• *ABSTRACT*

A bibliometric analysis of the publications on tropical soils and agriculture shows that different strategies can be found across countries, in the way scientists publish and disseminate their results, choose their research topics (fertilization and microbiology of soil being the research priorities in the Third World), and distribute their effort across fields. We propose some indicators measuring these orientations, and a reconsideration of the data sources used in the evaluation of research activity in the Third World, and of the influence of the North on the South, since we have found that Third World production is substantially higher than is usually estimated. Finally, we indicate some guidelines for policy definition in the light of these results, focusing on the necessity of an active and mobile scientific community, and of more important communication between scientists working in similar ecological environments.

National Scientific Strategies in Tropical Soil Sciences

Rigas Arvanitis and Yvon Chatelin

There is wide agreement that Third World countries ought to change the direction of their science policies. Until now the main emphasis has been on creating a scientific and technological potential, whatever the directions of the research done in the country's scientific institutions. The result has, indeed, been an increase in scientific manpower, the creation of research institutions and the creation of a science policy bureaucracy in almost every country in the world. As Hebe Vessuri puts it, the main challenge in the years to come for Third World countries will be to define a scientific and technological policy that responds to the needs of the population and to the needs of the local productive sectors. This will also be the way to create a really autonomous scientific community.[1]

Many efforts have to be undertaken in order to meet this challenge.[2] In our judgement, it is necessary radically to change our view of what science actually *is* in the developing world.[3] Science in these countries is generally said to be weak and unimportant, with scientists mostly interested in what happens in the United States or Europe. To a certain

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point this is true, as many studies on the information flows between the 'periphery' and the 'centre' have shown. It is also true that these countries experience budgetary and organizational difficulties.[4] But, at the same time, an increasing amount of their research has been dedicated to national needs. Our argument is that this research cannot possibly be seen when using the traditional criteria of 'mainstream' science, not because it is 'bad' science, but more simply because the scientists choose a way of publishing and disseminating the information that does not accord with the criteria of 'mainstream' science.

We will show in this paper that Third World countries adopt different strategies from those of the developed countries — that is, different thematic orientations and different ways to treat science and to disseminate its results.[5] We also want to show that the research orientations are chosen by the Third World countries themselves.

Third World countries have been credited with around 6 percent of the world's scientific production.[6] Whatever the bias in the data, this effectively shows a disequilibrium between the South and the North. But, as we will show, this figure does not seem realistic. The main bias comes from the databases used in evaluating the scientific production of Third World countries. Most, if not all, of the studies on the world distribution of scientific production are done by using the *Science Citation Index* (*SCI*) database of the Institute of Scientific Information (ISI).[7] This multidisciplinary database is very selective (3200 journals in a world total estimated at about 70,000). The problem is not selectivity by itself: one has to choose. Rather, it seems that the bias is strongly in favour of centrally located scientific communities, writing in English, in particular in the United States. That makes the *SCI* a valuable instrument for the evaluation of scientific research in the US, but not in the Third World — nor, as some argue, even in Canada.[8] This situation becomes critical with Third World countries. Brazil, for instance, has 149 scientific reviews and the *ISI* database has only four Brazilian reviews.[9] Argentina, Mexico and Venezuela were represented in this database by four, three, and two journals respectively.[10] Only 2 percent of *SCI*'s journal coverage is published in the Third World (counting the two main scientific producers, India and Brazil). One cannot be surprised to learn that the US produces 40 percent of the international production and receives 60 percent of the citations, or that 80 percent of the world scientific production is written in English.[11]

No database can be exhaustive. But the majority of databases constructed purely for scientific reasons (and not for bibliometric uses) do have a satisfactory coverage.[12] In fact, we will use a large French multidisciplinary database, PASCAL, less biased towards English. Our sample will thus be of a different size and nature than what is usually labelled as 'mainstream'.[13] As is the case with studies on different bodies of literature, we have obtained results that contradict those of *ISI*-based analysis.[14] Rabkin and Inhaber recognize that 'the tools we used are clearly biased in favour of central nations', and they add that 'because there has not been developed a better tool for evaluating world science, we had to use those sources'.[15] We hope to demonstrate that this is not the case, and that the focus on mainstream science systematically bypasses the really important questions that should be answered when speaking of Third World science. As we claim in the concluding remarks, to deal with the Third World one has to solve conceptual issues, rather than statistical ones.

Definitions and Method

We limited our study to *soil sciences* and agriculture. This choice was dictated by our previously presented position that in order to measure the scientific effort of a country, one has to do so according to the country's needs. Agriculture is central to the vast majority of tropical countries, and these sciences are central to the issues of development, as can easily be understood by the recent food and agricultural problems the Third World countries are facing.[16] We also think that no generalizations about science are possible: the strategies of a physics community would be very different from those of an agronomic or soil sciences community. The chosen area of 'agricultural sciences' is here understood in a restrictive sense; we did not include such disciplines as agricultural engineering, agricultural economics, food sciences, entomology, and the like. Similarly, we did not include all kinds of work linked to animal production. Our choice may appear arbitrary, but it corresponds to the image of what is commonly called the 'agricultural vegetal sub-sector'. Its unity is given by the common conception that practically all agronomists, soil scientists, policymakers and social scientists adopt in their everyday work.[17] At a more disaggregated level, disciplinary boundaries are a matter of discussion among scientists; we therefore chose as a practical and operational criterion the classification of the bibliographic database, PASCAL, taking into account all classes used in a bibliographic search by a soil scientist on soils and agriculture (see Appendix).[18] This allows a rough approach to the very content of the sciences.[19] As we will show, scientific strategies vary not only between countries, but also between disciplines, or according to subject matter.[20]

Agricultural sciences are 'atypical', because they do not fit the 'mainstream' concept. Some of the agricultural sciences, if not all, are of a more local interest. As an applied science (or rather group of sciences), its public is certainly less international than, say, physics. But there is still a very large possibility of international exchange, as is demonstrated by the very existence of the International Agricultural Research Centres, and also by the growing cooperation between scientists of different countries.[21] In the *ISI* database, none of twenty-five high-impact journals deals with either soils or agriculture. In fourteen journals giving high citation impacts to Third World authors, none is in these fields. And, of course, none of the twenty-three most cited articles written by Third World scientists concern agriculture. Also, as a general trend, agricultural scientists in most of the Third World countries tend to write more easily in journals published by their own institutions, which in many cases are institutional or extension bulletins of sparse circulation.[22]

Our knowledge of agricultural sciences is limited, even in developed countries. In studies of overall scientific production, this domain is rather difficult to delimit. For instance, Frame, Narin and Carpenter use 'Biology' as one of their eight fields of science.[23] Developed (OECD and Eastern European) and Third World countries produce respectively 10% and 13.06% of their research in this field. But agriculture is only a part of 'Biology', and most studies do not identify it. Research specifically oriented to the understanding of agricultural sciences is rather rare.[24]

Agricultural sciences occupy an important share of scientific activity, especially of Third World countries. Davis shows that agronomy represents 22.3% of sub-Saharan scientific production, nearly as much as biology (22.4%) but less than medical sciences (38.2%).[25] These publications receive only 14.5% of the citations to the sub-Saharan group of countries. In a small country like Venezuela, agricultural sciences cover 21% of scientists and engineers. This compares well with the exact sciences (physics, chemistry, mathematics, biology), which comprise 28%, medical sciences 15%, and engineering 17%.[26] We chose agricultural sciences for some other reasons too. One of us (YC) is a soil scientist, and could check the content of the literature. Also, since we are French, we wanted to evaluate the French participation in sciences relevant to tropical areas. As other studies show, and as everyone knows, French research in developing countries (and particularly in Africa) is quite important. ORSTOM and CIRAD (ex-GERDAT), two French research institutions working in tropical areas, mainly in agronomy and related disciplines, are responsible for 6.7% of the *ISI*-identified literature in sub-Saharan countries.[27] France also has an important agricultural

sciences community, writing in French. Ginette Gablot, on the basis of the literature indexed by the PASCAL database, finds that in agronomy, in the 1975–80 period, articles written in French (by French, Francophone or, more rarely, foreign authors) represent between 12% and 18% of total agronomical research.[28] This figure is substantially higher than in other domains, where it can fall as low as 8 percent.

We chose to work on the basis of the publications indexed by PASCAL (about 600,000 references by year) because of its good coverage of French theses, US PhDs, books, articles and congress proceedings, and because of its accessibility.[29] Since agricultural sciences are a 'French specialty', PASCAL, with its more accurate description of the French-speaking world, seems a better choice than any of the specialized databases in agriculture.[30] The bibliography has been drawn from eighteen categories in the classification scheme of PASCAL (shown in the Appendix). We limited ourselves to one year: 1983. This year has been chosen in order to have a full coverage of world production, as understood by PASCAL criteria, and not to include one of the major international scientific meetings that would modify the 'normal' scientific production.[31]

We also cross-checked, and made an additional selection of, the publications manually (or should we say 'visually'?). It seems to us that in order to collect both the publications concerning Third World countries (in our case the criterion was tropical areas) and the production of Third World scientists, one has necessarily to proceed manually, even though one can work on an on-line database. This is mainly because of the cooperative nature of scientific work. Databases retain only the affiliation of the first author. Thus, a paper having a Third World scientist as second or third author will not be identified by automatic interrogation. This becomes crucial if, as in our case, one wants to evaluate the cooperation between Third World and central countries. Another reason for this manual search is that there exists a substantial number of studies that cannot be identified as 'tropical' by just looking at 'Authors' affiliation', 'Publishing country of the journal', or name of the country in the 'Keywords' fields. But one can identify documents that mention a tropical soil or a tropical plant in the Abstract or Keyword section. Manual content selection is a high cost method, but the only one that avoids the undercoverage of Third World science, and that clearly serves our analytical objectives.

We grouped the publications in three categories corresponding to geographical and cultural areas:

(i) publications authored by scientists in Northern countries (hereafter the *North*) — that is, North America, USSR and Europe;

(ii) publications authored by scientists in large peripheral countries (the *Periphery*). New Zealand, Australia, Israel, and South Africa, are 'new' countries, culturally similar to the central countries, which have a highly developed scientific community and a mainly tropical or sub-tropical ecological environment. These countries also share another common characteristic: their real production of publications surpasses the production one would expect using an economic criterion, such as the National Product.[32]

(iii) publications authored by scientists in the Southern countries (the *South*) — that is, the rest of the world belonging to tropical areas. The two biggest producers in the South are India and Brazil.

It should be clear that our analysis is limited in scope and time. Because of their bad coverage by PASCAL and obvious (for us) linguistic problems, we did not retain Japan and China in further analysis. It is also probable that Asian countries are badly covered by the base.[33] Moreover, most of our comparative work retains only the fourteen biggest producers, covering more than 30 of the 1983 publications. Finally, a wider time span would have allowed us to analyze changes that occur in the strategies of each country and within disciplines. This article is a first approach to a problem that seems very much forgotten by the scientometrics literature: the use of science not only *of* developing countries but also *for* developing countries.

Findings

Agricultural sciences in 1983 were represented by 9398 references in the PASCAL database, in those sections that we selected. Of these, 2040 references (21.7%) concerned a tropical environment or a tropical country. Table 1 shows the distribution of this production by areas. The South produces half of the research on tropical areas — that is, 11% of the total of world research in agricultural sciences. This figure surpasses the traditional 'near to 6%' usually admitted for Third World countries. The Periphery produces about a quarter of tropical agricultural research, and the North a little less. The 'Others' represent difficult-to-identify references, anonymous items, affiliation to international institutions, and so on.

The linguistic distribution is shown in Table 2. English represents three quarters of the production, which is not a surprise. On the contrary, the strong position of Portuguese (all Brazilian references), and the low percentage for Spanish, is surprising. This may reflect a poor coverage of

TABLE 1
Origin of Publications on Tropical Agricultural Sciences

North	420	21%
Periphery	536	26%
South	1042	51%
Others	42	2%
Total	2040	100%

Spanish-speaking countries, although PASCAL has a quite good coverage, and even has a 'Spanish keywords' section. The most probable explanation is the Latin American tendency to publish more in very local publications. Velho claims that this is the case for Brazil, but, as our figures show, it affects the Spanish-speaking American countries more than it does Brazil.[34] French has a relatively high proportion, which reflects the French work done mainly by institutions like ORSTOM and CIRAD, and by French-speaking African countries.

TABLE 2
Linguistic Distribution of Tropical Agriculture Research

English	1530	75%
French	204	10%
Portuguese	143	7%
Spanish	102	5%
German	20	1%
Others	41	2%
Total	2040	100%

Scientific Production

In Table 3 we present the result of our computations in all three groups of countries. France appears as the most importantly active country in the tropical areas, followed by the USA. Of course, PASCAL has a bias in favour of France. Nevertheless, given the magnitude of the difference, and considering the quality of the coverage of foreign European and North American publications, we think that this dominant position reflects a real situation. Relative to the number of inhabitants or to the national product (or whatever other indicators), this position would be even more important. One might wonder about the very low position of Great Britain compared to Germany, that did not have an empire. As we will see,

TABLE 3
Publications on Tropical Areas by Country[35]

Country	Publications	% to subtotal	% to total
France	133	31.7%	6.7%
United States	116	27.6%	5.8%
West Germany	41	9.8%	2.1%
Great Britain	34	8.1%	1.7%
Holland	29	6.9%	1.5%
USSR	17	4.0%	0.9%
Belgium	14	3.3%	0.7%
Spain	11	2.6%	0.6%
Canada	6	1.4%	0.3%
Other Northern	19	4.5%	1.0%
Total North	420	100.0%	21.0%
Australia	280	52.2%	14.0%
New Zealand	143	26.7%	7.2%
Israel	74	13.8%	3.7%
South Africa	39	7.3%	2.0%
Total Periphery	536	100.0%	26.8%
India	303	29.1%	15.2%
Brazil	183	17.6%	9.2%
Egypt	98	9.4%	4.9%
Nigeria	65	6.2%	3.3%
Argentina	46	4.4%	2.3%
Philippines	26	2.5%	1.3%
Chile	21	2.0%	1.1%
Taiwan	20	1.9%	1.0%
Mexico	17	1.6%	0.9%
Senegal	16	1.5%	0.8%
Cuba	16	1.5%	0.8%
Others	231	22.2%	11.6%
Total South	1042	100.0%	52.2%
Grand total	1998		100.0%

Britain's contribution to the Third World lies more in the publishing opportunities it offers than in the fieldwork itself. Also very striking is the absence of East European countries. These countries seem to be very much oriented toward the study of non-tropical plants and soils. Of the eighteen Russian references, seventeen were in a Russian journal: the majority of them were general discourses about soil sciences in the tropics, not empirical studies. We should add that PASCAL has quite good coverage of Russian publications, which are very much used in other areas of the soil sciences. This also reflects a real situation.

The countries of the Periphery (essentially Australia and New Zealand) occupy a very distinctive position. Dan Yaalon has said that 'Australia is the paradise of soil scientists'.[36] In another of his studies, he explains the more advanced research of USSR, Canada and Australia in geochemistry, as compared to the United States, by some economic considerations.[37] These countries need this type of research in order to exploit effectively their impressive and largely unknown natural resources. The very high presence of the Periphery group of countries also lies in an artefact of our study. We have computed all of the research done by these countries (as in the case of Southern countries), and this inflates, proportionally to the North, the importance of their production. Moreover, there is virtually no research done by Australians, New Zealanders, Israelis or South Africans outside their own countries. This implies, as a rule of method, that the production of the North cannot be compared with that of the Periphery or the South, but that a comparison between Periphery and South is valid; this is also true because of similarities in the natural environments of the Periphery and the South.

As far as Southern countries are concerned, we have already mentioned their importance as a whole in agricultural sciences and, in particular, in tropical agricultural sciences. We were not surprised to see India rank first, far ahead of Brazil and Egypt. Overall our ranking seems to correspond to the image one can draw even with a superficial knowledge of what happens in agricultural sciences in tropical areas. We have to mention the absence of some quite important countries: Algeria, Madagascar, and the Sudan, for instance. These seem to have more difficulty in becoming 'visible' outside their frontiers.[38] Almost all the countries that fall below thirty publications seem to be under-represented (with the exception of Senegal).[39]

Publication Pattern in Tropical Agricultural Sciences

In order to study the publishing strategy of each country, we used first the concept of 'fixation power' — that is, the proportion of studies

published in a country that are carried out by the scientists of this country.[40] This fixation power is one of the indicators of scientific autonomy. A fixation power ratio of 100% would indicate autarky. Probably the best publishing policy is one that maintains a balance between international and national publications. We have computed this figure for each of the fourteen countries with a significant number of publications. The results are presented in Table 4. A first group of countries

TABLE 4
Fixation Power of Fourteen Countries in Tropical Agricultural Sciences — 1983

France	92.4%
Brazil	77.5%
Holland	75.8%
West Germany	73.1%
Egypt	71.4%
Argentina	69.5%
United States	68.1%
South Africa	58.9%
Great Britain	55.8%
New Zealand	50.3%
Australia	43.9%
India	34.9%
Israel	25.6%
Nigeria	6.1%

is composed of those having a ratio of over 70% (including Argentina's, very near to the 70% ratio). All these countries are *not* English speaking. On the contrary, all the other countries of the list are English speaking or have easy access to English. A high fixation power accompanied by high institutional production could be an indicator of 'inbreeding'.[41]

The cases of Holland, Israel and Nigeria oblige us to add another factor in order to explain their ratios: countries with very small local publishing opportunities are obliged to publish abroad (Israel and Nigeria). Holland illustrates the contrary situation because it has, on its territory, numerous publishing possibilities; this also explains why Holland has also an extremely high attraction power (see Table 12, below). There may well be other factors at work. But we believe that the respective position of each country in Table 4 is a deliberate choice either to be inserted in the international production or, on the contrary, to stimulate mainly national production, bearing in mind the two limitations, language and publication possibilities.[42]

It is only in these terms that the different positions of Brazil, Egypt and India can be understood. Brazil and Egypt show a policy deliberately oriented toward national publication (note that Egyptians publish much in English); on the contrary, India is more internationally oriented. Argentina's figures are more ambivalent. Its similarity with the US figure should not induce a rapid comparison between those two countries because of the size of their respective production (see Table 3), and also because as a rule of method the productions of the South and Periphery should not be compared to that of the North.

In the second group of countries, composed of those with a low fixation power, the case of Great Britain is particular, because, while there exists a large number of British journals dedicated to soil sciences and tropical agriculture, British scientists seem to prefer publishing abroad. The USA had a medium position, reflecting both its very powerful editorial policy and the large portion of this research that US scientists perform. Americans are also important organizers of international meetings. All these reasons explain why 30% of US production was published in non-US journals.

Communications to Scientific Meetings

As we have already said, a very high fixation power could indicate a high degree of insularization. We think this is partially true. In fact, this figure should be compared with the participation at international meetings, which is the most obvious form of communication at an international level. Communications to congresses represent 15% of our database; they are not quantitatively the most important type of documents (79% are articles, and 6% are books and other items). Still, this share of publications is the best indicator of 'visibility' at an international level.[43] We recall that there was no congress of any of the big international scientific associations in the year we studied (Table 5). We must stress the

TABLE 5
Share of Communications to Congresses by Region

	South	Periphery	North
1. Total scientific production	51%	26%	21%
2. Communications in congresses	41%	23%	34%
Ratio 2/1	0.80	0.88	1.61

fact that PASCAL has a good coverage of international meetings, though it is difficult to assess the internationality of all the congresses through the references. Moreover, the North's share is inflated because this figure covers both communications to a congress and the country which organized the congress. The North countries, especially the United States, are the biggest conference organizers.

Proportionally to its share in world production, the South shows a low participation in congresses. In fact, we know that this figure underestimates the real participation to round tables, conferences, congresses, and so on, by Southern scientists. What the figure really shows is that Third World scientists seem, at the international level, to be less mobile than their colleagues of the North. Budgetary difficulties should be remembered, as well as the generally bad exchange rates of the national currencies to the US dollar. Nevertheless, this is a problem that has its roots far beyond the financial aspects.[44]

The conclusion one can draw from such an analysis is that a country can afford to be autonomous in terms of national publications if it adopts a policy of international communication in order not to create insularization — that is, if it has *an active and mobile scientific community*. In terms of policy, this should mean not so much to encourage international publications, but rather *to encourage participation and organization of meetings, both in and out of their country*. In fields like tropical agriculture, this could also be accompanied by a policy of South–South exchange.

Autocentred Research

In order to measure the degree of autonomy of national research, we computed what can be called 'autocentred publications'. These are publications that simultaneously satisfy the three following criteria:

(i) the research is carried out by a national laboratory;
(ii) it treats a local agricultural problem;
(iii) it is published in a local review or book.

The North cannot, of course, comply with these three criteria. We computed the 'autocentred' research in the nine biggest producers that do not belong to the North, since the figure for the total references would really underestimate the size of such research. The nine countries are India, Brazil, Egypt, Nigeria and Argentina for the South, and all the Periphery (Table 6). A percentage of totally autocentred research that fluctuates between one fifth and one third of the tropical agricultural

TABLE 6
Autocentred Publications in the South and the Periphery

	Total	Auto centred	%
World	2040	448	22%
Nine Countries	1231	365	30%

production indicates a high degree of fluidity. That is, in the vast majority of the cases, a study is done in one place, it concerns another place, and the results are published in a third one. This fluidity indicates a wider integration in international networks than is usually assumed.[45]

The Focus of Research

We compared two types of research articles. One consists of general articles, presenting the research in more theoretical terms, with less reference to fieldwork or precise locations. An article on 'The Influence of Organic Acids on the Availability of Iron in Soil' is a general article. The other category includes precisely located research, as for instance this 'Note on the Soils of Adendan Area, Egypt'. Table 7 gives the figures for the ratio of general studies to located studies for fourteen countries.

TABLE 7
Local and General Articles by Country

Country	1. Local	2. General	Ratio 1/2
France	98	35	2.8
USA	64	52	1.2
Germany	25	16	1.5
Great Britain	24	10	2.4
Holland	22	7	3.1
Australia	115	165	0.6
New Zealand	72	71	1.0
Israel	31	43	0.7
South Africa	25	14	1.7
India	136	167	0.8
Brazil	115	68	1.7
Egypt	52	46	1.1
Argentina	19	27	0.7
Nigeria	51	14	3.6

The North does relatively more local research. This is paradoxical, though understandable, since it is a form of aid to the tropical countries. France, Great Britain and Holland show this emphasis. Germany and the United States, on the contrary, publish relatively more general articles. India has a higher proportion of general studies than any of the Northern countries. Brazil, on the contrary, shows a tendency toward localized research. Nigeria's case may be illustrative of a clear imbalance, with too many local studies.

The Research Domains

Using PASCAL classification, we studied the distribution of the world production by research domains (Figure 1), and have listed the categories in Table 8. The categories with very small production should be regarded with caution. These include Uses of Wastes [13], Hydroponic Culture [14] and Soil Pollution [18]. Some domains can be very much influenced by local ecological conditions (for example, research on dunes in Saudi Arabia). Moreover, portability of research is also an important factor:

TABLE 8
List of Codes Used in Figures (Agroline-PASCAL Codes in Parentheses)

Code	Content	
1	General Reports, Annual Reports, Conference Reports, Bibliographies	(A01)
2	Geomorphology	(C01)
3	Superficial Soil Formations	(C03)
4	Satellite Imagery & Remote Sensing	(A03)
5	Soils and Agriculture, General	(B01–2)
6	Cartography and Soil Classification	(B03–4)
7	Physico-Chemistry of Soils	(B05-A)
8	Organic Matter	(B05-B)
9	Physical Properties	(B06-A)
10	Water Dynamics	(B06-B)
11	Microbiology of Soils	(B07)
12	Fertilization (mineral and organic)	(B08)
13	Uses of Wastes	(B08-F)
14	Hydroponic Culture	(B09)
15	Soil–Plant Relations	(B10)
16	Soil Conservation	(B11)
17	Soil and Irrigation Management	(B12)
18	Soil Pollution	(B14)

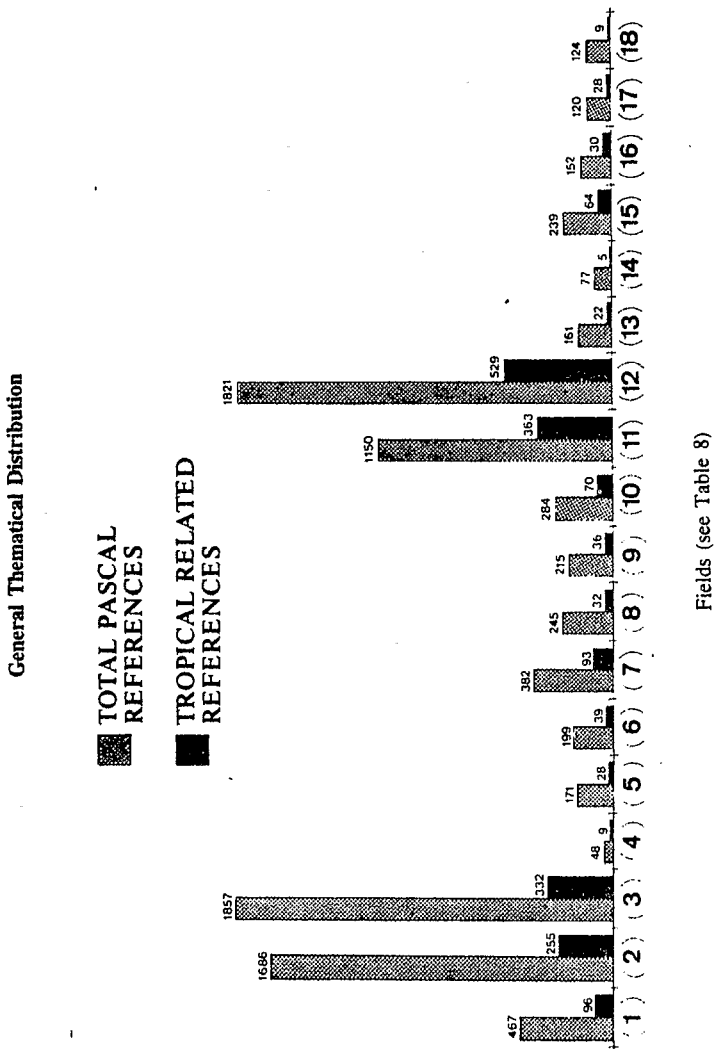


FIGURE 1
General Thematical Distribution

many geographical studies are done in European laboratories on Southern countries with the help of aerial photographs or satellite images [4]. Northern countries thus more easily produce 'local' studies in Geography and Geomorphology [2] and the study of Superficial Soil Formations [3] in their own laboratories.

We can establish the proportion of research dedicated to tropical areas (Figure 2), keeping in mind the absolute size of each domain (see shading of bars). Those domains where there is less research in the tropical zone are mainly Soil Pollution [18], Uses of Wastes [13], and Hydroponic Culture [14]. These are also domains with little research at world level (white bars). The lack of 'local' interest in the study of Organic Matter [8] which represents 13% of the world production, is more striking. It is a domain where there are many Russian studies which do not concern tropical areas. In 1964, Dan Yaalon noted this Russian presence, and also the strong position of the USA on the physical properties and mineral elements of the soil.[46] The evidence seems to indicate a serious lack of interest in a domain important to tropical agriculture. But we must stress that our co-word analysis of the same literature (see below) showed that the two biggest poles of research in terms of content were nitrogen fixation and mycorhiza, themes that clearly involve organic matter.[47] Those research domains where the proportion of studies carried out on, and about, tropical areas is between 15% and 20% of world production, mainly reflect work done in and by developed countries. This is the case in Cartography and Soil Classification [6], Soil Conservation [16], Satellite Imagery & Remote Sensing [4], Physical Properties of the Soil [9], and Geomorphology [2].

Finally, we can see six research domains with a high proportion dedicated to tropical areas (between 23% and 31%). They are all more or less related to a basic problem in tropical zones: fertility, and ways of improving it. This explains the interest in the Physico-Chemical Properties of Soils [7], Relationship of Soils and Plants [15], Water Dynamics [10], and Soil and Irrigation Management [17]; it also explains the two main categories, which are Microbiology of Soils [11] and Fertilization [12]. These two last domains represent 43% of the world production. The Third World performs 31.5% of the studies on fertilization, and 29% in microbiology. Northern countries do relatively fewer studies in these areas (for tropical environments), being more oriented towards general soil science. Peripheral countries also work in these two domains, but relatively less than the South. Tables 9 and 10 illustrate clearly these choices for the three biggest producers: India, Brazil and Australia.

FIGURE 2
Tropical Interests as a Percentage of World Production

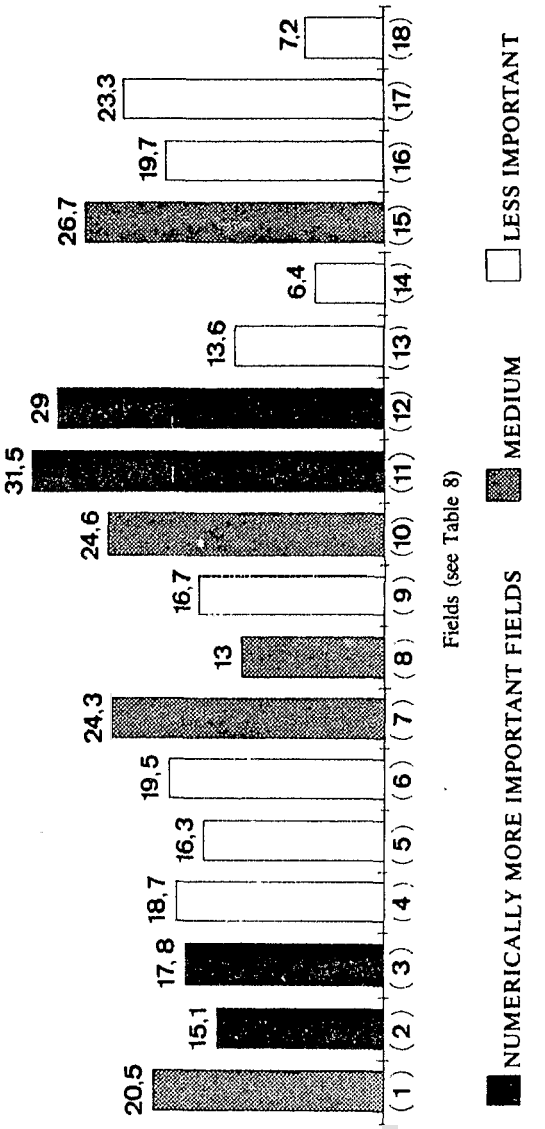


TABLE 9
Research in Microbiology

	Australia	Brazil	India
Total number of studies	52	33	88
General studies	90%	60%	75%
Foreign publications	73%	51%	77%

Microbiology research is a domain with a great percentage of general studies, and many foreign publications: this is a typical 'mainstream' domain. But each country chooses to be more (India) or less (Brazil) inserted in the mainstream. Fertilization research is much more attached to local environments. Brazil is the champion of local studies published nationally. The figures in Table 9 and Table 10 agree well with Velho's results on the production of four university research centres in Brazil, and with Texera's results on Venezuela.[48]

TABLE 10
Research in Fertilization

	Australia	Brazil	India
Total number of studies	59	85	113
General studies	49%	24%	49%
Foreign publications	67%	10%	62%

The Themes of Research

Sophisticated methods now exist which allow analysis of the scientific content of the literature. One of these is 'co-word analysis', which we have applied to our body of documents.[49] We will not present here the results of this analysis, since it falls outside our main argument, which is to show the existence of differing scientific national strategies. In this section, we will only discuss the keywords used to locate a document by its content (that is, by a scientific theme) in order to demonstrate that the differing strategies can be grasped by the very content of research papers.

In Table 11, we reproduce the list of the keywords that characterize 30% of the production for India, Brazil, and France and French-speaking countries (mainly composed of French-speaking Africa, Canada and

TABLE 11
Keywords Characterizing 30 Percent of Production in India, Brazil, and French-speaking Countries

India

— 87 sol — 77 plante céréalière — 45 Inde — 43 rendement
— 38 bactérie — 38 fixation azote — 38 plante légumière
— 37 oryza sativa — 33 oligoélément — 32 nutrition
— 30 zinc — 29 phosphore — 27 triticum aestivum
— 26 azote — 23 gramineae — 22 rhizobium — 21 absorption
— 21 microflore — 20 inoculation

Brazil

— 30 sol — 26 plante céréalière — 24 Amérique du Sud
— 24 sol tropical — 22 sol latéritique
— 21 fixation azote — 16 rendement — 14 nutrition
— 14 plante oléagineuse — 13 oligoélément
— 13 plante légumière — 13 Zea mais — 12 bactérie
— 12 fertilisation azotée — 12 phaseolus vulgaris
— 11 aluminium — 11 glycine max — 11 symbiose
— 10 étude en serre — 10 plante fourragère

French-speaking countries

— 51 sol — 23 zone tropicale — 12 agriculture
— 11 classification — 11 Sénégal — 10 Afrique
— 10 morphodynamique — 10 sol tropical — 9 cartographie
— 9 fixation azote — 8 microflore — 7 Afrique ouest
— 7 satellite Landsat — 7 télédétection
— 7 télédétection multispectrale — 7 algérois
— 6 argile minéral — 6 climat — 6 donnée MEB
— 6 ERTS Landsat — 6 morphologie — 6 plante fruitière
— 6 symbiose — 6 végétation — 5 analyse image
— 5 Antilles — 5 bactérie — 5 classification supervisée
— 5 écologie — 5 forét — 5 Guyane française
— 5 inoculation — 5 karst — 5 milieu aride
— 5 morphologie volcan — 5 mycorhize — 5 occupation sol
— 5 pédogenèse — 5 plante céréalière
— 5 plante oléagineuse — 5 sol sableux
— 5 structure sol — 5 végétal

Belgium). Each keyword is preceded by the number of documents in which it appears (its 'occurrence'). Indian production was indexed with 765 keywords, and a total of 2365 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 1154 occurrences. One can draw out 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 1218 times. A third of the sample can be characterized with 6.7% of the keywords, and half of it with 15%.

We can therefore see very different strategies. One is illustrated by India, with many studies on relatively few scientific objects. Brazil has a wider range of scientific interests, while French-speaking countries have the widest range (and also the widest of all countries, or group of countries, in our database). Moreover, the more frequent Indian keywords indicate general interests: very few words point to regional or located subjects. There is no cartography, no study of natural superficial formations, nouns of places are absent, and so on. The names of plants and the nitrogen fixation themes indicate the general axes of research. Brazil also deals with these subjects, but in a wider range of plants. There is also more emphasis on soils, and this tends to be more specific research than 'nitrogen fixation' or 'fertilization'. In the French group, more emphasis is given to cartography, regional studies, satellite imagery, and studies of natural environments.

The Influence of the North on the South

So far, we have presented data that indicate a relative autonomy of the Third World countries, as far as research themes are concerned. Of course, the real influence is exerted through the content of the research, and that cannot be easily grasped; it surely cannot be understood merely through a bibliometric study.[50] But one can ask the question: how much of the Third World research is published in the Centre's journals? There is also the question of the quantitative weight of the research orientations of the North, as compared with those of the South and the Periphery.

In order to answer the first of these two questions, we analyzed the 'attraction power' of the journals of the North. This attraction can be measured by the proportion of articles produced by foreign authors in the total of articles published in the journals of a given country.[51] It is an

indicator opposite to the 'fixation power' we defined above. An 'attraction power' of 100% would mean that the journals of the studied country only publish articles by foreigners. This is of course never the case, but, as can be seen in Table 12, some countries like Holland, East Germany, Great Britain and the United States publish mainly articles by foreigners.

TABLE 12
Attraction Power of the North

Countries	National production	Foreign production	Attraction power
United States	79	215	73.1%
Holland	22	251	91.9%
France	123	68	35.6%
Great Britain	19	163	89.5%
Germany (West)	30	59	66.2%
Germany (East)	2	36	94.7%

Holland is a special case because it gathers large editorial groups specializing in scientific editions. But we can also contrast this high attraction power with Holland's very high fixation power. Holland has an international soils museum, and the main office of the International Soil Sciences Association is in that country. Great Britain is also interesting because its importance is more in terms of the opportunities to publish that it offers, rather than of the research itself. Along with the United States, these countries represent the bulk of publication opportunities. Such a weight certainly affects the behaviour of scientists in the whole world.

The case of France illustrates exactly the opposite situation. France publishes mainly French articles. Moreover, it publishes a great deal of literature in French that comes from the French-speaking countries. This linguistic specialization represents a danger of 'insularization'. As we will soon see, it goes with a very strong influence of France on French-speaking countries of the Third World. Allied with the very strong presence of French scientists in Africa and the rest of the world, this looks more like 'insularization' on the scale of an empire, rather than of a country!

Last, we have presented the figures for the two Germanies, which publish many foreign studies on tropical soils and agriculture. Both countries are absent from the fieldwork, especially East Germany, but both attract foreign articles on some very specialized areas, such as biochemistry applied to soils and microbiology.

FIGURE 3
Thematical Distribution by Group of Countries

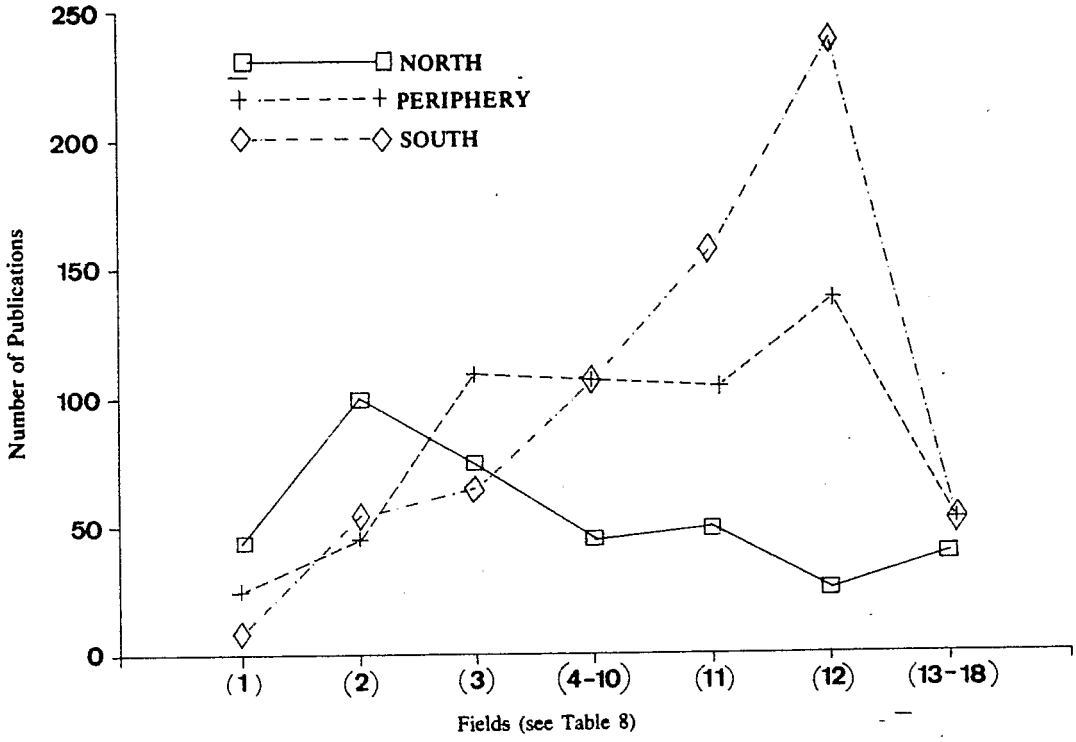
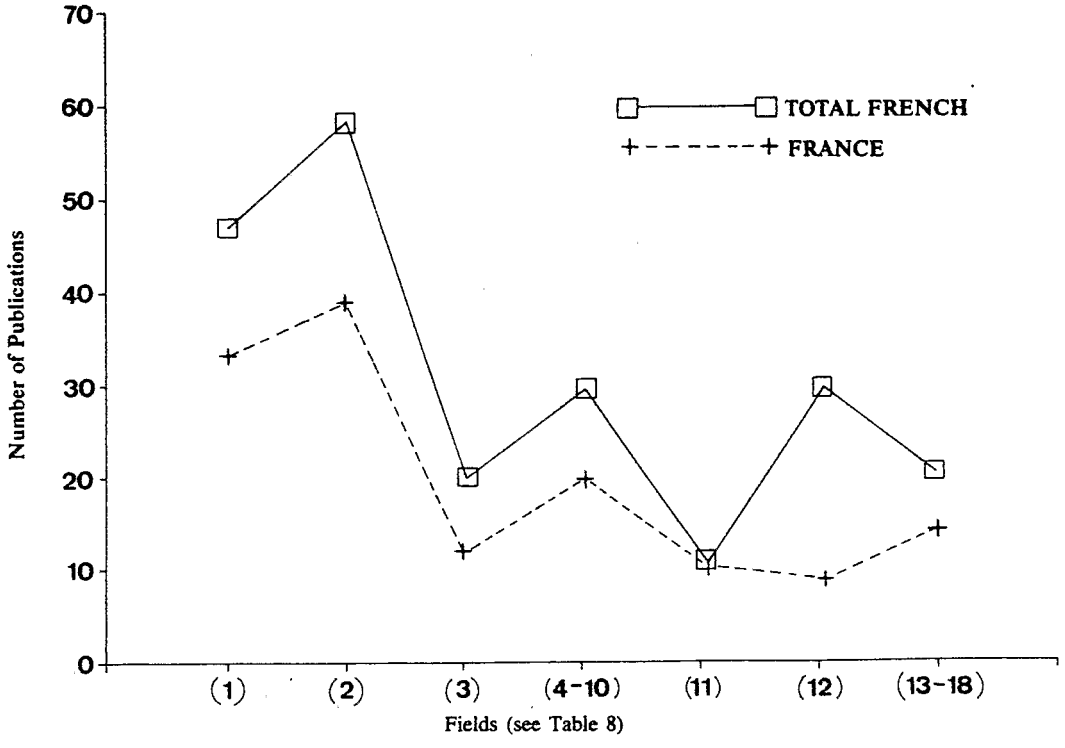


FIGURE 4
Thematical Distribution of French-Speaking Research



Let us now turn to the second question, the quantitative influence of the North in terms of orientations within the big domains we have presented above. Figure 3 illustrates the distribution of the number of studies by domains of science. Each curve represents one of our geographical areas: North, Periphery and South. Northern countries have a rather equally distributed research effort in all domains, with some emphasis on geomorphology and pedogenesis. On the contrary, the distribution of research of the South and the Periphery show similar emphasis of research on Fertilization [12], and Microbiology [11]; the South, as can be seen, accentuates these topics proportionally more than does the Periphery. This allows us to correct the traditional image of the South doing what the North wants it to do. It seems to us that these are clear and conscious choices on the part of Southern countries, without the participation of Northern countries. But that does not mean that there is no influence at all. In some countries there is a very close relationship between the work performed by Northern and Southern scientists. This is clearly the case in African French-speaking research. Figure 4 shows the number of publications by group of topics, for France, on the one hand, and total French-written production (including France), on the other. The two curves are similar, with the exception of fertilization studies. The profile of these curves is exactly opposite to that of the preceding curves of the South and the Periphery. What this different strategy means in terms of the practical applications of research remains to be discovered. The fact is that French and French-speaking countries have chosen quite different ways of approaching soil research.

Conclusions

We have argued that bibliometric studies greatly underestimate the research production of Third World countries, for many reasons. One has to do with the database used, which is usually the *ISI* database. This base, although it is the only one counting citations, does not give good coverage of the Third World countries and the non-English-speaking world. This leads us to suggest a more intensive use of different databases and of 'grey literature'.

A second reason for this underestimation is that some countries deliberately choose not to be totally inserted in the 'mainstream'. Our results show, both for Central and Southern countries (France and Brazil), that this orientation also corresponds to a type of research, more oriented towards local scientific topics. The Third World countries choosing this

strategy are less influenced, at least quantitatively, by the central countries — that is, USA and Europe. This is not true for every country, because there exist strong influence areas, as we saw clearly with French-speaking Africa, as compared with France. Also this orientation — priority to local research and national publication — has some difficulties. First of all, it means a wider scope of topics. The danger is dispersion and bad dissemination of results. It is the danger of 'inbreeding' pointed to by Velho and Krige. We think that the only way to avoid this danger is to encourage participation in international meetings more than publication in international reviews. Our data on scientific meetings shows that the South is under-represented in this scene. One has to be imaginative in designing ways in which the South can get more closely linked. Nowadays, given the structure of the journal (and airline) networks, it seems quicker to communicate from Abidjan to Mexico through New York than directly! Also, as we have shown, publication is determined by two external factors: language access and publication opportunities. Both of these obstacles are less important in informal communication, thus our emphasis on meetings. For us, the lesson goes something like this: write inside and talk outside.

The image one gets by studying the world scientific production in a specific area is much more diversified and rich than is assumed in the national/international debate. The main question appears to concern, not the integration in the mainstream, but the *use of knowledge*. It is by using the already available knowledge that one can construct a creative science not totally dictated by the Central countries. We know that this point raises the difficult issues of *research priorities*, and management of *evaluation structures*.

Although these evaluation structures have been, until now, very much designed under a Centrally biased scheme, most Third World countries have tried to deal with their own needs. We have shown that all Third World countries do not adopt the same scientific strategies, nor do Central countries work on the same topics. We did not find traces of a supposed scientific division of labour, where the Centre would do basic research and the South applications. Basic issues very often grow out of applied questions; in terms of policy this means encouraging basic research only in as much as it is linked to the applied areas, and not basic research *per se*, and encouraging applied research only in as much as it helps in solving some specific problems. The right question then is not what proportion of basic, applied or development research should be done, nor what should be published nationally or internationally; rather, it is *what are the problems, what knowledge do we have to solve them, and where is there a need of research*?

In terms of a bibliometric analysis of agriculture, soil and natural sciences, that new framework can be translated into a more thorough look, not at the proportion of science produced by the Third World, but rather at the science one can use in a tropical area, whoever may be its producer. Putting things that way may help in defining less asymmetric research cooperations. As far as analytical instruments are concerned, there is an urgent need to develop new tools, and encourage statistical analysis of science. We believe that we have shown that some indicators are very sensitive to the issues we have just mentioned: communications to meetings, attraction and fixation power, thematical distribution, general *versus* local topics, and keyword distribution are some of the possible indicators.

Finally, one could argue that having looked at an applied science, our results are necessarily biased in favour of local research, local publishing, and so on. But soil sciences are not all applied; and, even in the same domain, we could contrast different strategies with research more or less locally defined, and more or less internationally published. The difference is striking in the cases of Brazil and India. Moreover, we know of very applied research that shows high international scientific production. This is the case, for instance, in fish stock management, to name just one applied international domain.[52] What seems to be less 'international' is not the science, but rather the way it is used.

In defining alternative policies, one should not forget that publishing is a sort of ultimate activity, particularly in applied sectors of science. It seems necessary to put *more emphasis on the research process itself, and on alternative communication strategies*. Also, it is necessary to think of science not as an isolated activity, but as *a social activity linked to the national debates*. We will finish by quoting Anderson and Buck, who have stated this point quite clearly:

> Writers on the development of science and on science and development might consider drawing a lesson from the history of science in the West. Instead of worrying about how to keep knowledge politically and ideologically chaste, they should be wondering how to transform scientific theories and concepts into objects of *social and political controversy* in developing societies. Were that to happen, then science would be well on the way to escaping from the kind of sterile academicism which besets so much research in so much of the world. More importantly, science might take hold of the people of the Third World, and they might take hold of it.[53]

• *APPENDIX*

Constitution of the Data Base for the Bibliometric Analysis of Tropical Soil Sciences

We extracted all the documents from the 1983 *Bulletins signalétiques* of the PASCAL database (No. 226 and No. 381) in the following categories:

Bulletin signalétique 226:
Formations superficielles
Géomorphologie
  Sols

Bulletin signalétique 381:
Généralités
  Compte-rendus généraux, rapports d'activité, congrès, bibliographies
    Méthodes et techniques diverses
      Télédétection
Sols, Agronomie générale
  Généralités
  Techniques et méthodes d'analyse
  Cartographie des sols
  Classification des sols
  Pédogenèse
  Physico-chimie du sol
    Eléments minéraux, oligo-éléments, propriétés ioniques et d'échange
    Matière organique, évolution de la matière organique, complexe argilohumique, 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 phosphatée
    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 CO_2

Relations sol-plante
Conservation des sols, érosion
Potentialités, aménagement du territoire

In the analysis, we used the codes of Agroline-PASCAL, which are more simple and manageable (see Table 8).

• NOTES

A preliminary version of this paper was presented at the 'Derek de Solla Price Seminar' on the 'Dynamics of the Scientific Disciplines in the Periphery' organized by Hebe Vessuri and Yakov Rabkin in February 1987, in Costa Rica. We would like to thank the PASCAL team headed by Bill Turner, particularly Pascale Coget, Denise Pelissier and Ghislaine Chartron, for their constant help. Our thanks also go to our referees, Lea Velho and J. Davidson Frame, who made many insightful comments.

1. H. Vessuri, 'The Universities, Scientific Research, and the National Interest in Latin America', *Minerva*, Vol. 24, No. 1 (1986), 1–38. Most specifically about the new technologies, see Vessuri, 'La Evaluación de la Capacidad Científica de América Latina ante el Desafío de las Nuevas Tecnologías', *Acta Científica Venezolana*, Vol. 37 (1986), 351–62.

2. For instance, the project named 'Prospectiva Tecnológica para América Latina' defines the objectives of a technological policy in terms of satisfying the basic needs of the population and guaranteeing the conservation of natural resources. Another interesting project in Latin America has been the STPI Project under the direction of Francisco Sagasti. For an excellent discussion of the differing views on the growth of science in the Third World, see the Review by Mary B. Anderson and Peter Buck, 'Scientific Development: The Development of Science, Science and Development and the Science of Development', *Social Studies of Science*, Vol. 10, No. 2 (May 1980), 215–30.

3. For a similar opinion, see Marcel Antonorsi and Ignacio Avalos, *La Planificación Ilusoria: Ensayo Sobre la Experiencia Venezolana en Política Científica y Tecnológica* (Caracas: Cendes/Ateneo, 1980). These authors point to the fact that, until recently, science policy has been thought of as an independent policy, and science as an isolated activity, following the recommendations of the international organizations (for instance, UNESCO). But there also exist strong advocates of the 'scientificist' point of view: see, for instance, Marcel Roche and Yajaira Freites, 'Produción y Flujo de Información Científica en un País Periférico Americano (Venezuela)', *Interciencia*, Vol. 7, No. 5 (1982), 279–90, and also E. Fuenzalida, *Investigación Científica y Estratificación Internacional* (Santiago de Chile: Editorial Andrés Bello, 1971). The logical conclusion of this position is that everything should be done to integrate national research into the international 'mainstream'. For a global review of these opposing views, see Hebe Vessuri, 'The Social Study of Science in Latin America', *Social Studies of Science*, Vol. 17, No. 3 (August 1987), 519–54.

4. There now exist many studies reporting on the financial and organizational difficulties. For instance, M. Schoijet, 'The Condition of Mexican Science', *Minerva*, Vol. 22, No. 3 (1983), 381–413; L. Lomnitz, 'Hierarchy and Peripherality: The Organization of a Mexican Research Institution', *Minerva*, Vol. 17, No. 4 (1979), 527–48; L. Busch, W. B. Lacy and P. Marcotte, *The Sudan Agricultural Research Corporation: Organization, Practices and Policy Recommendations* (Lexington, KY: Intsormil & University of Kentucky, 1983); N. Clark, 'Organisational Aspects of Nigeria's Research System', *Research Policy*, Vol. 9 (1980), 150–72.

5. A recent analysis by Kapil Raj illustrates how singular can be the scientific practice of a Third World country, namely India: K. Raj, 'Images of Knowledge, Social Organization and Attitudes to Research in a Department of Physics in India' (Paris: Ecole des Hautes Etudes en Sciences Sociales, mimeo, 1987).

6. E. Garfield, 'Mapping Science in the Third World', *Science and Public Policy*, Vol. 10, No. 3 (1983), 112–27. In this paper, Eugene Garfield shows that North America, USSR, Western and Eastern Europe and Japan represent 94% of the 1973 world production, whereas India has 2.0%, Argentina 0.44%, and Brazil 0.23%. Frame, Narin and Carpenter find that the Third World represents 6% of the world production (5.53%, if we exclude Rhodesia and South Africa); see J. Davidson Frame, F. Narin and M. P. Carpenter, 'The Distribution of World Science', *Social Studies of Science*, Vol. 7 (1977), 501–16. Both articles are based on the *ISI* database. Figures can be substantially higher if one uses the *WIPIS* (*Who is Publishing in Science*): the research team in Lima directed by Sagasti computed 11% for the 1980 production, but that includes Japan in the Asian total, which is around 4.5% in the *Science Citation Index*: see GRADE, *El Comportamiento de la Comunidad Científica Peruana* (Lima: GRADE, 1984).

7. Some of these studies are Frame, Narin & Carpenter, op. cit. note 6; Garfield, op. cit. note 6; J. Davidson Frame, 'National Economic Resources and the Production of Research in Lesser Developed Countries', *Social Studies of Science*, Vol. 9 (1979), 233–46; Y. M. Rabkin, T. O. Eisemon, J. J. Lafitte-Houssat and E. E. Rathgeber, 'Citation Visibility of Africa's Science', ibid., 499–506; Rabkin and H. Inhaber, 'Science on the Periphery: A Citation Study of Three Less Developed Countries', *Scientometrics*, Vol. 1, No. 3 (1979), 261–74; C. H. Davis, 'Institutional Sectors of 'Mainstream' Science Production in Sub-Saharan Africa, 1970–1979: A Quantitative Analysis', ibid., Vol. 5, No. 3 (1983), 163–75.

8. C. T. Bishop, 'Canadian Journals are Better than Some Think', *Science Forum*, Vol. 10, No. 3 (March 1977), 20–22.

9. L. Velho and J. Krige, 'Publication and Citation Practices of Brazilian Agricultural Scientists', *Social Studies of Science*, Vol. 14 (1984), 45–62.

10. Roche & Freites, op. cit. note 3.

11. Garfield, op. cit. note 6.

12. In agricultural fields, one could use AGRICOLA, CAB, or AGRIS. A comparative and detailed analysis of the databases dedicated to agriculture can be found in L. William and M. Populer, 'La Documentation automatisée au service de l'agriculture', *Annales de Gembloux*, No. 87 (1981), 151–61, and No. 88 (1982), 51–66. Davis recommends the use of AGRICOLA, because this database collects information at a regional level, although he does not use it; see Davis, op. cit. note 7.

13. The word 'mainstream' proposed by Frame, has been largely accepted in the literature as 'what-is-inside-the-*SCI*'. We are aware that this abusive use was not in Frame's initial intentions, although we think that the ISI database is *not* valid for mainstream research either; see J. D. Frame, 'Mainstream Research in Latin America and the Caribbean', *Interciencia*, Vol. 2 No. 3 (1977), 143–47.

14. Velho & Krige, op. cit. note 9; M. Jagodzinski-Sigogneau, J.-P. Courtial and B. Latour, 'How to Measure the Degree of Independence of a Research System?', *Scientometrics*, Vol. 4, No. 2 (1982), 119–33.

15. Rabkin & Inhaber, op. cit. note 7.

16. A good overview of the situation in African agriculture can be found in Chapter 10 of the *State of the World — 1986: A Worldwatch Institute Report on Progress Toward a Sustainable Society* (New York: Norton, 1986); see also C. K. Eicher and C. B. Doyle, *Etude critique de la recherche sur le développement agricole en Afrique sub-Saharienne* (Ottawa: International Development Research Center, Manuscript Report 100f, 1984).

17. On the importance of 'everyday' or 'common' conceptions of the world in scientific theories, see Y. Chatelin, *Une Epistémologie des sciences du sol* (Paris: Mémoires ORSTOM, No. 88, 1979); L. Busch, 'Science, Technology, Agriculture, and Everyday Life', *Research in Rural Sociology and Development*, Vol. 1 (1984), 289–314; and a recent book on the distinct ways of 'thinking nature': Y. Chatelin and G. Riou (eds), *Milieux et paysages: essai sur diverses modalités de connaissances* (Paris: Masson, 1986).

18. M. Callon, 'Struggles and Negotiations to Define What is Problematic and What is Not', in K. D. Knorr, R. Krohn and R. Whitley (eds), *The Social Process of Scientific Investigation* (Dordrecht and Boston, MA: Reidel, 1981), 197–219.

19. We also did a co-word analysis of the corpus of articles: Y. Chatelin and R. Arvanitis, *Les Stratégies scientifiques et le développement: sols et agricultures des régions chaudes* (Paris: ORSTOM, forthcoming).

20. For a more detailed discussion of factors affecting research activity in agricultural sciences, see L. Busch and W. B. Lacy, *Science, Agriculture, and the Politics of Research* (Boulder, CO: Westview Press, 1984), especially Chapter 3. The analysis of the same factors but in the case of Third World Scientists is to be found in J. Gaillard, 'Les Chercheurs des pays en développement', *La Recherche*, Vol. 19 (June 1987), 861–70.

21. This exchange is more likely to be done on a South–South basis, on disciplines linked closely to local natural environments. To some degree this already happens, as is reported in a citation study on zoology and botany in Africa (Rabkin et al., op. cit. note 7).

22. See Lea Velho, *Science on the Periphery: A Study of the Agricultural Scientific Community in Brazilian Universities* (unpublished PhD thesis, SPRU, University of Sussex, 1985). This seems to be a problem in most fields of science, and in most Third World countries. A recent symposium on scientific communication in Latin America, organized by the Venezuelan Association for the Advancement of Science (AsoVAC) in October 1986, in Caracas, has pointed to this as a very difficult problem to resolve. Some case studies of scientific reviews were called for; see H. Vessuri, 'La Revista Científica Periférica: El Caso de Acta Científica Venezolana', *Interciencia*, Vol. 12, No. 3 (1987), 124–34.

23. Frame, Narin & Carpenter, op. cit. note 6. All the analysis that is done on the Computer Horizons data (articles from Narin, Carpenter and Frame) use this category. Third World countries participate mainly in Clinical Sciences and Biology; Frame found that, in 1984, 14.5% of the Third World research (less India) is classified as Biology (almost completely in Agriculture). We thank J. Davidson Frame for this information.

24. With some notable exceptions: see Busch & Lacy, op. cit. note 20, and Velho, op. cit. note 22. In an article on the negotiation structures of agricultural sciences, Busch strongly supported the idea of developing an applied sociology of agricultural science: L. Busch, 'Structure and Negotiation in the Agricultural Sciences', *Rural Sociology*, Vol. 45, No. 1 (1980), 26–48.

25. Davis, op. cit. note 7.

26. *Estadisticas de Ciencia y Tecnología* (Caracas: CONICIT, 1980).

27. Davis, op. cit. note 7.

28. G. Gablot, *Le Français dans les publications scientifiques et techniques françaises et étrangères* (Paris: Association Nationale des Scientifiques pour l'Usage de la Langue Française, 1982).

29. PASCAL is not covering doctoral theses from Third World countries very well, other than African. In fact, countries with a relatively high number of French researchers are better covered. This is the case of Brazil *versus* other Latin American countries, in soil sciences. Extension bulletins are not present in the database.

30. French represents about 20% of the PASCAL database.

31. In particular, we avoided the international congress of the Soil Sciences Association, which occurs every four years.

32. Frame, op. cit. note 7. Israel is even more atypical, since it publishes more articles per inhabitant than the USA: see J. Blickenstaff and M. J. Moravcsik, 'Scientific Output in the Third World', *Scientometrics*, Vol. 4, No. 2 (1982), 135–69.

33. Countries from Asia (Malaysia, Thailand, China) should be regarded with more care, since they seem to have developed efficient tropical agricultures. PASCAL is not the best source for such an analysis. In their recent article, Frame and Narin find that Chinese *ISI*-covered production in Biology is higher than other Central countries, but less than in the Indian sample: see J. Davidson Frame and F. Narin, 'The Growth of Chinese Scientific Research: 1973–84', *Scientometrics*, Vol. 12, Nos 1–2 (1987), 135–44.

34. This may reflect a bad coverage of Spanish speaking countries, although PASCAL has quite a good coverage, and even has a 'Spanish keywords' section. Spanish-speaking researchers acquire their doctorates mainly in the USA, so have probably a greater access to English, than Brazilians. But the most probable explanation is the Latin American tendency to publish more in very local publications. This fact is also stretched by Velho for Brazil, and, as our figures show, it affects relatively more the Spanish-speaking American countries than Brazil. See Velho, op. cit. note 22.

35. Publications written by researchers in tropical territories of:

France	14 articles
United States	21 articles
Great Britain	4 articles
Spain	7 articles

36. D. H. Yaalon, 'Has Soil Research National Characteristics?', *Soils and Fertilizers*, Vol. 27, No. 2 (1964), 89–93.

37. D. H. Yaalon, 'Publications as a Measure of a Nation's Research Effort', *Geotimes*, Vol. 11, No. 3 (1966), 20–21.

38. The case of Sudan is the most striking to us, since we know from the Busch, Lacy & Marcotte study (op. cit. note 4) that there were 212 agricultural scientists in the Sudan in 1980, and that the 'situation [as far as scientific manpower and relation of scientists to supporting staff is concerned] appears to be better than that of most developing countries' (Ibid., 16).

39. The number of scientists in agricultural sciences is not well known for all these countries, or is difficult to find. Here we give the data collected by ISNAR for 1980 in some of the countries appearing in our ranking:

	Scientists 1980	Articles 1983
India	7103	303
Brazil	2957	183
Egypt	2724	98
Nigeria	1084	65
Argentina	1064	46
Philippines	1050	26
Chile	281	21
Mexico	1079	17
Senegal	105	16

Sources: ISNAR/IFPRI, *Resource Allocation to National Agricultural Research: Trends in the 70s: A Review of Third World Systems* (The Hague: ISNAR/IFPRI, 1981), and our data.

40. Gablot, op. cit. note 28.

41. This high percentage of nationally published work can be a sign of 'inbreeding', and it has been argued that this is a sign of weak quality research: see Velho & Krige, op. cit. note 9. These authors used this word to qualify a production that is mainly published in institutional reviews and journals. We can add that this 'inbreeding' seems to occur at national level when too much production is published nationally *and* when there is a low participation in international meetings.

42. When we talk of a deliberate choice (at national level), this does not mean that the country has a deliberate policy in the sense of encouraging national production, or, on the contrary, of international visibility. It means that the researchers tend to choose more frequently one or the other strategy. Of course, this choice is a personal one, as Velho says, op. cit. note 22. But the evaluation structures have an impact far beyond these individual wills: see R. Arvanitis, 'L'Evaluation et la sociologie de la recherche', in Y. Chatelin and Arvanitis (eds), *Pratiques et politiques scientifiques* (Paris: ORSTOM, 1984), 85–90.

43. Our study of the French soil scientists obliges us to put much more emphasis on communications to international meetings than foreign (or 'mainstream') publications as a valid indicator of international 'visibility': see Chatelin & Arvanitis, op. cit. note 19, Chapter 5.

44. A detailed analysis of each country should be done, especially for those countries that showed a high fixation of publications by national journals. For instance, we examined France, which has 92% nationally published production. We studied the production of the soil scientists belonging to a French tropical research organization, and found that on the whole they publish few articles abroad but do participate in a very important number of international meetings (Chatelin & Arvanitis, op. cit. note 19, Chapter 5). This is not the case with most of the researchers of Third World countries.

45. This is also supported by the analysis of coauthorship. Third World countries have a very high number of authors by article. The four European countries have a low number of authors by article: 1.48 to 1.63. With the exception of South Africa, all Periphery countries and the United States are in a middle position: their number of authors ranges from 2.1 to 2.2. The striking figure is that of the big Third World producers: around 2.5 authors for India and Egypt, and nearly 2.8 for Brazil. One can note an historical process: the older countries (Europe) have the lowest number of coauthors, followed by the first Peripheral countries (USA, Australia) then followed by the younger countries, which all belong to the Third World. We seem to be confronted by a paradox in that it is those countries that invented the modern 'ethic' of science that follow it less. To us, the most probable explanation lies in the fact that, in most of the Third World countries, scientists are encouraged to publish at an international level through the evaluation systems they adopt; this is also the conclusion of Velho, op. cit. note 22, and of other studies on the institutionalization of research in Third World countries. See, for example, the articles in H. Vessuri (ed), *Ciencia Académica en la Venezuela Moderna* (Caracas: Fondo Editorial Acta Cientifica Venezolana, 1984).

46. Yaalon, op. cit. note 36.

47. The themes we found were: Nitrogen Fixation, Mycorhizes, Nitrogen Cycle related to Forest Ecosystems and Agroforestry, Soils and Plant Nutrition (this includes research on the oligo-elements, plant-soil relation, and so on), Alteration of Tropical Soils (Morphodynamics, Analysis of Superficial Formation, and so on), Cartography, Satellite Imagery, Bioclimatology and Management of Land (with the more classic soil science activity of Cartography, Classification of Soils), Physical Properties of Soils, Water, Pollution, Acidity, Erosion, Characteristics of Tropical Soils, Medicinal Plants, Enzymatical Activity of Organic Matter, Agriculture and Development, and other more plant-specific themes. See Chatelin & Arvanitis, op. cit. note 19, Chapters 6 and 7.

48. Velho, op. cit. note 22, worked on the basis of the total production of the population she studied. She found that the production of four universities in Brazil in agricultural sciences was published mainly locally (between 92% and 96%). Yolanda Texera, 'Publicación Científica: Análisis del Caso de la Agricultura Vegetal en Venezuela', *Interciencia*, Vol. 7, No. 5 (1982), 273–78, also found similar figures for the total production in agricultural sciences in Venezuela (between 94 and 96%). Fuenzalida, op. cit. note 3, found 72% national publication for Brazilian university researchers, but only 34% for Chileans. On a point of methodology, we have here a proof of the validity of PASCAL for studying the production of non-French scientific literature, since we are working with a small proportion of the Third World production, and yet find results similar to those studies using a much more exhaustive base of local data.

49. An introduction to co-word analysis can be found in M. Callon, J.-P. Courtial, W. A. Turner and S. Bauin, 'From Translations to Problematic Networks: An Introduction to Co-Word Analysis', *Social Science Information*, Vol. 22, No. 2 (1983), 191–235. For recent research using this method, see M. Callon, J. Law and A. Rip (eds), *Mapping the Dynamics of Science and Technology* (London: Macmillan, 1986).

50. See the section entitled 'Les Dominations scientifiques', in Chatelin & Arvanitis, op. cit. note 42, 149–83, with examples of scientific dominations in the fields of geography, soil sciences, economics and relevant literature in the sociology of science. The examples tried to pinpoint the opposition between 'tropical' sciences versus 'universal' knowledge.

51. Gablot, op. cit. note 28.

52. *Rapport de recherche sur l'aquaculture et la dynamique des populations* (Paris: Centre de Sociologie de l'Innovation, Ecole des Mines, 1983).

53. Anderson & Buck, op. cit. note 2, 229 (our emphasis).

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