

4. Bibliometrics of Tropical Soil Sciences: Some Reflections and Orientations

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This chapter presents some methodological problems in realizing a bibliometric study in soil and agricultural sciences in a tropical environment. Soil science research in the tropics is a complex field and, therefore, needs to be analyzed cautiously. This is especially true where new scientific communities from the Third World are showing an important and active participation in science. We believe that the factors operating in this arena are far from unique. They remain largely overlooked, and the influence of tropical researchers in the world of science is often underestimated when the quality of science or the impact of scientific literature is evaluated. Moreover, we feel that scientists would benefit from being more aware of the forces which orient the scientific production in their spheres of knowledge.

A. Focusing on Tropical Soil Sciences

Bibliometrics, the statistical analysis of bibliographic material, is of recent development.¹ This is especially so in soil science.² The intent of bibliometric analysis is to grasp an overview of a science, including the work of laboratories, institutions, and scientists working in a determined field. This analysis can be useful to scientists who sometimes lack a comprehensive

This chapter is a précis of the authors' *Stratégies Scientifiques et Développement: Sols et Agriculture des Régions Chaudes* (Paris: ORSTOM Éditions, 1988). IFRSDC is a division of the Office de la Recherche Scientifique et Technique Outre-mer (ORSTOM).

1. For a global introduction to bibliometrics, see J. P. Courtial, *Introduction à la Scientométrie* (Paris: Anthropos, 1990).

2. The first bibliometric analysis of soil sciences was Daniel Yaalon, "Publication as a Measure of a Nation's Research Effort," *Geotimes* 11 (3) (1966): 20-21. To our knowledge, our 1988 study is the only more recent one. Lea M. Velho has also worked on the scientific production of Brazilian university soil scientists (Ph.D. diss., 1985).

perspective of their discipline. It can also be used in a more pedagogical way to explain the patterns of organization of knowledge in a field of learning. The scientific community can profit from systematic bibliometric analysis with a global perspective. It should be noted, however, that the uses to which these scientific indicators are put can often be in conflict with prescribed beliefs, and the mere possibility of drawing such a large picture is itself problematic.

The authors of this essay are, respectively, a researcher in the sociology of science and a tropical soil scientist. In this investigation, we wanted to know, first, how the study of soils in tropical areas is organized. Some questions regarding this organization are obvious: what share of the scientific literature is produced in the tropics and how much in northern latitudes? What countries contribute most to this body of scientific knowledge? How does the contribution of northern influence that of southern countries? Evident as they may appear, these questions have never been extensively investigated. Few have researched the geopolitics of research, and rarely have the inherent biases of such an investigation been analyzed. In many instances, the research tools for such undertakings are unavailable. Since we are going to examine facets of tropical soils research in some detail, we must mention briefly some of the political problems in a bibliometric analysis of this sort.

Science is universal in so far as the corpus of knowledge it creates is held to be scientifically valid in all countries. But it is not universal in the way the science itself is carried out, nor in its application, and still less in the motivations of the individual scientists doing the work. This disparity is true of all science, but perhaps more so in the natural sciences where the medium of investigation is in precise and diverse environments. Soil, or a landscape, is just such an environment, particular to a specific locale. One can decide to study a soil because of its properties or because of its uses in crop production. The results obtained may serve other scientists. Allocations toward that research, the timing of the research, and the ways by which results are disseminated and accessed in the literature, all depend on a variety of contributing factors, not least the initial input and affiliation of the scientists or scientific body doing the work.

Science is also a dynamic process which remains fragile in many developing countries, despite recent improvements. Today, scientists from the Third World have been recognized not only in relation to the developed world, but also for their work as original contributors. This is particularly true with soil science. Despite the fact that its concepts and science were developed in the north, the emphasis of much current research depends on choices made by local scientists. Pressures exerted on scientists of develop-

ing countries are often much stronger than those felt by their counterparts from industrialized countries. Developing country scientists are required to do applied research in areas of national interest, especially research which contributes to the country's self-sufficiency; they are requested to help the growth of their educational systems; often they are asked to participate actively in politics.³ These pressures translate into stresses and conflicts which may cause pressures within the local scientific community, stresses which must also be dealt with in conditions often less amenable than those faced by their northern counterparts.⁴ These scientists are also more dependent on outside expertise and lack many information resources.⁵ It is inevitable that any investigation into the world distribution of scientific knowledge will enter immediately into an arena of opposing interests and motivations. This is especially true in the arena of scientific funding and production, which is increasingly organized by a multiplicity of national and international players.⁶

These observations are not abstract but arise every day in dealing with funding and scientific policy in the international arena.⁷ Why does a laboratory receive funding for research that will benefit some users whose activities may be in conflict with that of the funding body? What type of knowledge should international bodies fund? Is there a need to redirect funding in order to benefit more rapidly the welfare of nations and people, such as research in agricultural and industrial activities? In soil science, these sorts of questions are generally absent from the scientific literature, yet seem to be integral to the scientific process of soils research: funding, designing, executing, and disseminating scientific research is often an exercise in geopolitics. This is not known to all scientists because most of them work on a limited scope. Tropical soil science is no different, for it is a discipline

3. (a) H. M. C. Vessuri, "O Inventamos, O Erramos: The Power of Science in Latin America," *World Development* 18 (11) (1990): 1543-53. (b) S. Schwartzman, *A Space for Science: The Development of the Scientific Community in Brazil* (University Park, P.A.: Pennsylvania State Univ. Press, 1991). (c) J. Fortes and L. A. Lomnitz, *La Formación del Científico en México: Adquiriendo una Nueva Identidad* (Mexico, D.F.: Siglo Veintiuno, 1991). (d) R. Arvanitis, "De la Recherche au Développement. Les Politiques et Pratiques Professionnelles de la Recherche Appliquée au Vénézuéla," Ph.D. diss., Paris VII, published in Spanish (Caracas: Fondo Editorial Acta Científica Venezolana, 1992). (e) G. Argenti, C. Filgueira, and J. Sutz, "From Standardization to Relevance and Back Again: Science and Technology in Small Peripheral Countries," *World Development* 18 (11) (1990): 1555-67.

4. (a) M. Schoijet, "The Condition of Mexican Science," *Minerva* 22 (3) (1983): 381-413. (b) J. Gaillard and R. Waast, "La Recherche Scientifique en Afrique," *Afrique Contemporaine* 148 (1988): 3-30.

5. M. Roche and Y. Freitas, "Producción y Flujo de Información Científica en un País Periódico Americano (Venezuela)," *Interiencia* 7 (5) (1982): 279-90.

6. A. J. J. Botelho, "Struggling to Survive: The Brazilian Society for the Progress of Science (SBPC) and the Authoritarian Regime (1964-1980)," *Historia Scientiarum* 38 (1991): 45-63.

7. J. Gaillard, *Scientists in the Third World* (Lexington, Ky.: University Press of Kentucky, 1991).

which depends both on the scientific progress in the field and on local scientific communities in developing countries. Moreover, soil science has been the locus of many scientific controversies which have developed along national lines, the most famous being that of soils classification, where the United States, Russia, France, and the Food and Agriculture Organization (FAO) have all competed to supply the world's classification scheme.

These questions may help explain why the Institut Français de Recherche Scientifique pour le Développement en Coopération, a division of ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer), in France, created a team dedicated to the understanding of the scientific process in developing countries. Bibliometrics is one of our principal tools of analysis.

B. Using Bibliographic Databases

Bibliographic databases are a unique analytical resource which help us to access the literature of scientific research more efficiently. However, to some extent, all bibliographic databases are problematic. Each database offers a unique coverage of the literature: none can claim to be comprehensive of all the literature of a subject. A classic misunderstanding among researchers is believing that what is indexed in a database is mainstream science.⁸ "Mainstream science" would be a valid concept in this regard if every database retained the same set of journals as a core, but this is not usually the case. What is indexed in databases is often skewed by commercial imperatives, including document acquisition cost, literature coverage policies of the database, and choices by the indexers at the citation level.⁹ These biases are apparent in the coverage of locally produced articles from developing countries, which traditionally have had less representation in the major bibliographic databases. The factors which govern these selections have not been extensively examined in print.¹⁰

Soil science involves both agriculture and geology; it is important in international development; it is a physical science unto itself; and as soils are both versatile and dynamic (more a process than an object), they are, there-

8. The notion has acquired quite a different sense from that first proposed by J. D. Frame, "Mainstream Research in Latin America and the Caribbean," *Interciencia* 2 (3) (1977): 143-47.

9. G. Whitney, "Access to Third World Science in International Scientific and Technical Bibliographic Databases," in *Proceedings of the International Conference on Science Indicators in Developing Countries*, eds. Rigas Arvanitis and J. Gaillard (Paris: ORSTOM Editions, 1992 [A selection of papers from this conference has also appeared in a special issue of *Scientometrics* 23 (1) (1992)]), pp. 391-409.

10. Recently, many authors tried to investigate some of these biases. See *Proceedings of the International Conference on Science Indicators in Developing Countries*, ed. Arvanitis.

fore, in a constant state of flux. This may explain the growing claim in soil science circles that it is becoming increasingly multidisciplinary.¹¹

Bibliometric researchers are advised to state at the outset of their work that the bibliographic databases used for analysis are problematic and prone to skews. Some databases are biased toward English and index only specific sets of sources. Others only analyze certain types of published material and exclude others. Skews such as these should alert the researcher to be careful when studying Third World literary output. This is particularly true of the *Science Citation Index* (SCI). For instance, Cuba has a citation rate sixteen times higher in BIOSIS, the biological database of the BioScience Information Service, and *Chemical Abstracts* than in the SCI.¹² With Brazil, *Chemical Abstracts* lists 201 chemical reviews, whereas only six are listed in the SCI.¹³ Again, of the seventy-six veterinary reviews listed by the SCI, only four come from developing countries.¹⁴ The point is not to dismiss the SCI as a research tool, but to reveal its shortcomings. The same is true of many other databases, but only the SCI provides a yardstick for measuring the impact of specific research by citation analysis.

Given these caveats, one approach for bibliometric studies is to work with one database, either specialized or general, and try to understand the trends that appear in that single source.¹⁵ We made a choice to use a French database, PASCAL, which indexes some 400,000 references per year and currently contains almost 8,000,000 records. PASCAL is a multidisciplinary database covering the years 1973 to the present, which indexes literature from some 9,000 international journals, with coverage of all the sciences, including physics, applied technologies, psychology, medicine, the life sciences, biotechnology, earth sciences, astronomy, civil and mechanical engineering, computer science, transportation, energy, and agriculture. It also abstracts monographs, master's and doctoral theses, proceedings of conferences, as well as reports and many patents. The two specialized subfiles on agriculture and earth sciences cover all aspects of these disciplines.

11. (a) Yvon Chatelin, *Une Epistémologie des Sciences du Sol* (Paris: ORSTOM Editions, 1979). (b) Chatelin and G. Riou, eds., *Milieux et Paysages; Essai sur Diverses Modalités de Connaissance* (Paris: Masson, 1986).

12. R. Sancho, "Misjudgments and Shortcomings in the Measurement of Scientific Activities in Less Developed Countries," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis, pp. 411-23.

13. M. A. Cagnin, "Patterns of Research in Chemistry in Brazil," *Interciencia* 10 (1985): 64-77.

14. J. M. Russel and C. S. Galina, "Research and Publishing Trends in Cattle Reproduction in the Tropics: Part 2. A World Prerogative," *Animal Breeding Abstracts* 55 (11) (1987): 819-28.

15. This does not satisfy the need for a comparative analysis of the content of databases. That type of work should be done by librarians or documentation specialists, not by policy analysts or scientists in search of a good description of the science they work in. For recent efforts, see *Proceedings of the International Conference of Science Indicators*, ed. Arvanitis.

Extraction of pertinent data from these files occurred in two phases for this analysis. First, we extracted all references that were related to soil science and to agriculture as a whole. Our core concept was "soil," but we also looked at those terms which can be applied to soil science and the work of soil scientists in general. We tried to place ourselves in the position of a soil scientist who would want to know what is produced in one year in the discipline which has a direct impact on his field (see Appendix for the disciplinary coverage of the file). Second, we limited this set with keywords on tropical topics. For the year 1983, PASCAL contained 9,398 references in soil science. This can be considered as a sample of world literary output. However, to date, no one has determined what is the exact statistical value of such a sample, which is true for any set of articles used as a proxy of published world literature.

C. Selecting the Useful Science for Tropical Environments

Our sample needed to reflect the reality of research for tropical countries. Bibliometric research of a specific field in tropical areas, meaning tropical and subtropical zones, is further complicated because it involves not only scientists from tropical countries, but also scientists in developed countries who have worked extensively in the tropics. Most tropicalists, (scientists from developed countries working on tropical environments) come from the United States, France, the United Kingdom, and Germany. It is noteworthy that some industrial countries are practically absent from the tropical sciences, notably countries of Eastern Europe, although their importance for the discipline as a whole may be extensive. How then does one select in a database what could be construed as useful literature for developing countries? We made our selection of citations carefully, by including only those documents which have a tropical object in the title, the abstract, or the keywords. Thus, we gathered 2,040 tropical soil citations out of 9,398 references, which amounts to 21.7% of the entire "Agriculture and Soil Science" file. These are given in Table 4.1. With this selection, we obtained a corpus of literature that has direct application to soils research in developing countries, as well as for the scientists from the north who work on tropical soils.

We further distinguish three world areas, which correspond to geographical and cultural areas. First, publications authored by scientists in northern countries (hereinafter the north) include North America, the former USSR, and Europe. These represent 21% of the tropical soil and agriculture production in 1983. The principal producers are France (6.7%) and the United

Table 4.1. Subject categories with citations in the total file and the tropical file

	Category	Total	Tropical
1	General, Conference Reports, and Bibliographies	467	96
2	Geomorphology	1,686	255
3	Superficial Soil Formations	1,857	332
4	Satellite Imagery and Remote Sensing	48	9
5	Soils and Agriculture, General	171	28
6	Cartography and Soil Classification	199	39
7	Physicochemistry of Soils	382	93
8	Organic Matter	245	32
9	Physical Properties	215	36
10	Water Dynamics	284	70
11	Microbiology of Soils	1,150	363
12	Fertilization (Mineral and Organic)	1,821	529
13	Uses of Wastes	161	22
14	Hydroponic Culture	77	5
15	Soil-Plant Relations	239	64
16	Soil Conservation	152	30
17	Soil and Irrigation Management	120	28
18	Soil Pollution	124	9

Source: PASCAL, 1983.

States (5.8%). The strong presence of French literature doubtless reflects a common skew in databases such as PASCAL, which will index the literature of their respective country more thoroughly. By contrast, AGRICOLA reflects a United States skew and CAB Abstracts, an emphasis on the United Kingdom. The percentage in PASCAL is still remarkable because the United States is a more important producer in the overall Agriculture and Soils file (tropical and nontropical). This strong showing may be partly explained by the colonial past of France, and its heavy tropical scientific interests forged toward the end of the nineteenth century and the beginning of this century.¹⁶

Second were publications authored by scientists in large peripheral countries (the periphery). These include Australia, Israel, New Zealand, and South Africa, which are countries culturally similar to the North, which have a highly developed scientific community and a mainly tropical or subtropical ecological environment. These countries also share another common characteristic: their production of publications surpasses what one

16. C. Bonneuil, *Des Savants pour l'Empire. La Structuration des Recherches Scientifiques Coloniales au Temps de "la Mise en Valeur des Colonies Françaises," 1917-1945* (Paris: ORSTOM Editions, 1991).

would expect using an economic criterion such as the gross national product (GNP) as measurement.¹⁷ These four countries represent 26% of the tropical file, largely dominated by Australia (14%).

The third and largest group was publications authored by scientists in southern countries (the south), including the remainder of the world belonging to tropical areas. They represent 51% of tropical soils literature production. The two biggest producers in this group are India (15.2%) and Brazil (9.2%), followed by Egypt (4.9%).¹⁸

We emphasize that, for the time being, there exists no automated search strategy that would satisfactorily retrieve data of use only for the tropical world. Future advances in searching tools may give better answers. Our two stage approach seems realistic.

D. Analyzing Tropical Scientific Literature

It is important in planning a bibliometric study to make clear the distinctions of country, discipline, type of research work, and, when possible, the type of research institution doing the work.¹⁹

Bibliometric studies are done as if all scientists had equal access to publishers. Another implicit assumption is that all scientists agree on what constitutes their best publication strategy. This assumption states that all scientists wish to publish in big-name scientific journals, in order to gain a foothold in the international scientific community. Therefore, "good science" is included in the pages of journals like *Soil Science*, *Geoderma*, *Soil Science Society of America Journal*, and science that is less good is often relegated to secondary journals, mainly locally edited reviews.²⁰

This *ceteris paribus* approach does not reflect the actual situation. First,

17. J. D. Frame, "National Economic Resources and the Production of Research in Lesser Developed Countries," *Social Studies of Science* 9 (2) (1979): 233-46.

18. Our analysis is limited in scope and time. Because of their poor coverage by PASCAL we did not retain Japan and China in further analysis. It is also probable that other Asian countries are poorly covered. Most of our comparative work retains only the fourteen biggest producers, covering more than 30% of the 1983 publications. A wider time span would have allowed us to analyze changes that occur in the strategies of each country and within disciplines.

19. This last aspect is a difficult task, since one needs to have information on the scientific institutions of all countries represented.

20. This is a sketchy and oversimplified view. The Institute for Scientific Information has proposed a more sophisticated tool for the evaluation of quality of science: citation analysis. After much debate, it appears that citations reflect not the quality of science, but rather the impact of journals or articles. Recently, J. L. MacLean and M. J. M. Vega indicated that a better test of the quality of a journal is not the number of times it is cited, but the number and type of citations it emits. MacLean and Vega, "Citation Behaviour of Philippine Biological Scientists," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis.

in many developing countries, there exist a set of journals that are considered by local scientists to be as valuable as foreign titles. In fact, in the natural sciences, at least half of the scientists publish locally;²¹ in some cases the proportion can be as much as 92%, as is the case of soil science in Brazil.²² It is important to bear in mind that a national publishing capacity is not free of costs, nor free of political, sociological, or other factors that affect editorial selection. Second, even if local journals are a second choice, they serve a different purpose than mainstream international journals. They are not read by the same public, and they do not contain the same type of information.²³ It appears that a large proportion of scientists tend to publish simultaneously in both local and international journals.²⁴

Since we had access to few local publications, we worked hard to determine the proportion of totally autocentered publications. These are publications that simultaneously satisfy three criteria: (a) the research is carried out by a national laboratory; (b) it treats a local agricultural problem; and (c) it is published in a local journal or book. We computed the autocentered research in nine countries that do not belong to the north, since northern countries cannot satisfy to the criteria of the definition. These included India, Brazil, Egypt, Nigeria, and Argentina for the south, and all the periphery countries (Australia, Israel, New Zealand, South Africa). Autocentered soils publications for the world excepting northern countries represent 20% of all publications; this figure rises to 30% for the nine top publishing countries. A percentage of totally autocentered research that fluctuates between one-fifth and one-third of tropical agricultural citations indicates a high degree of fluidity; that is, in the vast majority of cases, it is customary for a study to be done in one place, concern research in another, and for the results to be published in a third. This fluidity indicates a wide integration in international networks.

The target of interested readers is largely determined by the publication

21. Gaillard, *Scientists in the Third World*.

22. (a) Lea M. Velho, "Science on the Periphery: A Study of the Agricultural Scientific Community in Brazilian Universities," Ph.D. diss., SPRU, University of Sussex, 1985. (b) Velho, "The Meaning of Citation in the Context of a Scientifically Peripheral Country," *Scientometrics* 9 (1-2) (1986): 71-89.

23. (a) MacLean and Vega, "Citation Behaviour of Philippine Biological Scientists," pp. 557-68. (b) T. O. Eiseimon and C. H. Davis, "Publication Strategies of Scientists in Four Peripheral Asian Scientific Communities: Some Issues in the Measurement and Interpretation of Non-Mainstream Science," in *Scientific Development and Higher Education*, ed. P. G. Altbach (New York: Praeger, 1990).

24. For ecological research in Argentina, apart from the above references in note 23 see J. E. Rabinovitch, "Publications of Scientists in Developing Countries: National and International Production of Argentinian Ecologists," pp. 467-77, or R. Meneghini, "Brazilian Production in Biochemistry: International vs. Domestic Publication," pp. 457-65, in *Proceedings of the International Conference on Science Indicators*, Arvanitis.

capacity of the researcher's country and field. In tropical soil science, few truly tropically oriented research journals exist. Therefore, soils articles will be dispersed in a variety of journals, covering not only soil sciences but other agricultural sciences as well, which may be local agricultural periodicals. They also may appear in general science journals such as *Science* or *Nature*. This explains, in part, the different publishing patterns at national or regional levels. Some countries/regions have a high local writing capacity; these researchers will publish a higher percentage locally. For example, Asian and Latin American scientists publish more nationally than their African colleagues.

The presence or absence of a local publishing capacity, can be measured by what we term the fixation power of a country, that is, the proportion of studies published in a country that are carried out by scientists of that country. It is also an indicator of scientific autonomy. A fixation power ratio of 100% would indicate autarky. The best publishing situation is one that maintains a balance between inter national and national or local publications. Countries with a high fixation rate are those having a ratio of over 70%.

The fixation power ratios of the Netherlands (76%), Israel (26%), and Nigeria (6%) illustrate local publishing opportunities. When these ratios are low, scientists are publishing abroad (Israel and Nigeria). The 76% fixation power ratio attributed to the Netherlands, however, does not represent the contrary situation, because it is unlikely that this high percentage reflects the work solely of Dutch authors, but rather the fact that the country has numerous publishing possibilities for scientists from around the world; this also explains why the Netherlands has an extremely high attraction power, which is the proportion of articles produced by foreign authors in the total of journal articles published within a country. There may well be other factors at work. However, we believe that the respective position of each country is a deliberate choice to be part of the international publishing world or, on the contrary, to stimulate mainly national output, bearing in mind the two limitations, language and publication possibilities.

It is in these terms that the different positions of Brazil (77%), Egypt (71%), and India (35%) can be understood. Brazil and Egypt show a policy deliberately oriented toward national publication (note that Egypt publishes mostly in English); in contrast, India is probably more internationally oriented.

A second group of countries with a low fixation power include South Africa, Great Britain, New Zealand, Australia, India, Israel, and Nigeria. The case of Great Britain (55.8%) is of interest. While there exists a large number of English journals dedicated to soil science and tropical agricul-

ture, British tropical soil scientists seem to prefer publishing abroad. The United States is positioned in the middle, reflecting both its very powerful publishing capacity and the immense research that United States scientists perform. They are also important organizers of international meetings. These and the other reasons explain why 30% of United States production was published in non-United States journals.

Further distinctions can be made in looking at the type of work published. Soil microbiology is more internationally oriented than fertilization studies. In the agricultural sciences, we know that animal production seems more locally oriented than crop science.²⁵ Other studies seem to indicate that locally published research is not necessarily more applied.²⁶ The differing patterns of publication seem difficult to reduce into a dichotomy between applied and fundamental research.

The way soil science is studied and presented is a more workable distinction. A study titled "Some Aspects of the Action of Termites on Clays" has a more general character than a study on "Soil-slope Relation in the Lowlands of Selangor and Negri Sembilan, West Malaysia." Clearly, mainstream publications emphasize general work, rather than that which is specific to a locale. The question of when does a local topic become more universal is not easily answered. Most local descriptions of soils rapidly become the general inheritance of the discipline, as is the case, for instance, of andosols first discovered and described in Japan, then in New Zealand, and then in the rest of the world.

It is beyond the scope of this bibliometric study to analyze this dynamic.²⁷ Distinguishing general types of articles from those with more specialized topics seems more realistic than distinguishing papers of fundamental or applied research. We found the proportion of local to general papers to be very high for the Netherlands, France, and Great Britain, and less so for the United States and Germany. Two southern countries, Brazil and Nigeria, also have a high ratio of local to general studies, whereas New Zealand and Egypt are midratio and big producers, like India, Australia, and Israel have a higher proportion of general studies. These countries share a mainstream orientation.

25. Gaillard, *Scientists in the Third World*.

26. (a) Gaillard, *Scientists in the Third World*. (b) MacLean, "Citation Behaviour of Philippines Biological Scientists." (c) Eisemon, "Publication Strategies of Scientists in Four Peripheral Asian Scientific Communities." (d) J. E. Rabinovitch, "Publications of Scientists in Developing Countries," pp. 467-77. (e) R. Meneghini, "Brazilian Production in Biochemistry," pp. 457-65.

27. Some authors try to discover if there exists a general pattern of growth of the disciplines in bibliometric terms, for instance, Courtial and B. Michelet, "A Mathematical Model of Development of a Research Field," *Scientometrics* 24 (2) (1990): 123-38.

Analysis at the subject level in the discipline is instructive and corroborates these results. We studied the distribution of the world literary output by subject, and the many factors which influence this output. Some subjects in soils can be influenced by local ecological conditions (for example, research on dunes in Saudi Arabia). Portability of research is also important; many geographical studies on southern countries are done in European laboratories with the help of aerial photographs or satellite images and samples taken from the field.

Four of eighteen soils subjects in PASCAL have very high rates. These are fertilization (mineral and organic), microbiology of soils, superficial soil formation, and geomorphology. These tropical subjects each make up between 15% and 20% of the whole and are work done by developing countries. Others, like cartography and soil classification, soil conservation, satellite imagery and remote sensing, physical properties, and geomorphology, are done by developed countries. Tropical soil subjects with less research are soil pollution, uses of wastes, and hydroponic cultures. Interestingly, these are also subjects with little research production at the world level. The lack of local interest in the study of organic matter, which represents 13% of the world production, is more striking. It is a subject where there are many Russian studies which do not concern tropical areas. In 1964, Daniel Yaalon noted this Russian presence and the strong position of the United States on physical properties and mineral elements of the soil. The evidence seems to indicate that there is a lack of interest in this area in tropical agriculture. We must stress that our co-word analysis of the same literature showed that the two biggest poles of research, in terms of content, were nitrogen fixation and mycorrhiza, themes that clearly involve organic matter.²⁸ This is an analysis of the strength of relations between words used for indexing in several documents.

Third World countries choose subject categories that bear directly on their current agricultural needs, which confirms our observation that the pressure from government exerted on southern scientists is often strong and is reflected in the area of their work. A comparison of the tropical literature in microbiology of soils and fertilization illustrates these choices and the contrasting pattern of production of southern countries. Microbiology research is a subject with a high percentage of general studies in many foreign publications—this is a typical mainstream domain—but each country chooses to be more (India) or less (Brazil) a part of the mainstream. Much fertiliza-

28. Chatelin and Arvanitis. *Stratégies Scientifiques et Développement; Sols et Agricultures des Régions Chaudes* (Paris: ORSTOM Editions, 1988).

tion research is site-specific to local environments. Brazil ranks high in local studies published nationally.²⁹

Another way of understanding the scope of research in a country is to look at the keywords used to locate a document by its content. In Table 4.2 are reproduced the keywords that characterize 30% of the production for India, Brazil, and French-speaking countries (Belgium and parts of Africa and Canada, but excluding France). Each keyword is preceded by the number of documents in which it appears.

Indian production was indexed with 765 keywords and a total of 2,365 occurrences. Of these keywords, 2.5% allow access to a third of the sample and 8.2% of the words correspond to half the Indian documents. Proportionally, more keywords were used to index the Brazilian literature: 444 keywords and 1,154 occurrences. One can call up 30% of the Brazilian documents with 4.7% of the keywords; 13.5% of the keywords characterized half of the sample. There is an even wider span of themes in French literature. Some 668 keywords occur 1,218 times. A third of the sample can be characterized with 6.7% of the keywords, and half of it, with 15%.

Different strategies can be observed. For example, India has many studies on relatively few scientific subjects, Brazil has a slightly greater range, while French-speaking countries have the widest range. Indian keywords often indicated general interests; very few words point to regional or site-specific subjects. There were a few cartographic studies, some of natural formations. The main keywords indicated the names of plants and nitrogen fixation themes. Brazil also dealt with these subjects, but in a wider range of plants. There was also more emphasis on soils, and this tended to correspond to specific research besides nitrogen fixation or fertilization. In the French-speaking group, more emphasis was given to cartography, regional studies, satellite imagery, and local studies of natural environments.

However, using subject categories or keywords reveals little about the dynamics of research. We wished to examine in detail how the content of one publication is organized in relationship to the contents of a set of publications, which is done by co-word analysis. Fourteen thematical clusters were identified as the general orientation of research in 1983 in tropical soils and agriculture.³⁰ The list in Table 4.3 reproduces the names of the

29. The figures agree well with Velho's results on the production of four university research centers in Brazil (Velho, "The Meaning of Citation in the Context of a Scientifically Peripheral Country"), and with Y. Texera's results on Venezuela (Texera, "Publicación Científica: Análisis del Caso del al Agricultura Vegetal en Venezuela," *Interciencia* 7 (5) (1982): 273-78.

30. No automatic clustering method was used, rather we used the direct cartography of the network of keywords. The links are calculated by a simple equivalency indicator that calculates the ratio of the co-occurrence of a pair of words relative to the occurrence of each word of the pair. These indicators vary from 0 to 1 (or 0 to 100). The clusters chosen were the more frequent

Table 4.2. Top-ranked keywords constituting 30% of soil science literature within each geographic group

INDIA					
87	sol	37	oryza sativa	26	azote
77	plante céréalière	33	oligoélément	23	gramineae
45	Inde	32	nutrition	22	rhizobium
43	rendement	30	zinc	21	absorption
38	bactérie	29	phosphor	21	microflore
38	fixation azote	27	triticum aestivum	20	inoculation
38	plante légumière				
BRAZIL					
30	sol	14	nutrition	12	phaseolus vulgaris
26	plante céréalière	14	plante oléagineuse	11	aluminium
24	Amérique du Sud	13	oligoélément	11	glycine max
24	sol tropical	13	plante légumière	11	symbiose
22	sol latéritique	13	Zea mais	10	étude en serre
21	fixation azote	12	bactérie	10	plante fourragère
16	rendement	12	fertilisation azotée		
FRENCH-SPEAKING COUNTRIES					
51	sol	7	algérois	5	forêt
23	zone tropicale	6	argile minéral	5	Guyane française
12	agriculture	6	climat	5	inoculation
11	classification	6	donnée MEB	5	karst
11	Sénégal	6	ERTS Landsat	5	milieu aride
10	Afrique	6	morphologie	5	morphologie volcan
10	morphodynamique	6	plante fruitière	5	mycorhize
10	sol tropical	6	symbiose	5	occupation sol
9	cartographie	6	végétation	5	pédogenèse
9	fixation azote	5	analyse image	5	plante céréalière
8	microflore	5	Antilles	5	plante oléagineuse
7	Afrique ouest	5	bactérie	5	sol sableux
7	satellite Landsat	5	classification super- visée	5	structure sol
7	télé-détection	5	écologie	5	végétal
7	télé-détection multispectrale				

keyword in a group of words linked to each other at a quantitative level. For details on this methodology see (a) M. Callon, Courtial, W. A. Turner, and S. Bauin, "From Translations to Problematic Networks: An Introduction to Co-Word Analysis," *Social Science Information* 22 (2) (1983): 191-235; and (b) Courtial, *Introduction à la Scientométrie* (Paris: Anthropos, 1990).

Table 4.3. Fourteen thematic co-word clusters (A-N) with keyword associations

Nitrogen Fixation [A]	Environmental Management-Development [J]
Legumes, forage	Pollution [K]
Mycorrhiza [B]	Water-Erosion, Erosion [L]
Nitrogen Fixation [A]	Soil Chemistry [E]
Nitrogen cycle	Cations exchange
Forest Ecosystems [C]	Acidification
Tropical rain forests	Soil and Nutrition/Fertilization [D]
Aforestation	Tropical soil
Agroforestry	Organic Matter [M]
Nutrition-Fertilization [D]	Medicinal Plants [N]
Oligoelements	Nitrogen Fixation [A]
Phosphor	Enzymatic activity
Soil Chemistry [E]	Soils [G]
Complex exchanges	Mineralogical clays
Tropical Crops [F]	Tropical Crops [F]
Cereals	Industrial cultivation
Soils [G]	Agriculture-Development [J]
Alteration	Nitrogen Fixation [A]
Amendments	Rhizosphere
Profiles	Tropical Crops [F]
Morphodynamics [H]	Oil plants, fruits, fibre
Karst	Pastures
Desertification	Fertilization [D]
Soils [G]	Green manure
Cartography	Nitrogen Fixation [A]
Teledetection [I]	Anabaena azolla

clusters (represented by clusters A through N) and the principal keyword associated with them, by decreasing order of appearance. This is a simplified representation that does not reproduce the rich complexity and thematic links. The first clusters can be considered core research (nitrogen fixation, mycorrhiza, forest environments, fertilization), while the last ones are more marginal but sufficiently coherent in the sample to appear as newer research interests (green manure, *Anabaena azolla*). The main clusters indicate that research is oriented toward biological factors effecting soils and their relation to soil characteristics and agricultural development. It is interesting that classic soil science nestles between the core subjects and the new.

In summary, the following observations about disciplinary interests are deduced. On the whole, northern countries have a rather equally distributed tropical research effort in all subject categories, with some emphasis on geomorphology and pedogenesis. The distribution of research in the south and in the periphery show an emphasis on fertilization and microbiology;

the south accentuates these topics proportionally more than does the periphery. This is a slightly different view of the south doing mostly what their Northern counterparts are doing. These are clear and conscious choices on the part of southern countries. This does not mean there is no influence from the north. Types of work done in the north often appear elsewhere later, set in a southern context. There is a close relationship between the work of northern and southern scientists in some countries. One case is French-speaking African researchers who publish in the same areas as French soil researchers but with a higher proportion of fertilization studies from the African countries. We find proportionally higher citations in the French-speaking world to those subject areas that are less well represented in other southern and periphery countries. France and French-speaking countries seem to have chosen different ways of approaching soil research.³¹

Another factor which obviously plays an important role in publication is language. Although English is essentially the *lingua franca* of science, many researchers evaluate the cost of translation against the need to have access to the literature in English. This is especially true for the non-English-speaking world, which has numerous publication opportunities of its own, even if these are less well distributed than the journals written in English. India has an English-speaking scientific community and publishes regularly in mainstream journals. Brazilians publish more in Portuguese than English. In former French colonies which are independent countries today, scientists publish mainly in French, tend to avoid the English-speaking mainstream and may constitute a French-speaking mainstream.³² The natural attraction to the linguistic precursor of the former colonial power certainly plays an important role.

In tropical soil science, English represents 75% of the total citations, followed by French (10%). Surprising is the relatively strong position of

31. These results suggest a need to study the international research collaborations as well as the impact of strong scientific countries on smaller and newer ones. Some research is beginning to appear on this topic: (a) N. Narvaez-Berthelemot, L. P. Frigoletto, and J. F. Miquel, "International Scientific Collaboration in Latin America," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis; (b) J. El Alami, J. C. Doré, and Miquel, "International Scientific Collaboration in Arab Countries," in *ibid.*; (c) M. T. Fernández, A. Agis, A. Martín, A. Cabrero, and J. Gómes, "Cooperative Research Between the Spanish National Research Council and Latin American Institutions," in *ibid.*; and (d) F. W. Lancaster and S. Abdullah, "Science and Politics: Some Bibliometric Analysis," in *ibid.* Currently, our team at ORSTOM is researching scientific collaborations between European and Third World laboratories forged by the Science Technology and Development Program of the European Communities in Tropical Agriculture and Tropical Medicine.

32. This is suggested by D. Pillot in *Francophone and Anglophone Farming Systems Research: Similarities and Differences*; keynote address to the Fourth National Seminar on Farming Systems (Thailand, Prince of Songkla University, 1987). Rather than a cultural or linguistic difference between the French and English farming systems research, it appears that different approaches are promoted by different types of research institutions.

Portuguese/Brazilian (7%), and the low 5% for Spanish. This may reflect a poor coverage of Spanish-speaking countries in the database, though PASCAL has a reasonable coverage and even has a Spanish keywords section. The most probable explanation is the Latin American tendency to publish in very local publications. Velho claims that this is certainly the case with Brazil, but, as our figures show, it affects the Spanish-speaking American countries more than Brazil.³³ French stands at 10%, in part because of work done by institutions like ORSTOM and CIRAD, along with French-speaking African countries.

In conclusion, the factors affecting the publication pattern of scientists are diverse. The most important appear to be

- (1) the existence of a local publishing capacity,
- (2) the type of research results that are published,
- (3) the subfield of a science that is the subject of research, and
- (4) the ability to publish in English (and to a lesser extent French) versus national languages.

E. On the Structure of Scientific Communities

These criteria are reflected in the way scientific communities are structured. This hypothesis needs to be tested by further bibliometric and sociological studies. Some disciplines are more centrally organized, with the center in rich countries; others are more decentralized, with strong regional/national networks. International relationships are a basic element in understanding the scientific literature of a discipline. A good scientific community is one that manages its relations intelligently within the international arena and with the mainstream.³⁴

An implicit assumption in bibliometric studies such as this is that science is disseminated mainly through the literature, although there is a more complex configuration. Science is also spread through informal communication channels and oral communication, along with publications. This is true in developing countries where scientists are less pressed by the "publish or perish" dogma, and evaluation of research is based less on publication.³⁵

This does not imply that most tropical scientists are less professional in

33. Velho, "Science on the Periphery."

34. R. Waast, *Proceedings of the Seminars on the Emergence of Scientific Communities in Developing Countries: Algeria, Brazil, India, and Venezuela* (Paris: ORSTOM Editions, 1980).

35. (a) Velho, "The Meaning of Citation in the Context of a Scientifically Peripheral Country."
(b) Lomnitz, M. W. Rees, and L. Cameo, "Publication and Referencing Patterns in a Mexican Research Institute," *Social Studies of Science* 17 (1) (1987): 115-33.

the world of academia. Careers are based not only upon an ability to teach and subject expertise, but often upon national political abilities, which are as important as professional research capacity.³⁶ Brazilian scientists are not keen on distinguishing between their roles as research scientist and professional in society,³⁷ and national politics play a much more important role than for scientists in industrialized countries.³⁸

Such factors help to explain the importance of communication at scientific meetings, congresses, and symposia, which represented 15% of the total references. The highest figure for a southern country was 41%. Southern and periphery countries made up 52% of all the papers at congresses. PASCAL indexes the published proceedings of conferences which reflect participation by Third World scientists. Our experience in Africa and Latin America, however, confirms that the diffusion activity of our Third World colleagues is often through participation in scientific meetings. It is also through participation at these meetings that scientists and their countries acquire international standing and visibility. Third World countries are beginning to participate heavily in a diversity of scientific enterprises, which will place them more and more as equal partners in a wide span of research activities. This should result in national scientific communities, while internationalizing the scientific norms of behavior which are common to all researchers.³⁹ Bibliometrics cannot measure the latter process, but some indicators clearly suggest the process has begun. One of them is the analysis of coauthorship. The studies of D. de Beaver and R. Rosen indicate that collaborative research enhances productivity, and that collaborative research is growing.⁴⁰

In our soil production sample, Third World countries had high numbers of authors per article (2.48 authors for India; 2.79, for Brazil). European countries, by contrast, had a low number, 1.48 to 1.63. With the exception of South Africa, all periphery countries and the United States are in the

36. (a) Argenti, "From Standardization to Relevance and Back Again." (b) Schwartzman, "Coming Full Circle: For a Reappraisal of University Research in Latin America," *Minerva* 24 (4) (1986): 456-75. (c) Vessuri, "El Proceso de Profesionalización de la Ciencia Venezolana: La Facultad de Ciencias de la Universidad Central de Venezuela," *Revista Quipu* (Mexico) 4 (2) (1988): 253-84. (d) Vessuri, "La Formación de la Comunidad Científica en Venezuela," in *Ciencia Académica en la Venezuela Moderna*, ed. Vessuri (Caracas: Fondo Editorial Acta Científica Venezolana, 1984).

37. Schwartzman, *A Space for Science*.

38. Botelho, "Far from Silicon Valley: Give Me a Laboratory and I Will Not Raise the World," presented at the XVth Annual Meeting of the Society for the Social Studies of Science (Minneapolis, Minn., 1990).

39. Fortes, *La Formación del Científico en México*.

40. D. de B. Beaver and R. Rosen, "Studies in Scientific Collaboration, Parts I-III," *Scientometrics* 1 (1-3): 64-84, 133-49, 231-45, 1978-79.

middle, with their number of authors ranging from 2.1 to 2.2. The striking figure is that of the big Third World producers India, Egypt, and Brazil. One can note an historical and somewhat anomalous process: the older countries (Europe) have the lowest number of coauthors, followed by the first peripheral countries (United States, Australia) and the younger countries, which all belong to the Third World.⁴¹ The factors which have created this anomaly are complex and deserve further investigation.

F. Changing Our View of Scientific Production

It appears that new scientific communities are emerging with their own agendas and functions. This is important in the assumption that research will solve development problems. We now know that this is not necessarily the case. There is a need for the strengthening of local scientific communities which are incipient in many countries, especially in Africa.⁴² Few simple ways of knowledge or other international technology transfers between north and south exist,⁴³ and little internal technology transfer, from laboratories to the productive sector.⁴⁴ Stronger scientific communities in the south mean stronger involvement in fundamental science. The assumption that developing countries mainly publish in areas of applied science is not wholly accurate. Some countries are dedicated to themes bearing directly on agriculture, but they do not seem to limit themselves to the applied aspects.

Scientific knowledge cannot be truncated in small bits with basic research on the one hand and applied on the other. A research problem is defined as being of interest, and, within that problem, scientists will eventually occupy all types of research. Scientific research is a process, not merely a production activity, which policymakers often overlook when urging scientists to

41. This is also the conclusion of Velho, "The Meaning of Citation in the Context of a Scientifically Peripheral Country," and of other studies on the institutionalization of research in Third World countries. See, for example, the articles in Vessuri, "El Proceso de Profesionalización de la Ciencia Venezolana." We disagree with the argument that coauthors in the developing countries are more numerous because every single member of a lab signs an article written by only one scientist. No figures assert such practices. But developed country scientists publish relatively more articles in common with foreign colleagues.

42. Gaillard, "La Recherche Scientifique en Afrique."

43. A. Rath, "Science, Technology, and Policy in the Periphery: A Perspective from the Centre," *World Development* 18 (11) (1990): 1429-43.

44. (a) Argenti, "From Standardization to Relevance and Back Again." (b) A. Pirela, R. Reingifo, and Arvanitis, "Vinculaciones Universidad-Empresa en Venezuela: Fabula de Amores Platonicos y Cicerones," *Acta Científica Venezolana* 42 (1991): 239-46. (c) J. Ruffier, "Pensar la Modernización de la Industria Uruguaya," in *Uruguay: El Debate Sobre la Industrialización Posible*, ed. G. Argenti (Montevideo: Ciesu/Ediciones de la Banda Oriental, 1991), pp. 13-49.

do applied research.⁴⁵ Let us give an example which is particularly interesting. In a previous study, a research program of the legume *Canavalia*, we found a large body of literature on the biochemistry of the plant's toxicity. Not until there existed a coordinated research program on the plant did Venezuela begin to study its biochemistry in order to understand the nature of its toxic elements and ways to eliminate or neutralize them. Some dozen years of research were needed to understand all the aspects involved in the management of the plant. Ten years earlier, a United States laboratory had worked on biochemical methods involving the toxins of the plant, particularly one toxic chemical. Of course, the Venezuelan laboratory used the results of the United States laboratory, but can we really talk of a transfer of knowledge? We believe this is not the case, even if the Venezuelan laboratory used some of the methods and results of the United States laboratory, the Venezuelan research was very different: in the case of the United States, the plant was used as a laboratory specimen, in the other it was the transformation of the plant itself that was of interest.⁴⁶

In summation, the question of scientific literary output in developing countries is sometimes obscured by the views of the north and by an obsolete conception of how science evolves.⁴⁷ We too often evaluate developing countries' scientific production only by the small share of published research that is indexed and made available in the north.⁴⁸ Scientific communities of the south are not necessarily governed by the same criteria as the north, but are characterized by informality and their merger of research with other activities. The dynamics of scientific research, basically so different in the south, are a major factor. A new appraisal of the scientific production in developing countries is needed using valid bibliometric studies.⁴⁹ The questions then become: what determines that a topic is "researchable?" What orients the interests of the scientists in the south toward new areas of

45. Arvanitis, *De la Recherche au Développement*.

46. Arvanitis and T. Bardini, "Analyse d'un Programme Pluridisciplinaire par Deux Méthodes d'Analyse de Réseaux: Le cas du Groupe de Recherche sur *Canavalia*," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis.

47. Sociology of science has changed our view. See B. Latour, *Science in Action* (Open University Press, 1987). For applications of a new conception of science in the policy and management of research, see D. Vinck, ed., *Gestion de la Recherche. Nouveaux Problèmes. Nouveaux Outils*, (Brussels: De Boeck Professional Publishing, 1991).

48. For an example, see S. Arunachalam and U. N. Singh, "Access to Information and the Scientific Output of India," *Journal of Scientific and Industrial Research* 51 (1) (1992): 99-119.

49. (a) S. Thomas, "The Evaluation of Plant Biomass Research: A Case Study of the Problems Inherent to Bibliometric Indicators," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis. Thomas has shown that, in the case of biomass research, neither publication, in peer reviewing, is, by itself, an appropriate instrument for the evaluation of the impact of research. (b) Arvanitis and Gaillard, "Pour un Renouveau des Indicateurs de Science pour les Pays en Développement," in *Proceedings of the International Conference on Science Indicators*, ed. Arvanitis.

research? How do northern and southern research teams cooperate? These and other important questions can perhaps be examined by bibliometric analysis. Obviously, more work needs to be done on these topics, with the close participation of divergent disciplines including sociology, soil sciences, economics, and other agricultural sciences.

Appendix. Construct of the Bibliometric Database for Analysis of Tropical Soil Sciences

All documents were extracted from the 1983 *Bulletins Signalétiques* (No. 226 and No. 381) of the PASCAL database in the following categories:

Bulletin Signalétique No. 226:

Formations superficielles

Géomorphologie

Sols

Bulletin Signalétique No. 381:

Généralités

Comptes-rendus généraux, rapports d'activité, congrès, bibliographies

Méthodes et techniques diverses

Télétection

Sols, Agronomie générale

Généralités

Techniques et méthodes d'analyse

Cartographie des sols

Classification des sols

Pédogenèse

Physico-chimie du sol

Éléments minéraux, oligo-éléments, propriétés ioniques et d'échange

Matière organique, évolution de la matière organique, complexe argilo-humique, cycle de l'azote et du carbone

Propriétés physiques

Structure et texture, densité, comportement mécanique, échanges gazeux et thermiques

Dynamique de l'eau et des solutés (état et transfert)

Microbiologie des sols, enzymes du sol, interactions microorganismes-végétaux

Fertilisation minérale et organique, nutrition

Généralités

Diagnostic foliaire

Fertilisation des différentes cultures

Fertilisation azotée

Fertilisation potassique

Oligo-éléments

Utilisation des déchets solides et liquides

Maladies de carence, toxicité
Pollution du sol
Amendements et engrais minéraux divers, correction de pH
Amendements et engrais organiques
Substrats artificiels, hydroponie, fertilisation par CO₂
Relations sol-plante
Conservation des sols, érosion
Potentialités, aménagement du territoire

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THE LITERATURE OF SOIL SCIENCE

EDITED BY

Peter McDonald

Cornell University Press

ITHACA AND LONDON

19 FEV. 1996

O.R.S.T.O.M. Fonds Documentaire

N° : 43232
Cote : B ex 1 P23

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010003927