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ABSTRACT

Publication-based indicators of agricultural research activity were developed to assist in the evaluation of the knowledge transfer component of an agricultural research network involving the six Southern Cone countries of South America (Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay). The generation of agricultural knowledge in these countries, as reflected by the CAB Abstracts database, has grown by about 50% over the period 1973 to 1982. The academic sector accounts for a substantial amount of this activity, about 40%. There is however significant cross-country variation in these figures.

The transfer of agricultural scientific knowledge among agricultural researchers in the region and between these researchers and the world's research community was studied using the SCISEARCH database. The region generally relies heavily on international sources of knowledge; domestic sources are also important, especially in the larger systems; while regional sources are only of minor importance. There is some evidence, however, that in recent years regional sources may have become relatively more important for the smaller research systems. There is also a suggestion that the region's researchers, particularly those in the smaller systems, are drawing on an ageing scientific knowledge base.

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INTRODUCTION

The Cooperative Program for Agricultural Research (Cono Sur-PROCISUR) was established in 1978 under an agreement between the Inter-American Development Bank (IDB), Inter-American Institute for Agricultural Cooperation (IICA) and the governments of the six Southern Cone countries of South America: Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay. It has been in operation since 1980 and was extended as the PROCISUR project in 1984. The program, which receives technical and administrative support from IICA and is largely funded by a grant from IDB, aims:

a. To establish a system for cooperation between the agricultural research institutions of participating countries, in order to promote efficient use of available resources for the solution of common problems;

b. To strengthen the national research activities of participating countries, initially in the areas of wheat, maize, soybean, sorghum, and beef cattle; and later also including winter and summer cereals, oilseeds, and cattle in general.

c. To promote the creation of an effective mechanism for technology transfer from the international agricultural research centres to research bodies in the program areas.

Specific regional activities designed to strengthen national research capacity by reinforcing ties between participating countries include: i) improving exchange of information and documentation, ii) promoting manpower development through periodic technical meetings, seminars, courses and in-service training, and iii) sharing materials and results relevant to research on common problems. One example of the way in which the exchange of information is being improved under the program is the provision of selective dissemination of information services from the Brazilian agricultural research organisation EMBRAPA, to sister institutions in the participating countries, free of charge.

Our particular interest in the project was in the development of a methodology that would contribute to an evaluation of the success of the program in the area of the exchange of information and documentation. Unfortunately, though much discussed, little quantitative evidence of this transfer process is available. The work reported here was an attempt to obtain bibliographic indicators that measure cross-country flows of scientific information and track changes in this transfer process over the 1974-1984 period.

We have also developed a set of publication-based indicators of agricultural research output for the six Southern Cone countries over the 1973-1982 period. These indicators have been used to characterize not only the cross-country, temporal differences in the region's agricultural research output, but also to highlight substantial differences in the institutional structures which contribute to this research effort.

We have also carried out a more detailed analysis of the cross-country flows of scientific knowledge between the six countries. It aims to assess the nature and degree of scientific knowledge transfers - undistorted by other information transfers that accompany the process of technological change - and so improve our understanding of the networks, or 'invisible colleges', which are an integral component of agricultural research.

In another publication (Pardey and Thorpe [10]) we present an analysis of the economic and agricultural development policy implications of the study. This paper deals with the bibliometric aspects of the study and compares our results with those obtained by others working in the same area.

PUBLICATION INDICATORS

The use of bibliometric analysis as a quantitative indicator of agricultural research activity is criticised by some who question its validity on such grounds as the spurious publication record of individual scientists or narrowly defined groups of researchers or subject areas. Such critics often prefer to use indicators based on inputs to the research system, such as personnel or expenditure data, which they regard as somehow intrinsically more reliable. In fact, both personnel and expenditure indicators present substantial difficulties of consistency if we apply them in a cross-country context, or even in the same country over an extended period of time [9].

Frame [1] has examined the correlation between research output indicators such as publications and other commonly used indicators of scientific and technological activity, such as personnel and expenditure data. His conclusion is that, insofar as any of the indicators examined reflect developing country scientific and technological capabilities, national rankings based on publication counts correlate highly with rankings based on other indicators.

We maintain that, at the aggregate level at least, there is a reasonably close association between gross additions to the stock of scientific knowledge and the amount of research captured by these publications indicators. Naturally, as Gilbert [5] has pointed out, we must be aware of the limitations of the indicators we use and due account must be taken of each indicator's strengths and weaknesses. However, our study was focused on just one component of a more comprehensive agricultural technology transfer project.

A more serious problem from our point of view is the question of the status of publications among the Latin American agricultural research community. In Europe and the United States we are familiar with publications as a means by which researchers can establish intellectual property rights over their work which in turn affects their salary, promotion prospects and professional standing. However, is this also true of other parts of the world? The literature (Jiménez-Saa [6], Monge [8]), indicates that, among Latin American agricultural researchers at least, there is little incentive to publish. Apparently the "publish or perish" ethic is not as pressing in the southern half of the American continent. This point must therefore also be borne in mind when assessing our results.

METHODOLOGY

In this study two specific indicators were developed. First a publication count from the online CAB Abstracts database was used to measure the relative contribution of each Southern Cone country to the pool of scientific knowledge over the period 1973-1982. Total agricultural publication counts for each year between 1973 and 1982 for each of the six Southern Cone countries were obtained. Using CAB's subfile facility the figures were roughly divided into animal sciences, plants sciences and social sciences (this latter category consists only of those items appearing in World Agricultural Economics and Rural Sociology Abstracts). This process was then repeated, but restricted to the five specific commodities included at the inception of the Cono Sur project. In both cases estimates of the percentage of publications coming from universities and other academic institutions as well as the national research system were obtained. We also excluded publications from conference and symposium proceedings, newsletters and annual reports, both for quality control reasons and to avoid an implicit double counting problem whereby significant material of this nature may also appear in published form in scientific journals.

This procedure was intended to provide indications of the relative size of the six countries' total agricultural publications output, the relative importance of the Cono Sur project commodities to the region and to individual countries, and the role played by the academic sector in each country. Changes in time over the period of the project were also measured. These output indicators contrast with the commonly reported research input indicators, such as the personnel data recorded in Table 1 for the 1970 to 1985 period.

Table 1: Number of agricultural researchers[a] in Southern Cone countries: 1970-1985

	1970-74	1975-79	1980-85
Brazil	1920[b]	2550	3622
Argentina	835	898	1063
Chile	218	256	269
Bolivia	55	62	107
Paraguay	26	39	70
Uruguay	72	73	76

a. Agricultural researchers are measured in full-time equivalent units and explicitly exclude research support staff.
b. Observations represent quinquennial averages.

Source: Pardey and Roseboom [9]

We then turned to the SCISEARCH database to develop an indicator of the cross-country flow of scientific information. This database was used to obtain a source set of references dealing with the five Cono Sur project commodities for those publications with first author addresses in the six Southern Cone countries. The citations quoted by each source reference were then examined and an attempt was made to identify the affiliation address of the first author at the time when the cited paper was written. All cited references prior to 1972 were eliminated. By searching for these authors and dates of publication in a number of online databases (CAB Abstracts, SCISEARCH, Medline), it was possible to trace this information for all the citations sought. This procedure was intended to indicate the literature sources available to, and used by, Southern Cone researchers on the selected commodities over the period of the Cono Sur project.

The use of SCISEARCH database for studying the publication and citation patterns of developing country scientists presents a number of problems. This multidisciplinary database includes a relatively small fraction of the scientific journals published throughout the world, though at the same time it does include a very high percentage of the "important" and "significant" journals, as assessed on the basis of objective criteria, mainly involving citation ratings. Most importantly, the representation of developing country journals, including those published in Latin America, is very low. Therefore, we must continually bear in mind that the articles we identify as our source set represent the mainstream scientific contributions from the Southern Cone countries to the international pool of agricultural knowledge.

Garfield [3] has reported that the SCI database includes about 1% of material with first author affiliations in Latin America, and assures us that this is consistent with the level of Latin American coverage of other international databases, such as Chemical Abstracts and Physical Abstracts. However, international agricultural databases contain a far higher percentage of Latin American material. Long and Machado [7] report levels of 8%, 7% and 4%, for Agris, CAB Abstracts and Agricola, respectively. Similarly, SCI's coverage of all developing country material is different from that of specialized agricultural databases. The 1973 SCI included 5% of material from the developing world [2] compared with an average of 18% for the three international agricultural databases (Longo and Machado [7]).

Despite these problems, the SCI files are the only online sources of citation data in our area of interest. We therefore, somewhat reluctantly, decided to use SCISEARCH since we were primarily interested in devising a methodology for studying and tracking cited publications.

RESULTS AND DISCUSSION

National agricultural knowledge generation

The CAB searches for all publications with first authors giving an affiliation address in one of the six Southern Cone countries and with publication dates between 1973 and 1982, produced some 20,000 references. Of these the cumulative publication output of Brazil was by far the largest, accounting for some 70% of the total. Argentina and Chile were some way behind with about 15% and 10%, respectively, while Uruguay contributed less than 2% and Bolivia and Paraguay less than 1% each.

Table 2: Agricultural publication output of Southern Cone countries: 1973-1982

	Plant Sciences	Animal Sciences	Social Sciences	Total
	%	%	%	%
Argentina				
1973-77	24.5[a](823)[b]	18.4 (619)	1.4 (47)	44.3 (1489)
1978-82	24.6 (825)	28.9 (969)	2.2 (73)	55.7 (1867)
Bolivia				
1973-77	8.2 (15)	14.7 (27)	0.5 (1)	23.4 (43)
1978-82	26.6 (49)	44.6 (82)	5.4 (10)	76.6 (141)
Brazil				
1973-77	25.8 (3604)	12.4 (1737)	0.6 (83)	38.8 (5424)
1978-82	39.2 (5485)	21.2 (2953)	0.8 (118)	61.2 (8556)
Chile				
1973-77	28.1 (608)	17.5 (379)	0.6 (12)	46.2 (999)
1978-82	28.2 (610)	24.3 (522)	1.3 (29)	53.8 (1161)
Paraguay				
1973-77	11.0 (16)	35.2 (51)	0.7 (1)	46.9 (68)
1978-82	7.6 (11)	43.4 (63)	2.1 (3)	53.1 (77)
Uruguay				
1973-77	11.3 (40)	24.6 (87)	0.6 (2)	36.5 (129)
1978-82	34.7 (123)	24.3 (86)	4.5 (16)	63.5 (225)
Total				
1973-77	25.3 (5106)	14.4 (2900)	0.7 (146)	40.4 (8152)
1978-82	35.2 (7103)	23.2 (4675)	1.2 (249)	59.6 (12027)

a. Figures are given as percentages of national 1973-82 totals.
b. Figures in parentheses are publication counts.

Table 2 presents an overview of the basic data broken down according to the CAB subfiles for plant science, animal science and social science. It can be seen that the publication output of the region increased by about 50% between the periods 1973-1977 and 1978-1982. However, the increase was not evenly distributed across all three subfiles; the increase in plant sciences was 40%, in animal sciences 60%, and in social sciences 70% (though this latter increase was from a very small base of research activity). This suggests that the research portfolio of the region may have become slightly more animal intensive over this period, although, since the references themselves were not examined it could be that this apparent increase reflects increased activity in the medical parasitology area, which is also included in the CAB animal sciences subfile.

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The pattern of national growth in published output was also far from uniform over the decade. Bolivia, Brazil, and Uruguay experienced quite dramatic growth, in excess of 50%, while Argentina showed a more modest increase of 25%, and Chile and Paraguay minor increases of less than 20%. There does not appear to be any readily discernable pattern to these growth profiles. For instance, relative growth performance does not appear to be related to the size of the system.

Table 3: SCI: Leading Latin American countries contributing to the SCI database

Country	Rank Position		
	1973	1978	1982
Argentina	1[a]	2	2
Brazil	2	1	1
Venezuela	3	5	5
Chile	4	4	3
Mexico	5	3	4

a. Figures refer to position in a ranked list of Latin American countries contributing to the SCI database in the year concerned.

Source: Adapted from Garfield [3]

Garfield [3] has also studied the productivity of Latin American countries contributing source articles to the SCI database, and his figures place the six Southern Cone countries in the same relative order as do our data. The top five Latin American countries in the 1978 SCI - Brazil, Argentina, Mexico, Chile and Venezuela - account for 92% of all Latin American sourced articles. The same five were also the leading producers in the 1973 and 1982 SCI, but their relative positions changed over the years. Table 3 shows this change in position. Brazil's replacement of Argentina as the most productive Latin American country between 1973 and 1978 is interesting. Our study of the productivity of agricultural knowledge (using CAB Abstracts as opposed to SCI) showed no such change; Brazil was by far the leading producer during the entire 1972-1984 period. Southern Cone countries have, in fact, been major developing country contributors to the SCI database. Garfield [2] has earlier reported that Argentina, Brazil and Chile were 2nd, 3rd and 6th, respectively, in a ranked list of all developing country contributors to the 1973 SCI.

Table 4: Cono Sur project commodities publication output for participating Southern Cone countries: 1973-1982

	Maize	Wheat	Soybean	Sorghum	Beef	TOTAL
	%	%	%	%	%	%
Brazil	3.7[a] (5.4)[b]	1.8 (2.6)	4.6 (6.6)	1.6 (2.2)	3.6 (5.2)	15.3 (22.0)
Argentina	0.8 (4.6)	0.7 (4.0)	0.4 (2.3)	0.4 (2.7)	1.4 (8.2)	3.7 (21.8)
Chile	0.2 (1.7)	0.9 (8.6)	0.1 (0.8)	0.0 (0.3)	0.5 (5.1)	1.7 (16.5)
Uruguay	0.0 (2.5)	0.1 (7.6)	0.0 (3.1)	0.1 (4.2)	0.2 (12.1)	0.4 (29.6)
Bolivia	0.0 (0.5)	0.0 (0.5)	0.0 (0.5)	0.0 (0.0)	0.1 (1.3)	0.1 (2.8)
Paraguay	0.0 (1.4)	0.0 (0.0)	0.0 (0.7)	0.0 (0.0)	0.1 (9.7)	0.1 (11.8)

a. Publication output expressed as a percent of 1973-82 total agricultural publication counts for the region.
b. Figures in parentheses represent publication output expressed as a percent of 1973-82 total agricultural publication counts for each country.

The importance of the five commodities targeted by the Cono Sur study to the agricultural research activity of the region as a whole and in each country's research portfolio is summarized in Table 4. The first figure under each heading in Table 4 measures the commodity specific publication output of each country for the 1973-1982 period, relative to the total number of publications produced by all six Southern Cone countries during that period. Once again, the Brazilian system dominates the scientific output of the region at the commodity level, though Chile appears to contribute more to the regional pool of scientific knowledge in wheat research than would be suggested by the relative size of the system as reported in Table 1.

The second figure under each heading in Table 4 presents commodity level research output as a percentage of each country's total agricultural research output. It gives an indication of the relative importance of each commodity in domestic agricultural research portfolios. The commodities specified in the Cono Sur project appear to account for a significant amount of local agricultural research activity, except in the case of Bolivia, where only 2.8% of the publications identified were concerned with Cono Sur related commodities.

Counts of publications coming from the academic sector suggest that about 42% of the region's total agricultural knowledge is generated there. However, there are considerable differences between countries. Chile and Paraguay appear to be relatively university-intensive systems with less than 35% of their publication output originating in the non-academic sector. Argentina has a relatively balanced structure, with about 55% of the published output originating in the non-academic sector, while Brazil, Uruguay and Bolivia are relatively non-university intensive systems, with more than 55% of their publication output originating in the non-academic sector. In fact, virtually all the agricultural research publications from Bolivia (about 97%), originated outside the university sector.

Cross-country agricultural knowledge transfer

Our data on the transfer of knowledge among agricultural researchers in the Southern Cone countries and between these researchers and the world's scientific community as a whole, were obtained from the SCISEARCH database. The SCISEARCH file was first used to obtain the total scientific publication output of the six countries for the five commodity areas central to the Cono Sur project (maize, wheat, sorghum, soybean and beef) over a 13 year period between 1972 and 1984. These searches produced a total of 795 references, though a number of these were found to be from the Current Contents portion of the file and consequently did not include information on citations. These were removed from the file and our source set of references subsequently contained 445 items.

These source references were found to represent 116 journals from 15 different countries. More than two thirds of them were published in international journals originating in North America and Europe, and 70% were published in 1980 or later. Table 5 provides additional information on the subject characteristics of the source set of references and the type of journal in which they were published.

Table 6 lists the countries in which the source references were published and also includes similar information for all Latin American articles in the 1978 SCI (adapted from Garfield [3]). There is good agreement between these two sets of figures with regard to the high level of Latin American material published in North American and Western European journals (70-75%). However, there are some interesting differences. For example, our set includes a much higher percentage of material published in Brazil (20% as opposed to 5%) and a lower percentage of material from Chile (0.5% against 4%) as compared with Garfield's data. This may reflect differences in the publication habits of scientists in different disciplines and also the availability of suitable journals in the different countries concerned. It is instructive to compare the information in Table 6 with the figures reported by Velho [12], who was studying the publication and citation habits of researchers at a number of Brazilian agricultural universities. Velho's data differ markedly from those obtained by Garfield and ourselves, showing that 94% of all articles published by the Brazilian scientists appeared in Brazilian journals. This difference is doubtless due to the "international" bias inherent in the use of SCI data. It is, however, interesting to reflect on Velho's figures, bearing in mind that ten years previously Sandoval [11], in a study of Current Contents, had complained of the drain of biomedical manuscripts away from Latin American journals and towards international publications.

Table 5: Source Set: Characteristics of the publications

Subject Area	Type of Journal[a]				Total No. of References	Percentage of Total References
	I	R	N	D		
						%
Agronomy	38	19			57	12.81
Agricultural Engineering	8				8	1.80
Animal Production	9	7			16	3.59
Biochemistry/Physiology	70		4		74	16.63
Chemistry	3		10		13	2.92
Experimental Biology	16	11			27	6.07
Economics	1		1		2	0.45
Food Science and Technology	30				30	6.74
Genetics/Plant Breeding	13	6	25		44	9.89
General Science	2	1			3	0.67
Medicine/Human Nutrition	24	1	2		27	6.07
Meterology/Environmental Sciences	8				8	1.80
Plant Pathology	41	1			42	9.44
Soil Science	10				10	2.25
Veterinary Medicine	22		61	1	84	18.87
TOTAL	295 (66.3)[b]	46 (10.3)	103 (23.2)	1 (0.2)	445	100.00

a. I = International; R = Regional; N = National; D = Other Developing Country.

b. Figures in parentheses are percentages.

Table 6: Source Set: Place of publication of the references

Place of Publication	Percentage of Total References	
	Our data	1978 SCI[a]
	%	%
Southern Cone countries:		
Brazil	20	5
Argentina	5	2
Chile	0.5	4
Other Latin America	4	9
North America	37	43
Western Europe	33	33
Others	0.5	4

a. SCI data refers to all Latin American articles in 1978 SCI.

Source: Adapted from Garfield [3]

When the 116 journals were arranged in rank order depending on the number of references they contributed to the source set, the expected skewed distribution was obtained. The top 9 titles in the list contained 40% of the references; the top 27 titles, 65% of the references. Table 7 presents details on the top 27 titles (all those contributing 5 or more references to the source set).

It is usual to assess the impact or scientific quality of a set of articles by measuring their subsequent citation performance. Garfield has discussed the impact and other characteristics of Latin American articles in the SCI database in some detail [3]. Table 8 shows the productivity and impact of all articles with first author affiliations in Southern Cone countries in the 1978 SCI, adapted from Garfield's figures. The total of 388,000 source articles in the 1978 SCI, which provided author affiliation information, received about two million citations between 1978 and 1982. Impact is calculated by dividing the number of 1978-82 citations to a specific 1978 article by the total number of articles published in 1978. Thus the average SCI article had a five year impact of 4.8. Comparative figures for the 3100 Latin American articles are 9000 citations, giving a five year impact of 2.9. Table 9 places the Latin American contribution to SCI in context by showing the percentage of source articles from different regions of the world and their impact over the period 1978-82.

Table 7: Source Set: Rank order listing of journals contributing five or more references to the source set

Title	No. of References	Cumulative Percentage of Total References	Type of Journal[a]	Country of Publication	Subject Field[b]
		%			
Arquivos da Escola de Veterinaria da Universidade Federal de M.G.	61	13.7	N	Brazil	Vet
Revista Brasileira de Genetica	20	18.2	N	Brazil	Gen
Turrialba	19	22.8	R	C. Rica	Agr
Journal of Food Science	15		I	USA	FdSci
Phytochemistry	15		I	USA	Bioch
Plant Disease	15	32.6	I	USA	PlPath
Journal of the Amer. Oil Chemists' Soc.	12	35.3	I	USA	Bioch
Phyton	11	37.7	R	Argentina	ExBio
Anales de la Asoc. Química Argentina	10	40.0	N	Argentina	Chem
Crop Science	9		I	USA	Agr
Journal of Food Technology	9	44.0	I	UK	FdSci
Trans. Amer. Soc. of Agric. Engineers	7		I	USA	AgEng
Tropical Agriculture	7		I	UK	Agr
Tropical Animal Health & Production	7	48.7	I	UK	AnProd
Agricultural Meteorology	6		I	Netherlds	Met
Agronomy Journal	6		I	USA	Agr
Behavior Genetics	6		I	USA	Gen
Journal of Agricultural & Food Chemistry	6		I	USA	Bioch
Maydica	6		I	Italy	Gen
Phytopathology	6		I	USA	PlPath
Zentralblatt f. VeterinÄr-Medizin	6	58.2	I	W. Germ.	Vet
Agricultural Systems	5		I	UK	Agr
Amer. Journal of Clinical Nutrition	5		I	USA	Med
Amer. Journal of Reproductive Immunology	5		I	USA	Med
Anaïs da Academia Brasileira de Ciencias	5		N	Brazil	GenSci
Plant Physiology	5		I	USA	Bioch
Zeitschrift f. Acker- u. Pflänzenbau	5	64.9	I	W. Germ.	Agr

a. I = International; R = Regional; N = National.

b. AgEng = Agricultural Engineering; Agr = Agronomy; AnProd = Animal Production; Bioch = Biochemistry & Physiology; Chem = Chemistry; ExBio = Experimental Biology; FdSci = Food Science & Technology; Gen = Genetics & Plant Breeding; GenSci = General Science; Med = Human Medicine and Nutrition; Met = Meteorology; PlPath = Plant Pathology; Vet = Veterinary Sciences

Table 8: SCI: Impact of all Southern Cone articles in 1978 SCI

Country	No. of Articles	Impact 1978-82
Brazil	1060	2.6
Argentina	643	3.1
Chile	312	3.3
Uruguay	25	2.4
Bolivia	4	1.0
Total Southern Cone	2044 (0.5)[a]	n.a.
Total Latin America	3126 (0.8)	2.9

a. Figures in parentheses are percentages of total 1978 SCI articles.

Source: Adapted from Garfield [3]

Table 9: SCI: Percentage contributions to 1978 SCI from different regions of the world and their impact

Country	Percentage of 1978 SCI	Impact 1978-82
	%	
USA	44	5.7
Western Europe	17	4.5
UK	9	5.2
USSR	6	1.5
Japan	5	4.0
Canada	4	4.9
Third World Nations	4	1.7
Southern Europe	3	2.3
Scandinavia	3	6.4
Australia	2	4.4
Latin America	1	2.9
All Others	2	4.0

Source: Garfield [3]

In our study, however, we were interested in looking backward, rather than forward, in time to the knowledge base which contributed to the current Southern Cone research activity. We took the material cited by the source references to be a direct measure of the pool of knowledge upon which this current research literature drew. The 445 source references provided 7926 citations to the literature, an average of nearly 18 citations per reference. Of the 7926 citations obtained, more than half were to items published before 1972, which were eliminated from the sample, since the databases we were planning to use in the next stage of the study did not extend that far back. In any case, it also seemed reasonable to limit the cited material to fairly contemporary publications given that our purpose was to investigate the more recent transfer of agricultural knowledge between the countries concerned. A total of 3415 post-1972 citations remained. Table 10 presents a breakdown of these citations by type of document.

Table 10: Citations: Broken down by type of document

Type of Document	Number and Percentage of Total References		
	%		
Serials	75	2579	
Monographs	13	438	
Conference Proceedings	6	190	
Latin America			85
Elsewhere			105
Theses	5	160	
Southern Cone unversities			109
Elsewhere			46
Unidentified			5
Unidentified items	1	48	
TOTAL	100	3415	

The 2579 citations to serial publications referred to 501 different serial titles. Table 11 is a ranked order listing of the top 28 titles (all those receiving 20 or more citations from the source set of publications). Over 25% of the citations were to just 13 titles; 39% to 28 titles. Table 12 indicates the place of publication of the cited references. Clearly, researchers in the Southern Cone countries prefer not to cite material published in the region and have access to leading international journals, nearly 90% of the citations being to articles published outside Latin America. On this occasion, Velho's results were also similar to ours; the Brazilian university researchers cited non-Latin American journals 60% of the time and Brazilian journals 37% of the time, even though the vast majority of their own articles were published in Brazilian journals [12].

Table 11: Citations: Rank order listing of journals cited twenty or more times by the source set

Title	No. of Citations	Cumulative Percentage of Total Citations	Type of Journal[a]	Country of Publication	Subject Field[b]
		%			
Plant Physiology	117	4.5	I	USA	Bioch
Agronomy Journal	67	7.1	I	USA	Agr
Journal of Animal Science	62	9.5	I	USA	AnProd
Crop Science	61	11.9	I	USA	Agr
Journal of Food Science	58	14.2	I	USA	FdSci
Arquivos da Escola de Veterinaria da Universidade Federal de M.G.	48	16.0	N	Brazil	Vet
Journal of the Amer. Oil Chemists' Soc.	45	17.8	I	USA	Bioch
Phytochemistry	41	19.3	I	USA	Bioch
Biochimica et Biophysica Acta	38	20.8	I	Netherlds	Bioch
Phytopathology	36	21.8	I	USA	PlPath
FEBS Letters	32	23.5	I	Netherlds	Bioch
Journal of Biological Chemistry	31	24.7	I	USA	Bioch
Histochemistry	29	25.8	I	USA	Bioch
Plant Disease (Plant Disease Reporter)	28	26.9	I	USA	PlPath
Annual Review of Plant Physiology	27	27.9	I	USA	Bioch
Science	25		I	USA	GenSci
Veterinary Record	25		I	UK	Vet
Weed Science	25	30.8	I	USA	Agr
Applied and Environmental Microbiology	22		I	USA	PlPath
Journal of Food Technology	22		I	UK	FdSci
Planta	22		I	W. Germ.	Agr
Revista da Soc. Brasileira de Zootecnia	22	34.2	N	Brazil	AnProd
Biochemical Journal	21		I	UK	Bioch
Pesquisa Agropecuaria Brasileira	21	35.9	N	Brazil	Agr
Archives of Biochemistry and Biophysics	20		I	USA	Bioch
Journal of the Sci. of Food and Agric.	20		I	UK	Bioch
Nature	20		I	UK	GenSci
Proc. Nat. Acad. Sciences of the US	20	39.0	I	USA	GenSci

a. I = International; N = National

b. Agr = Agronomy; AnProd = Animal Production; Bioch = Biochemistry & Physiology; FdSci = Food Science & Technology; GenSci = General Science; PlPath = Plant Pathology; Vet = Veterinary Sciences.

Table 12: Citations: Place of publication of cited references

Place	Percentage of Total References
	%
Southern Cone countries:	
Brazil	8
Argentina	1.5
Chile	0.5
Other Latin America	1
North America	49
Western Europe	35
Others	5

However, given that a substantial number of authors publish in journals which do not originate in the country where the reported research was carried out, the place of publication was rejected as a means of mapping knowledge transfers. A more representative measure of the flow of information into the Southern Cone countries from identifiable national, regional or international sources was obtained by comparing the country affiliation of the source authors with the country affiliation of the principal cited authors. The results of this analysis are summarised in Table 13. The upper half of the table relates to all citing articles for the 1974-84 period while the lower half presents more detailed period-specific breakdowns.

Looking at the six country totals for the 1974-1984 period as a whole (right hand column of upper part of Table 13), about 70% of the cited knowledge base comes from international sources, with North American sources alone accounting for 42% of the scientific knowledge inflow. Approximately 24% of the transferred knowledge comes from domestic sources, while an amazingly low 4% comes from regional sources. Examining the figures more closely reveals considerable differences between individual countries. Most significantly, the use of regional sources of information in the smaller systems (Bolivia, Chile, Paraguay and Uruguay) has increased from zero in 1974/1978 to 12% in 1979/1981 and 7% in 1982/1984. In contrast, regional sources have become less important for Brazil, more reliance being placed on domestic sources. Argentina shows a dramatic decline in the use of domestic sources between 1974/1978 and 1979/1981, which was made up by international and, to a lesser extent, regional sources of knowledge. Some, at least, of these changes may be ascribed to the existence of the Cono Sur program during this period.

Table 13: Citations: Percentage of cited material in relation to the country of location of the cited author

Transfers from[a]/ Period[c]	Transfers To[b] Brazil	Argentina	Other CONOSUR[d]	All Countries
	%	%	%	%
National	26.5[e]	22.8	9.7	23.9
Regional	3.3	4.6	8.3	4.1
Self Citations	88.9	83.2	53.9	85.3
International	70.2	72.6	82.0	72.0
North American	41.4	41.2	47.8	42.0
European	17.1	20.2	24.5	18.6
Other	11.7	11.2	9.7	11.4
National				
1974-78	19.8	41.9	17.9	24.4
1979-81	30.2	22.3	11.3	26.7
1982-84	24.3	20.5	5.2	21.5
Regional				
1974-78	6.6	4.8	0	5.3
1979-81	2.1	8.9	12.1	4.5
1982-84	3.7	2.5	7.0	3.6
Self Citations				
1974-78	75.0	89.7	100.0	82.2
1979-81	93.5	71.5	48.3	85.6
1982-84	86.8	89.1	42.6	85.7
International				
1974-78	73.6	53.6	82.0	70.3
1979-81	67.6	68.8	76.6	68.8
1982-84	72.0	76.9	87.8	75.0

a. Country location of cited principal author.
b. Country location of citing principal author.
c. Represents period in which citing article was published. Upper half of table relates to all (citing) articles for the 1974-84 period.
d. Includes Bolivia, Chile, Paraguay and Uruguay.
e. Indicates, for example, that 26.5% of all the source material for Brazilian research published during 1974-84 was national in origin.

Garfield [4] has also noted the relative lack of regional citation in Latin American articles, and has introduced the concept of "self-citation". In this context "self-citation" is defined as the number of references in a nation's literature that cite that same nation's papers divided by the total number of references to all Latin American papers. It should not be confused with the usual meaning of self-citation as an author citing his or her own work. Thus, national self-citations indicate a form of "provinciality" or "insularity". Garfield quotes self-citation levels to all 1978 SCI articles of 91% for Argentina, 93% for Chile, 94% for Brazil and 100% for Uruguay. Velho, too, found a high percentage of self-citation (93%) among the Brazilian agricultural university staff [12]. Table 13 includes the self-citation percentages calculated for our data. Again, the larger systems are shown to be more insular than the smaller ones. Garfield comments that this phenomenon indicates that Latin American researchers are not aware of, or choose not to cite, papers from neighbouring countries, at least as far as the research reported in the international journals covered by SCI is concerned.

He goes on to suggest that scientific information from the US and Europe is more accessible to Latin American scientists, and vice versa, as a result of programs designed to increase contacts between scientists in these regions. He concludes that similar programs designed to intensify contacts between scientists within Latin America - travel grants, exchange programs, cooperative research projects, regional laboratories and journals, etc. - are to be recommended. These are, incidentally, exactly the kind of contacts that the Cono Sur-PROCISUR program is designed to stimulate.

Temporal aspects of knowledge transfers

In the previous section we quantified and discussed the flow of scientific knowledge into the Southern Cone countries during the 1974-84 period. It is also instructive to study the temporal aspects associated with what is inherently a dynamic process. We therefore also examined the currency of the citations quoted by our source set of publications.

For the source references published in the two periods 1973/1976 and 1980/1983 we calculated the citation lag in years (i.e., the difference between the date of publication of the cited article and the date of publication of the citing article) for all cited serial publications, some 5650 articles. The results suggest a marked decline in the currency of the current research effort in all six countries over the 1973-1983 period. In Brazil, for example, 50% of the cited articles have a citation lag of 6.5 years or less in 1973/1976, which increased by 29% to 8.5 years by 1980/1983. The increase in the cumulative citation lag of the remaining Southern Cone countries is even more dramatic with Argentina's lag increasing by around 39% and the smaller Southern Cone countries, when taken as a group, by approximately 126%. Budgetary and foreign exchange controls appear to have inhibited access of these research systems to non-local sources of knowledge either in a direct manner through restrictions on journal purchases, conference attendances or online searching, or indirectly through a decline in the number of researchers gaining access to these knowledge sources by undertaking sponsored studies in foreign research and educational institutions.

CONCLUSION

Our main aim in carrying out this study was to develop a methodology for measuring the cross-country flow of agricultural scientific information. As a preliminary exercise we also attempted to characterise the agricultural information produced by the six Southern Cone countries, with particular reference to the five commodities involved in the Cono Sur program.

The most striking feature of our results is the general lack of scientific information exchange among Southern Cone agricultural researchers. There is a marked tendency to look to national or international (i.e., industrialized country) sources, rather than to sources in neighbouring countries of the region. This tendency is most pronounced in the two largest systems in the region (Argentina and Brazil). The smaller systems (Bolivia, Chile, Paraguay and Uruguay) do seem to turn more often to regional sources, but even then these only make up some 8% of their total sources of information. It is interesting, however, to note that in recent years regional sources of knowledge have become relatively more important for these smaller systems. This may owe something to the existence of the Cono Sur program over this period.

The major limitation of our study has been the necessity to use the SCISEARCH database, which has conditioned our results. In particular, we have targeted scientific, as opposed to more general, knowledge transfers relating to agricultural research in the region. An extension to this analysis would be to use this methodology to carry out a manual count of cross-country knowledge flows. The source set of publications could comprise the lists of publications included as part of the national research institutes' annual reports. The publications presented in these lists represent those papers published by national researchers over the year being reviewed. If they were to be examined and an analysis made of the citations given in these papers, then a richer perspective of information flows at various levels in the transfer process would be obtained.

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