14, USA with 1.11, France with 1.08, England with 1.08, Peoples R China with 1.07 and Netherlands with 1.00 [Figure 9].

Dairy and Animal Sciences

For the period of 1993-2012, Poland obtained the highest SI of 2.06 in the area of Dairy and Animal Sciences

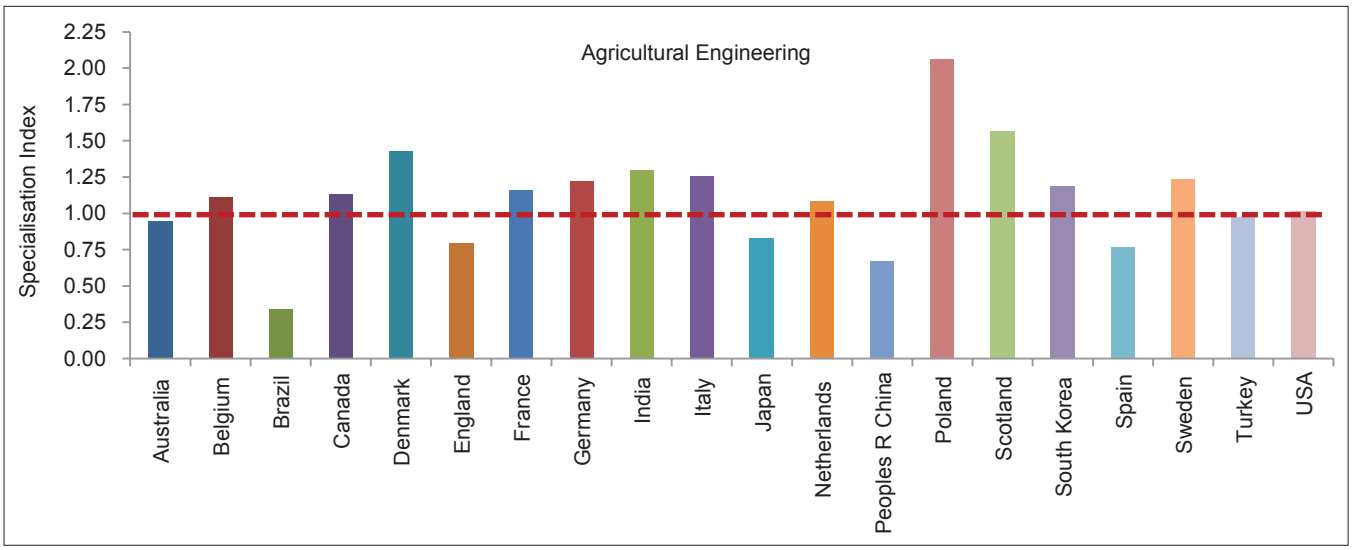

Figure 7: Specialization index for top 20 countries in agricultural engineering sub-domain (1993-2012)

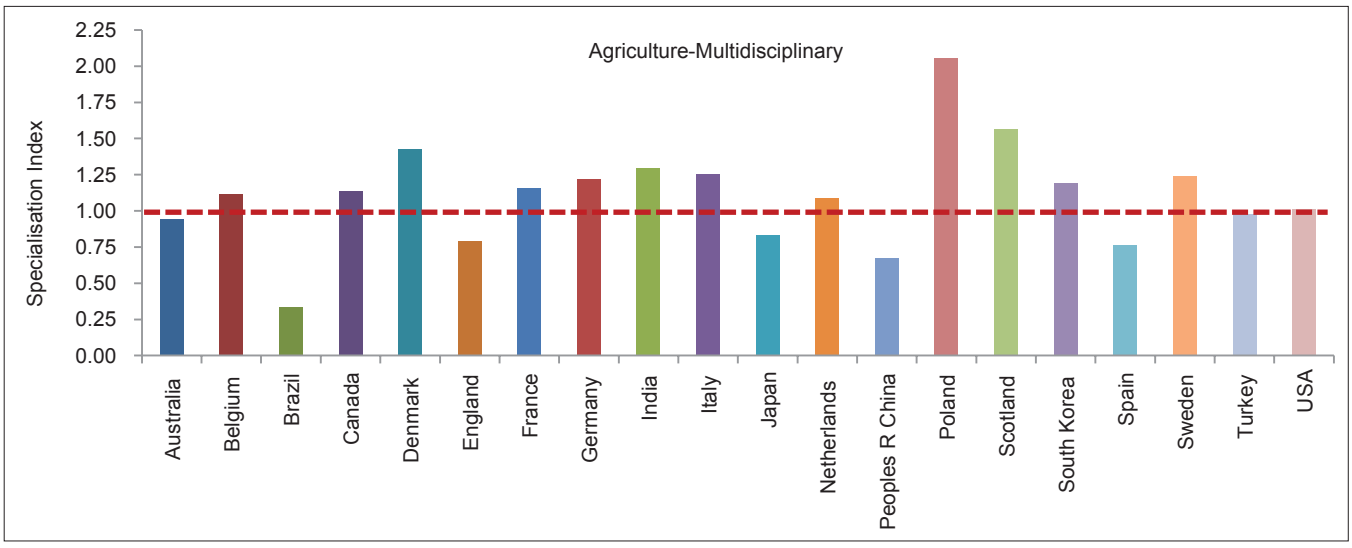

Figure 8: Specialization index for top 20 countries in agriculture-multidisciplinary sub-domain (1993-2012)

followed by Scotland with 1.56, Denmark with 1.43, India with 1.29, Italy with 1.26, Sweden with 1.24, Germany with 1.22, South Korea with 1.19, France with 1.16, Canada with 1.13 and Belgium with 1.11 [Figure 10].

Variation of Average Impact Factor in Agricultural Science Sub-Domains

Figure 11 gives the distribution of various agricultural science sub-domains according to AIF during the period under study. It is revealed from this analysis that there is a significant variation in AIF in various agricultural science sub-domains. There are many reasons for variation in IF in various sub-domains.[26] The number of researchers working in a field is one of the important factors, the more number of active researchers in a field tend to receive more number of citations than the field with less number of active researchers. The highest AIF (3.16) is for agriculture engineering followed by Agriculture-Multidisciplinary (1.69) and Agronomy (1.61).

Distribution of Publications and Citations of Top 10 Countries in Agricultural Science Sub-Domains

Table 6 provides distribution of publications and citations of top 10 countries in various agricultural science domains. USA had the highest number of publications in all domains: Agricultural Economics and Policy (4342), Agricultural Engineering (6099), Agriculture-Multidisciplinary (10,644), Agronomy (27,540) and Dairy and Animal Sciences (21,011).

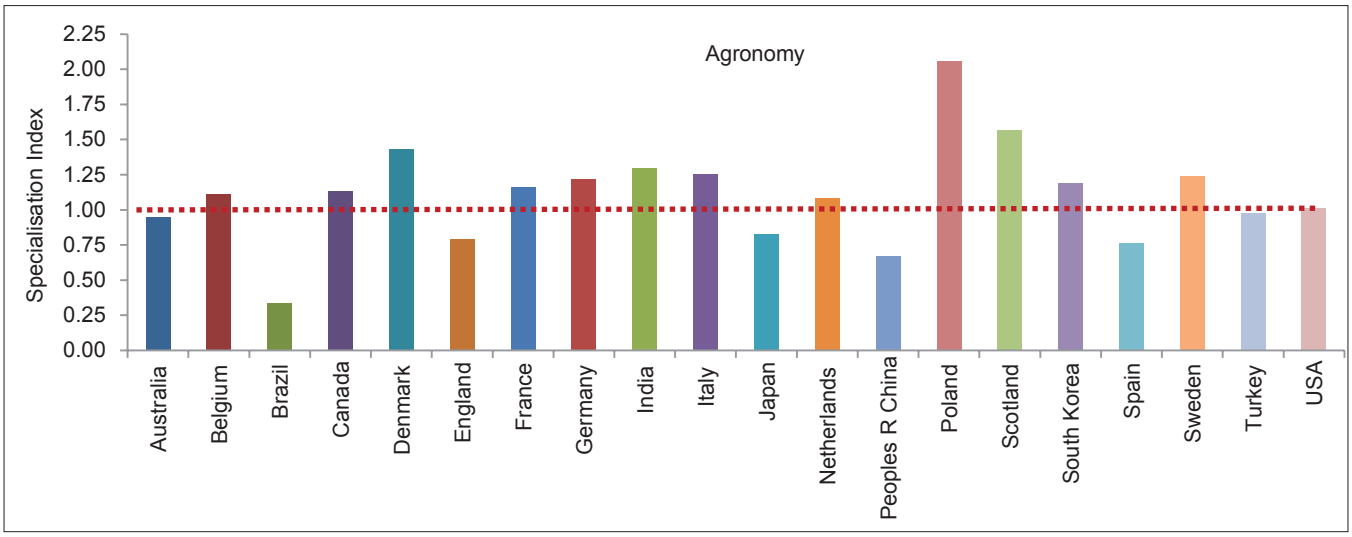

Figure 9: Specialization index for top 20 countries in Agronomy sub-domain (1993-2012)

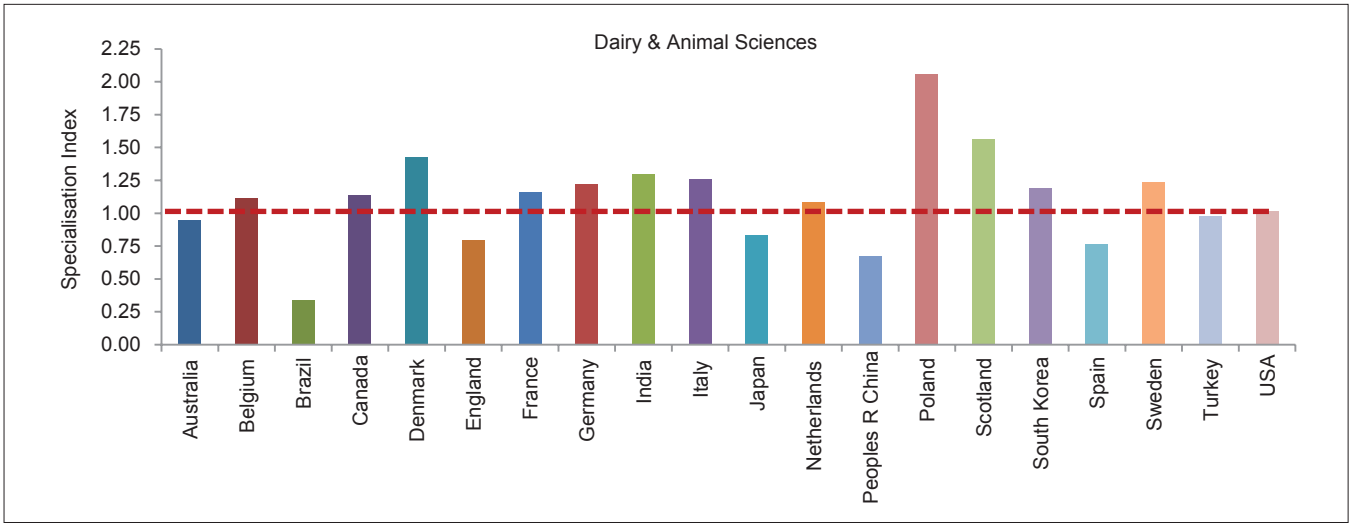

Figure 10: Specialization index for top 20 countries in dairy and animal sciences sub-domain (1993-2012)

Table 6: Distribution of publications and citations of top 10 countries in various sub-domains

Sub-domains	Rank	Country	TP	TC	ACP	AIF
Agricultural economics and policy	1	USA	4342	37160	8.56	1.11
	2	Canada	664	4040	6.08	1.08
	3	Germany	626	2327	3.72	0.78
	4	England	560	5260	9.39	1.55
	5	Australia	503	3730	7.42	1.16
	6	Spain	375	952	2.54	0.67
	7	France	244	1598	6.55	1.30
	8	Netherlands	240	2282	9.51	1.33
	9	Peoples R China	175	639	3.65	0.82
	10	Italy	162	1136	7.01	1.44
Agricultural engineering	1	USA	6099	64855	10.63	2.29
	2	Peoples R China	2611	21737	8.33	4.25
	3	India	2254	30925	13.72	3.59
	4	Spain	1305	19267	14.76	3.70
	5	South Korea	1199	7385	6.16	2.27
	6	Canada	990	14819	14.97	3.07
	7	Japan	897	9428	10.51	3.20
	8	Brazil	838	8194	9.78	2.77
	9	Italy	674	7867	11.67	3.23
	10	France	631	8579	13.60	3.56
Agriculture-multidisciplinary	1	USA	10644	185935	17.47	2.25
	2	Brazil	8008	27364	3.42	0.84
	3	India	6168	15912	2.58	0.57
	4	Spain	4992	78225	15.67	2.20
	5	Japan	4334	43515	10.04	1.55
	6	Peoples R China	3800	26988	7.10	1.96
	7	Germany	3202	40428	12.63	1.84
	8	England	3169	54707	17.26	2.16
	9	France	2406	44375	18.44	2.42
	10	Italy	2380	41332	17.37	2.40
Agronomy	1	USA	27540	391789	14.23	1.80
	2	Canada	6407	71315	11.13	1.44
	3	Japan	6131	58058	9.47	1.60
	4	Peoples R China	6009	54282	9.03	1.93
	5	Brazil	5706	21228	3.72	0.83
	6	India	5430	38130	7.02	1.37
	7	Germany	5224	79249	15.17	2.01
	8	Australia	4642	73194	15.77	2.07
	9	France	4607	77542	16.83	2.09
	10	England	4382	74845	17.08	1.96
Dairy and animal sciences	1	USA	21011	325565	15.49	1.93
	2	India	8713	13682	1.57	0.30
	3	Germany	5396	37721	6.99	1.14
	4	Canada	5130	68332	13.32	1.62
	5	France	4155	50075	12.05	1.62
	6	Japan	3743	26220	7.01	1.37
	7	Italy	3724	21372	5.74	1.08
	8	Peoples R China	3156	13948	4.42	1.26
	9	Spain	3111	30394	9.77	1.67
	10	Australia	3044	32804	10.78	1.35

TP=Total publications, TC=Total citations, ACP=Average citations per publication, AIF=Average impact factor per publication

Language-wise Distribution of Publications

Publications on agricultural science are spread over 19 languages. The most predominant language used for communication was English. Language-wise distribution of publications on agricultural science is given in Figure 12.

Distribution of Top Keywords

Keywords are one of the best scientometric indicators to understand and grasp instantaneously the thought content of the papers and to find out the growth of the subject field.[27] The high frequency keywords will enable us to understand what are the aspects of agricultural science have been studied. Figure 13 gives 5 years blocks-wise distribution of top keywords in agricultural science. Table 7 gives a list of high frequency keywords appeared more than 500 times.

Highly Cited Publications

The most highly cited 22 agricultural science publications (which have got at least 600 citations) during the period of study are listed in Table 8. The number of citations does not necessarily indicate the quality of paper, but it is a measure of its impact in this field. The most frequently cited one was "Biodiesel production: A review" published in Bioresource Technol. 1999; 70:1-15 by Ma and Hanna with 1483 citations. Out of 22 highly cited publications 15 are journal articles and 7 are review articles.

Journals Preferred for Publication by the Agricultural Scientists

The scientific literature on agricultural science is spread over 210 different Web of Science source journals. More than 33% of the publications are published in only 11 key-journals. Table 9 gives the leading journals each with IF, number of publications, number of citations, and ACP. For scientists, such information could be valuable with respect to the selection of the appropriate journals for publishing their own results.

Quality of Research Output

Around 99.69% (283227) of the total publications were published in the journals with IF ranging from 0.001-5.20 and received 99.98% (2,987,671) citations, and around 0.31% (876) publications published in journals having zero IF. A significantly large number

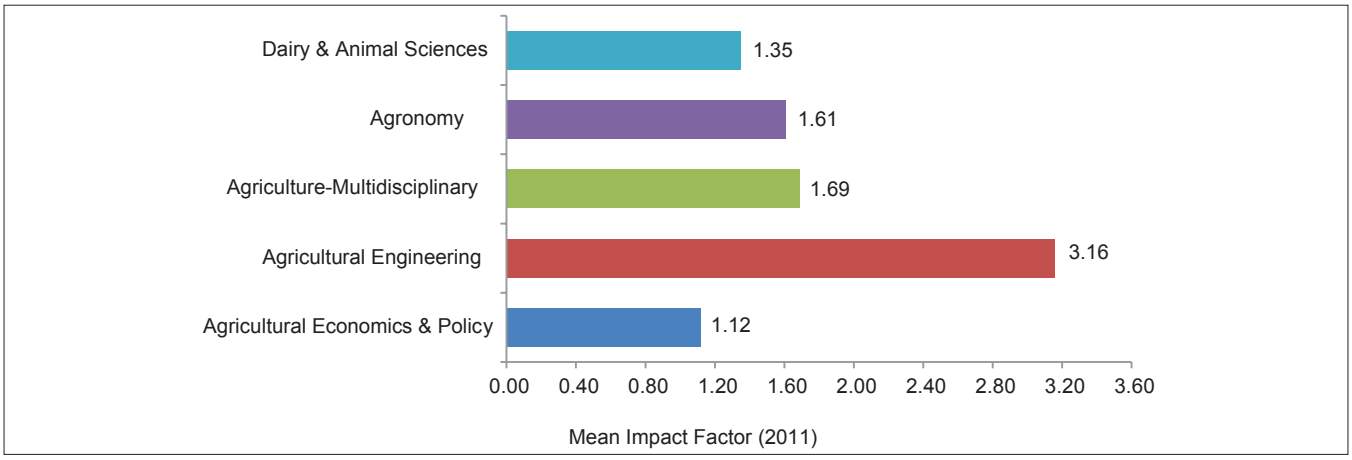

Figure 11: Variation of average impact factor in agricultural science sub-domains

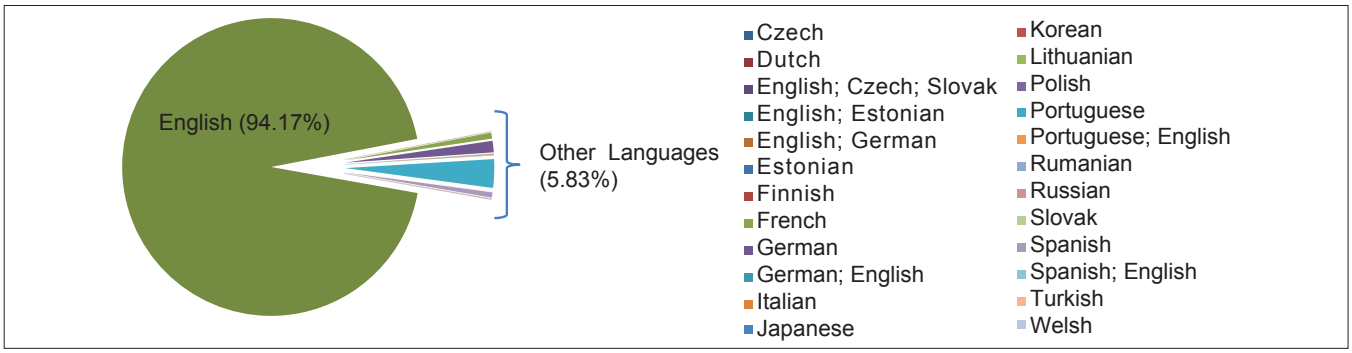

Figure 12: Language-wise distribution of publications in agricultural science

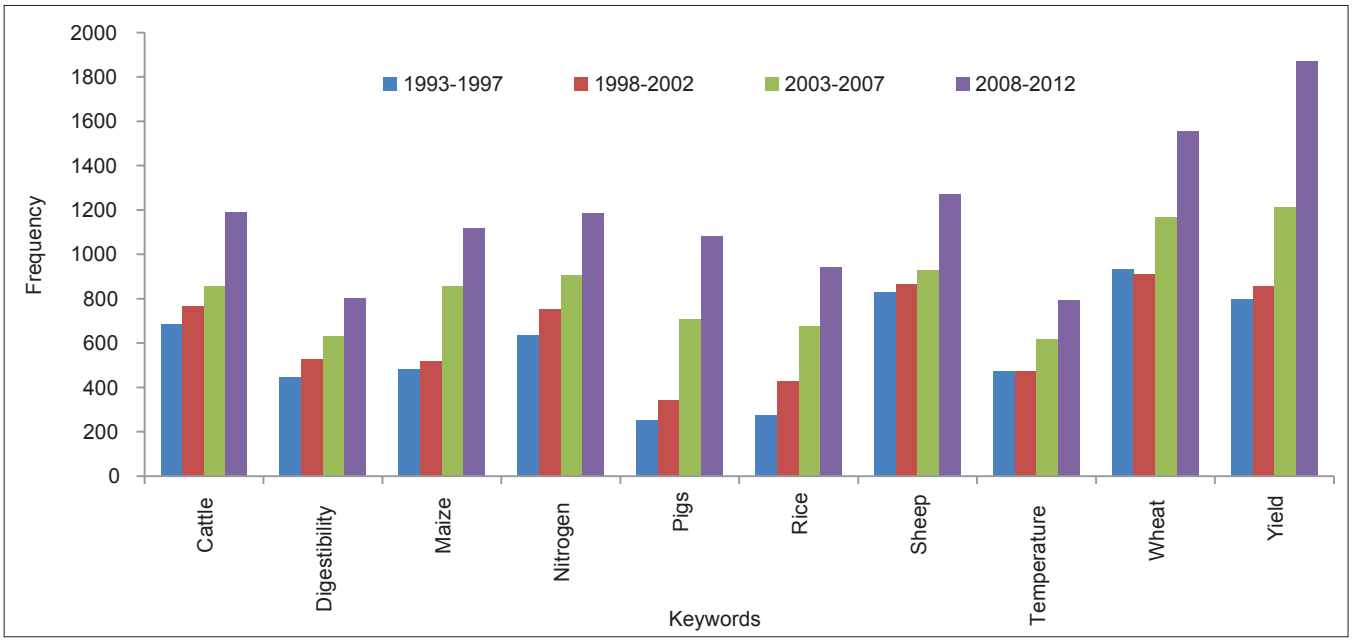

Figure 13: Five years block-wise distribution of top keywords in agricultural science (1993-2012)

of publications 32.62% (92663) appeared in journals having IF 1.00 - < 2.00. Table 10 gives distribution of publications and citations according to IF range of the journal publications.

CONCLUSION

This study explores the characteristics of global agricultural science research during 1993-2012 based on the Web of

Table 7: Distribution of high frequency keywords in agricultural science

Keywords	Frequency	Keywords	Frequency	Keywords	Frequency
Yield	4735	Molecular markers	974	Solanum tuberosum	737
Wheat	4566	Poultry	967	Mastitis	734
Sheep	3893	Calcium	959	Gene expression	731
Cattle	3496	Rapd	959	Alfalfa	725
Nitrogen	3478	Grain yield	958	Polymerase chain reaction	721
Maize	2974	Biological control	953	Populations	718
Pigs	5145	Inheritance	953	Tillage	713
Digestibility	2404	Photosynthesis	953	Growth performance	712
Temperature	2356	Amino acids	951	Rflp	710
Rice	2314	Hplc	948	Antioxidants	709
Quality	2276	Water	921	Efficiency	708
Phosphorus	2245	Oryza sativa	918	Grazing	695
Resistance	2171	Fertilization	917	Copper	693
Protein	2142	Simulation	905	Lignin	687
Soil	2125	Progesterone	903	Pasture	683
Broiler	2107	Energy	899	Elisa	681
Barley	1955	Dairy cows	898	Aflp	678
Genetic diversity	1783	Plants	889	Expression	677
Triticum aestivum	1656	Milk yield	878	Stability	677
Biomass	1594	Productivity	877	Climate change	676
Irrigation	1584	Drought	876	Adsorption	673
Corn	1569	Buffalo	875	Phaseolus vulgaris	672
Management	1487	Starch	873	Allelopathy	671
Chicken	1461	Agriculture	872	Microsatellite	671
Goat	1424	Diversity	868	Broilers	668
Milk	1402	Breeding	867	Kinetics	664
Heritability	1391	Environment	857	Economics	656
Soybean	1375	Disease resistance	850	Ethanol	653
Cultivars	1354	Antioxidant activity	849	Body weight	651
Dairy cow	1346	Germplasm	845	Systems	648
Germination	1344	Salinity	843	Cows	644
Quantitative trait loci	1341	Behavior	841	Degradation	644
Stress	1331	Lactation	841	Glucose	644
Beef cattle	1314	Bovine	837	Potassium	640
Nutrition	1306	Dairy cattle	834	Methane	639
Model	1270	Glycine max	833	Swine	639
Identification	1223	Evapotranspiration	830	Yield components	638
Fertility	1208	Nitrate	821	Chemical composition	633
Reproduction	1196	Rumen	812	Feed intake	633
Storage	1183	Cotton	805	Fertilizer	633
Zea mays	1162	Welfare	805	Biodiversity	625
Meat quality	1133	Competition	803	Heat stress	620
Fatty acids	1132	Milk production	799	Heterosis	620
Metabolism	1124	Zinc	799	Toxicity	618
Goats	1058	Polymorphism	798	DNA	604
Potato	1042	Forage	786	Pregnancy	604
Tomato	1029	Sorghum	786	Modeling	602
Fermentation	1001	Beef	767	Intake	598
Ph	981	Turkey	767	Tolerance	595
Antioxidant	974	Digestion	746	Fat	594

Ph=Potential of hydrogen, Hplc=High performance liquid chromatography, Rflp=Restriction fragment length polymorphism, Aflp= Amplified fragment length polymorphism, DNA= Deoxyribonucleic acid

Table 8: Highly cited publications in agricultural science (≥600 citations)

Bibliographic details	IF 2011	Times cited	Document type	Sub-domains	Country collaboration
Biodiesel production…by Ma *et al.*, Bioresour Technol. 1999;70:1-15	4.98	1483	Article	Agricultural engineering	USA
Statistical analysis of repeated…by Littell *et al.*, J Anim Sci. 1998;76:1216-231	2.10	1210	Article	Dairy and animal sciences	USA
Features of promising technologies…by Mosier *et al.*, Bioresour Technol. 2005;96:673-86	4.98	1125	Review	Agricultural engineering	USA
Hydrolysis of lignocellulosic materials…by Sun *et al.*, Bioresour Technol. 2002;83: 1-11	4.98	1083	Review	Agricultural engineering	USA
The chemistry behind antioxidant…by Huang *et al.*, J Agr Food Chem. 2005;53:1841-856	2.82	1024	Review	Agriculture-multidisciplinary	Singapore/ USA
Remediation of dyes in textile…by Robinson *et al.*, Bioresour Technol. 2001;77:247-255	4.98	1015	Review	Agricultural engineering	England
The comparison of RFLP, RAPD…by Powell *et al.*, Mol Breed. 1996;2:225-38	2.85	957	Article	Agronomy	USA/Italy
Antioxidant activity and total…by Velioglu *et al.*, J Agr Food Chem. 1998;46:4113-117	2.82	931	Article	Agriculture-multidisciplinary	Canada
Antioxidant activity of plant…by Kahkonen *et al.*, J Agr Food Chem. 1999;47:3954-962	2.82	922	Article	Agriculture-multidisciplinary	Finland
Total antioxidant capacity…by Wang *et al.*, J Agric Food Chem. 1996;44:701-05	2.82	844	Article	Agriculture-multidisciplinary	USA
Standardized methods for…by Prior *et al.*, J Agric Food Chem. 2005;53:4290-302	2.82	802	Article	Agriculture-multidisciplinary	USA
Development of reliable…by Paran *et al.*, Theor Appl Genet. 1993;85:985-93	3.30	790	Article	Agronomy	USA
Organic acids in the rhizosphere…by Jones, DL, Plant Soil. 1998;205:25-44	2.73	774	Review	Agronomy	Wales
Studies on adsorption…by Crini, G, Bioresource Technol. 2006;90:93-98	4.98	721	Review	Agricultural engineering	France
Analysis of acrylamide…by Tareke *et al.*, J Agr Food Chem. 2002;50:4998-5006	2.82	696	Article	Agriculture-multidisciplinary	Sweden
Fusarium Ear Blight…by Parry *et al.*, Plant Pathol. 1995;44:207-38	2.13	691	Review	Agronomy	England
Microbial decolorization…by Banat *et al.*, Bioresour Technol. 1996;58:217-27	4.98	662	Article	Agricultural engineering	England/India
Antioxidant activity of various…by Yen *et al.*, J Agric Food Chem. 1995;43:27-32	2.82	661	Article	Agriculture-multidisciplinary	Taiwan
Standardization of procedures…by Licitra *et al.*, Anim Feed Sci Technol. 1996;57:347-58	1.69	622	Article	Dairy and animal sciences	USA/Italy
Development and validation…by Ou *et al.*, J Agric Food Chem. 2001;49:4619-626	2.82	621	Article	Agriculture-multidisciplinary	USA
High level of genetic…by ElMousadik *et al.*, Theor Appl Genet. 1996;92:832-39	3.30	614	Article	Agronomy	France/ Morocco
Oxygen radical absorbing…by Wang *et al.*, J Agric Food Chem. 1997;45:304-09	2.82	601	Article	Agriculture-multidisciplinary	USA

Table 9: Preference of journals for publication in agricultural science (≥68% of cumulative of total publications)

Rank	Journal	IF 2011	TP	Percentage of TP	TC	Percentage of TC	ACP
1	J Agr Food Chem	2.82	23398	8.24	478472	16.01	20.45
2	Bioresour Technol	4.98	10072	3.55	165362	5.53	16.42
3	J Dairy Sci	2.56	9322	3.28	183462	6.14	19.68
4	J Anim Sci	2.10	8295	2.92	150257	5.03	18.11
5	Crop Sci	1.64	7758	2.73	97986	3.28	12.63
6	Indian J Anim Sci	0.12	6773	2.38	5770	0.19	0.85
7	Plant Soil	2.73	6381	2.25	126899	4.25	19.89
8	Theor Appl Genet	3.30	6252	2.20	178730	5.98	28.59
9	Poult Sci	1.73	5969	2.10	81433	2.73	13.64
10	J Sci Food Agric	1.44	5832	2.05	74293	2.49	12.74
11	Euphytica	1.55	4721	1.66	49981	1.67	10.59
12	Commun Soil Sci Plant	0.51	4396	1.55	23170	0.78	5.27
13	Pesqui Agropecu Bras	0.76	4269	1.50	13494	0.45	3.16

Contd...

Table 9: Contd...

Rank	Journal	IF 2011	TP	Percentage of TP	TC	Percentage of TC	ACP
14	Indian J Agric Sci	0.17	4171	1.47	3694	0.12	0.89
15	Asian Austral J Anim	0.58	4032	1.42	12874	0.43	3.19
16	Agron J	1.79	3684	1.30	53369	1.79	14.49
17	Anim Feed Sci Technol	1.69	3327	1.17	41353	1.38	12.43
18	Small Rumin Res	1.30	3304	1.16	25318	0.85	7.66
19	Agric Ecosyst Environ	3.00	3281	1.15	61604	2.06	18.78
20	Anim Reprod Sci	1.75	3047	1.07	37680	1.26	12.37
21	Crop Prot	1.40	2836	1.00	26041	0.87	9.18
22	Biomass Bioenergy	3.65	2827	1.00	44802	1.50	15.85
23	Cereal Res Commun	0.39	2813	0.99	6694	0.22	2.38
24	Appl Anim Behav Sci	1.92	2763	0.97	43255	1.45	15.66
25	Weed Technol	1.21	2757	0.97	23400	0.78	8.49
26	Can J Plant Sci	0.61	2580	0.91	14932	0.50	5.79
27	Field Crop Res	2.47	2570	0.90	39824	1.33	15.50
28	Reprod Domest Anim	1.36	2477	0.87	12871	0.43	5.20
29	Agric For Meteorol	3.39	2438	0.86	58957	1.97	24.18
30	Am J Agric Econ	1.17	2390	0.84	27240	0.91	11.40
31	Agric Water Manage	2.00	2370	0.83	25674	0.86	10.83
32	Anim Genet	2.40	2358	0.83	26568	0.89	11.27
33	Plant Breed	1.60	2242	0.79	21474	0.72	9.58
34	Weed Sci	1.73	2228	0.78	31022	1.04	13.92
35	Eur J Plant Pathol	1.41	2209	0.78	27054	0.91	12.25
36	Postharvest Biol Technol	2.41	2200	0.77	38724	1.30	17.60
37	Pest Manage Sci	2.25	2177	0.77	24653	0.82	11.32
38	Plant Pathol	2.13	2118	0.75	26249	0.88	12.39
39	Br Poul Sci	1.01	2068	0.73	24056	0.81	11.63
40	Cienc Rural	0.43	2047	0.72	1578	0.05	0.77
41	Ital J Anim Sci	0.34	2036	0.72	2182	0.07	1.07
42	Livest Sci	1.51	1989	0.70	8244	0.28	4.14
43	Ann Appl Biol	2.18	1951	0.69	18509	0.62	9.49
44	Soil Sci Plant Nutr	1.02	1950	0.69	12222	0.41	6.27
45	Ind Crop Prod	2.47	1763	0.62	17049	0.57	9.67
46	Genet Resour Crop Evol	1.55	1736	0.61	13791	0.46	7.94
47	Cienc Agrotec	0.53	1692	0.60	2531	0.08	1.50
48	Can J Anim Sci	0.77	1669	0.59	13261	0.44	7.95
49	Biosyst Eng	1.35	1663	0.59	13153	0.44	7.91
50	J Agric Sci	2.04	1612	0.57	16818	0.56	10.43

IF=Impact factor, TP=Total publications, TC=Total citations, ACP=Average citations per publication

Table 10: Distribution of publications and citations as per impact factor

Impact factor (JCR 2011)	Total journals	TP	TC	Percentage of TP	Percentage of TC	ACP
0.01 to <1.00	121	90070	249282	31.70	8.34	2.77
1.00 to <2.00	57	92663	927899	32.62	31.05	10.01
2.00 to <3.00	20	74547	1282279	26.24	42.91	17.20
3.00 to <4.00	7	15481	348248	5.45	11.65	22.50
4.00 to <5.20	2	10466	179963	3.68	6.02	17.20
Without IF	3	876	604	0.31	0.02	0.69
Total	210	284103	2988275	100.00	100.00	10.52

JCR=Journal citation reports, TP=Total publications, TC=Total citations, ACP=Average citations per publication, IF=Impact factor

Science database using the scientometric techniques. The study reveals an exponential growth of literature except in 2012, which may be attributed to input time-lag in the database. This reflects the extensive worldwide study on

agricultural science. An average 6.55% of annual growth of publications was observed.

Among 172 countries involved in research in agricultural science. USA topped the list with 69,636 publications followed by India with 22,615 publications, Brazil with 16,221 publications, Peoples R China with 15,751 publications, Canada with 15,206 publications, Japan with 15,150 publications, Germany with 14,882 publications and Spain with 13,663 publications.

The analysis shows that there have been significant changes in terms of the number of publications and citations in various countries. The study also examined the characteristics of qualitative measures such as ACP, AIF, PEI and SI. It is revealed from the data that most of the Asian countries such as India, Peoples R China, Japan and south Korea have contributed significantly in terms of the number of publications but failed to garner more number of citations and lagged behind the USA, Canada and European countries (except Israel) in terms of ACP, AIF, PEI and SI.

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How to cite this article: Sagar A, Kademani BS, Bhanumurthy K. Research trends in agricultural science: A global perspective. J Sci Res 2013;2:185-201.

Source of Support: Nil, **Conflict of Interest:** None declared