The Uphill Emergence of Scientific Communities in Africa*

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ABSTRACT

The increasing concern African decision-makers and international funding agencies feel for scientific research in Africa and its impact on development has led to the establishment of several support programmes, especially for agricultural research. What is the current state of scientific research in Africa? What holds back its development? After a historical review of science in Africa, this paper searches for answers by analysing available resources, and indicators of production, visibility, and utility throughout the continent. A description of the present day scientific structures and the constraints facing scientists is followed by a look at the fundamental question of how autonomous scientific communities can be established in Africa.

Introduction

AFRICA USED TO BE absent from the scientific scene. Is it now taking its rightful place? Starting nearly from scratch in 1960, African universities experienced an academic boom with a record 9% annual increase in the number of scientists (more than in developed countries) and have made a valiant effort to build up national research systems (NRS).

Many observers feel that the results are not yet satisfactory, only partly fulfil the development needs, and do not cope with the anguish the African states feel about their growing marginalisation on the world's economic scene. It was long believed that the accumulation of adequate manpower, funds, and organisation would automatically generate productivity. After looking at Latin America and Asia, we are beginning to feel that the worst constraints are institutional and organisational.

Should Africa have more science or limit itself to techniques? Should certain systems be changed to guarantee a level of quality that hitherto has been compromised because the focus was on quantity? This debate is creating problems for researchers and policymakers. After reviewing the research

* A slightly different version of this article was published in French under the title "La Recherche Scientifique en Afrique", in *Afrique Contemporaine*, n° 148, 4ème trimestre 1988, pp. 3-30. Throughout the article, the term "Africa" will refer to all the countries south of the Sahara, except for the Republic of South Africa. The countries north of the Sahara, whose resources and dynamics are different, are considered as "Arab Countries"?

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systems, we will discuss available resources, and indices of production, visibility, and utility and then consider existing structures and constraints on the scientific profession in Africa. Finally we will look at the vital question of emergence and reproduction of national scientific communities in Africa.

A Recent Experience

Similarities and Differences in Colonial Experiences

Setting aside the policies and goals of the colonising countries, the main differences in the colonial—British, French, Belgian—experiences in Africa lie in the links between the research carried out in the colonies and in the "mother country", and the way in which these relations were sustained or modified after independence (Trigo 1985).

Each country in the British Empire was seen as a distinct entity. This approach was incompatible with research centralisation and, in certain cases, regionalisation of research, although efforts were made to organise research in eastern Africa during the post World War II period. In the field of agriculture, this concept led to the establishment of separate agricultural services (responsible *inter alia* for research) in each of the colonies. However, they were much more interested in developing the land and extension work than in research (Masefield 1972).

The first British agricultural research stations in Africa date back to the beginning of the century and were fashioned after the Buitenzorg Institute in Java. The Amani Agricultural Research Station was established in Tanganyika in 1902[1]. When independence came, they were nationalised. The British rapidly withdrew as foreign scientists were replaced by local research staff and the spotlight shone on more site specific research. Consequently in the field of agriculture, food crops were assigned priority over export crops, although the latter, to this day are still deemed highly important since taxes levied on them provide convertible currency revenue for the governments[2].

The French experience was very different since research was centralised and closely bound to the mother country via the specialised institutions listed below. They were active not only in French-speaking Africa but also in French colonies in other regions of the world. In many cases, industry created private organisations as precursors to these institutes. For instance, the Syndicat général de l'Industrie cotonnière (1901) and the Association cotonnière (1903), which first started applied research on tropical textiles, led to the creation of IRCT in 1946. The central management for all these institutes has always been in France. Staff was exclusively composed of expatriates and no effort was made to develop a capacity for independent research in the colonies. Several regional centres controlled by the French institutes were established, e.g. at Bambey for the Sahelo-Soudanian zone, at Bouaké and Bingerville for the wet tropics, at Boukoko for the equatorial zone, at Loudima for the Guinean zone, and at Lake Alaotra for the medium altitude tropics. The end of the colonial era in 1960 did not suddenly alter the profile of French participation in the former

colonies. In most cases the French institutes continued to operate under technical assistance agreements concluded with the newly independent states.

French tropical agronomic research organisations* (current names)

IRHO - Institut de recherches pour les huiles et oléagineux (1942) - oil crops.
IRFA - Institut de recherches sur les fruits et agrumes (1942) - citrus and other, tropical fruits.
IRCT - Institut de recherches du coton et des textiles exotiques (1946) - textile crops.
CTFT - Centre technique forestier tropical (1947) - wood and forestry.
IEMVT - Institut d'élevage et de médecine vétérinaire des pays tropicaux (1948) - livestock and veterinary medicine.
IRAT - Institut des recherches agronomiques tropicales et de cultures vivrières (1960) - food crops.
IRCC - Institut français du café, cacao et autres plantes stimulantes (1960) - coffee, cocoa and tea.
IRCA - Institut de recherches sur le caoutchouc (1960) - rubber.

These institutes are now grouped under CIRAD.

* ORSTOM (created in 1943), although partly dealing with agricultural research is more basic oriented and has a different scientific structure than the other specialised institutes.

As concerns the structures of research organisations, it is difficult to trace a single path of change, but there were some visible trends. The main one, in the 1970s, involved the creation of national bodies responsible for science policy, such as the ministries of scientific and technical research or the like in Senegal, Ivory Coast, Cameroon, and Central African Republic. And as the national scientific policies became more specific, horizontal links were established between the research institutes. These links replaced, or complemented, the only vertical relations these institutes had with the decision-making centres in Paris. Now African supervisory services control the research programmes carried out by French, other foreign, or bilateral institutes, and negotiated at annual meetings of joint commissions.

In Belgian Congo, the Institut pour l'Etude agronomique du Congo belge (INEAC - the Belgian Congo Institute for Agronomic Studies) was created in 1933[3]. Like the specialised French institutes which were born from less structured organisations and initiatives, INEAC was the successor of the Régie des plantations, an Authority that existed between 1926 and 1933 to handle both research and production. Shortly after the first world war, several agricultural stations such as the one at Yangambi were created in the wake of the Kisantu and Eala gardens, founded in 1900 as botanical gardens and trial-adaptation centres. Although INEAC was financed essentially by Belgium, it had a relatively self-contained and hierarchical organisation, and soon became decentralised in its programme design and implementation. As in the French colonies, practically nothing was done to train African scientists and senior staff (Cornet 1965). On June 30, 1960, INEAC was composed of the Yangambi research centre and 32 experimental centres, stations, and plantations located in eight geographical sectors throughout Congo and Ruanda-Urundi (Drachoussoff 1987). Independence was still very young when these structures were transferred to the new states as the basis for their national agronomical research system. Because of the very serious problems in Belgian Congo, that became

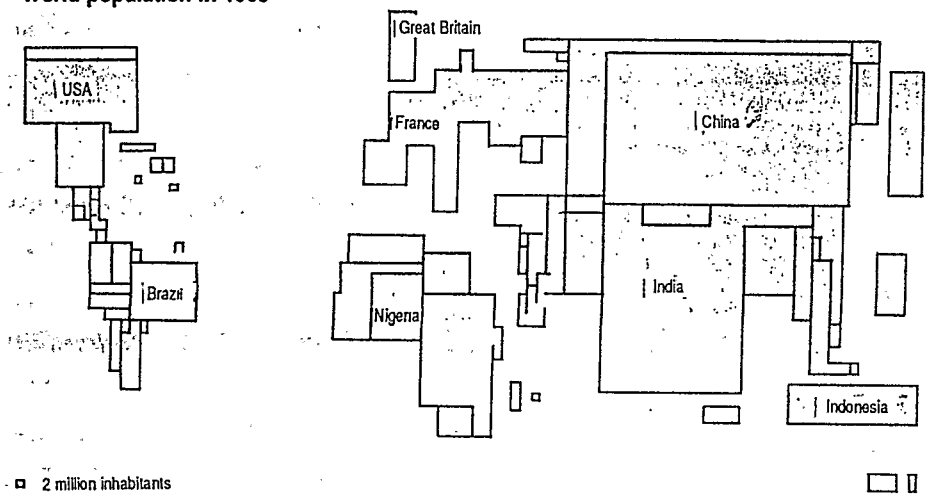

Figure 1. Distribution of scientists in Africa and throughout the world.

Source: Vallin (1986)
UNESCO and National Science Foundations (NSF), 1986.

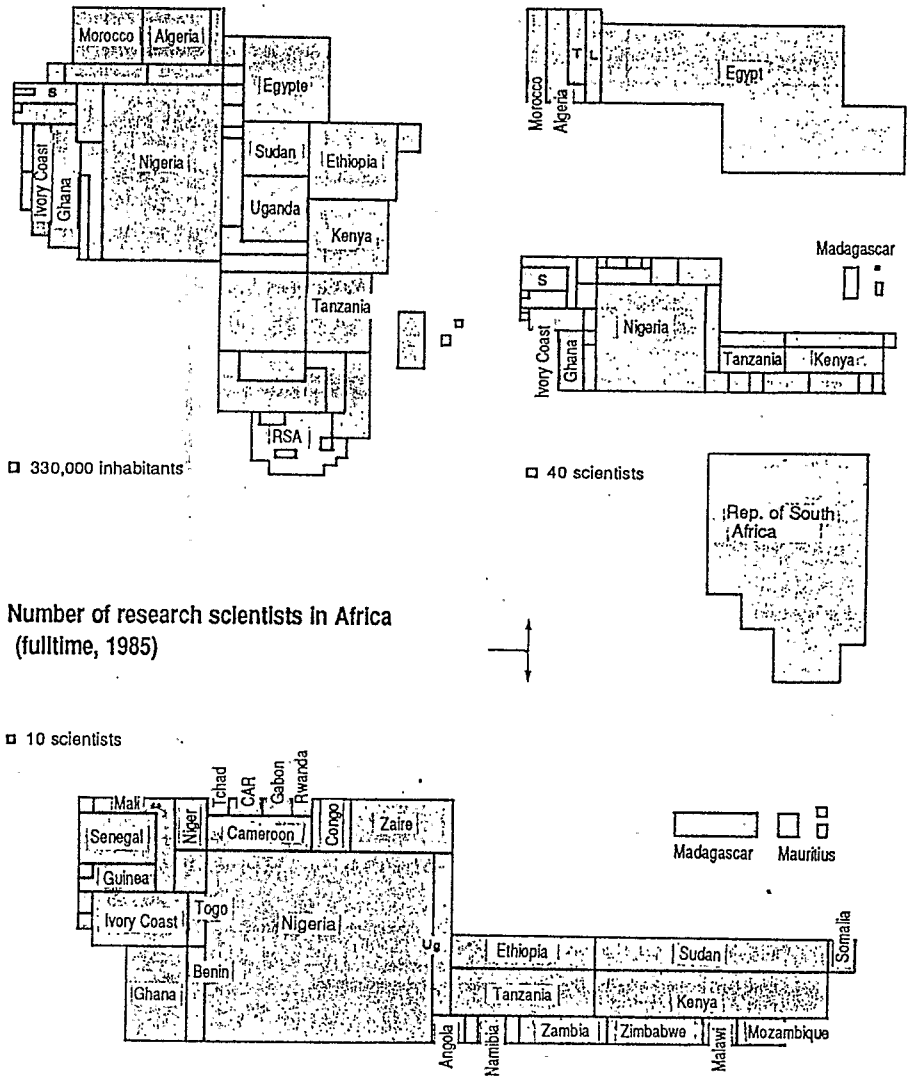

Figure 1 (*continued*)

Zaire in 1960, and the shortage of funds and manpowers, Zaire, Rwanda, and Burundi found it very difficult to shoulder this huge heritage.

Scientific Research and Higher Education: A Later Start in Africa Than on Other Continents

The first African research centres were fashioned after the centres the Dutch and British had established in their (former) Asian and West Indian colonies several decades earlier. The examples most often mentioned in mission reports by experts assigned to establish the new structures in Africa were the Imperial College of Tropical Agriculture in Trinidad and the Buitenzorg Insitute in Java. The same applies to the first schools of higher education.

Compared to other continents, even the oldest African universities are still quite young. In Latin America there were 23 universities during the colonial era and some 150 graduates towards the end of the 18th century. The British colonisers established the first universities in Asia (in Calcutta, Madras, and Bombay) in 1857. The University of Cairo was established in 1908. As concerns Black Africa, the very first was University College in Ibadan, Nigeria, and the first science degreees were awarded in 1950, The University of Dakar, the oldest of the French-language universities in Black Africa, was born in 1957, and became Senegalese in 1960 (Gaillard 1987).

Many authors explain that French-speaking Black Africa had a very small number of students who had graduated from a national university at the time of independence. Between 1952 and 1963, for instance, French-speaking Africa produced a mere four graduates in the field of agriculture while English-speaking Africa turned out 150 (Eisemon et al. 1982). The figure for French-speaking Africa, however, does not include graduates from universities in France or French institutions such as ORSTOM which, by independence time, had trained some 20 African scientists in agronomical sciences. The number of scholarships the industrialised countries granted to African students to study abroad rose considerable just before independence and in the 1960s and 1970s. This policy partly reflected an increased awareness of the value and role of higher education and development-oriented science; it also reflected the donor countries' desire to keep, or acquire, political and economic influence in the newly independent states[4]. The number of African graduates and national scientists started rising, and in the 1970s, the number rose faster and faster in both English- and French-speaking Africa. Now all the countries on the African continent have institutes of higher education, except Cape Verde, Comoros, Djibouti, Equatorial Guinea, Gambia, and Guinea-Bissau. In the 43 countries that offer higher education, the total number of students rose from 142,000 in 1960 to 1,169,000 in 1980 (UNESCO 1986).

In the post-colonial period, international research centres became active in Africa later than in the rest of the world. The International Institute of Tropical Agriculture (IITA) was created in Ibadan, Nigeria in 1967, a year after improved rice varieties were distributed to Asian farmers by the International Rice Research Institute (IRRI) created in Los Banos, Philippines in 1959. The International Centre for Maize and Wheat Improvement (CIMMYT) was

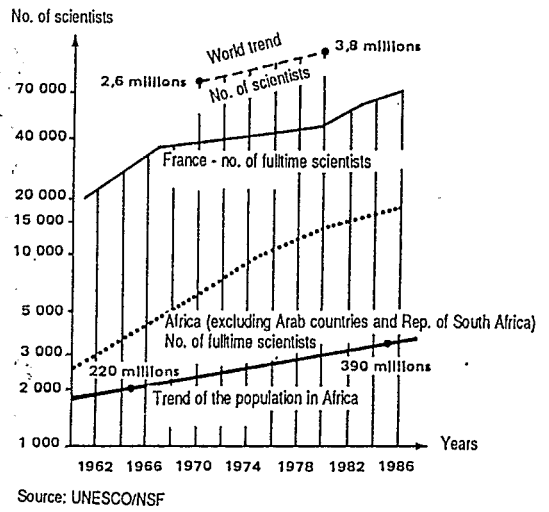

Figure 2. Growth in number of scientists in Africa.

formally established in 1966 but actually institutionalised an international programme that had begun in 1943. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was founded in 1972, in India. The ICRISAT Sahelian Centre was created in Niamey in 1981. Varieties developed in India were tested in Africa, but most of them proved to be unadaptable (Harrison 1987). After IITA, three other centres were created in Africa in the 1970s: the International Laboratory for Research on Animal Diseases (ILRAD, Nairobi, 1974), the International Livestock Centre for Africa (ILCA, Addis Ababa, 1974), and the West African Rice Development Association (WARDA, Monrovia, 1976) which has now moved to Bouaké, Ivory Coast.

Resources

Africa now has[5] 0.36% of the world's scientific potential (close to 20,000 research engineers and scientists), accounts for 0.4% of the world's research and development[6] (R&D) expenditure, and produces 0.3% of mainstream science[7] (published, listed, cited, and commonly used science). This may be small but it is not insignificant (Fig. 1) It is, in any case, much more (both in absolute and relative terms) than three decades ago (Fig. 2).

It is important to note:

— that the size and sophistication of scientific work differs enormously from one country to the next. Africa has two "giants", Nigeria and Kenya; 1/3rd of the total African scientific potential and 1/2 of the scientific output come from these two countries. There are about 15 middle-liners. At the other end, some 30 countries account for 1/6th of the continent's potential (Fig. 1). There are

actually two blocks: one which has already built its scientific institutions and the other block which still has to build it up—with the help of foreign aid.

— that the fields and themes for research are limited. Africa does not indulge in "heavy" science. There is little basic science, scientific engineering or social science. Efforts bear heavily on specific themes falling under medical and agricultural sciences. A noteworthy effort has been made in these fields, and African science is on the way to making its voice heard on the international stage.

— that once the critical mass (which need not be very great) has been obtained, there may be differences in the organisation and management of science, scientific orientation, and professionalism. This can be seen from the very different pace of scientific work in the various countries (Fig. 3) and the discrepancy in rankings both as concerns manpower and scientific output (Table 1). The next section looks at the quality of the resoures being used.

Table 1. Research Potential (Number of Scientists) and Mainstream Scientific Production in Africa: Recent Trends and Rankings.

Countries	Rank in Africa (and % of African total)				Trends (1975-1985)*		
	GDP (a)	Population (a)	No. of scientists (b)	Scientific production (c)	R&D spending as % of GDP	Growth in No. of scientists	Relative mainstream scientific production
Nigeria	1° (40%)	1° (26%)	1° (18%)	1° (38%)	=	A (× 4,6)	↗
Kenya	4° (6%)	6° (6%)	9° (4%)	2%HS (13%)	↗	A (× 3)	↗
Ghana	10° (3%)	8° (3,5%)	2° (14%)	↘	E	↘	
Other English-speaking countries	(23,5%)	(21,5%)	(27%)	(20%)	↘	C	↘
Ivory Coast	5° (4%)	12° (1,5%)	12° (3%)	7° (4,5%)	↗	C	↗
Senegal	14° (1,5%)	12° (1,5%)	8° (4%)	7° (4,5%)	↘	C	=
Cameroon	2° (7%)	11° (1,7%)	11° (2,5%)	(2%)	↗	C	↗
Other French-speaking countries	(10%)	(21%)		(10%)	↗	B	=
Other countries	(5%)	(<7,5%)		(11%)	↘	D à E	↘

Source: L'Etat du Monde, 1985 GDP, 1975 population. (a) Definition of classes: A = > × 3; B = × 1,9 to 3; C = × 1,6 to 1,9; D = × 1,4 to 1,6; E = < × 1,4. (b) UNESCO/ISNAR. (c) Davis, 1983.

* In many countries the economic and financial crisis has accentuated a downward trend that started in the beginning of the 1980s. This drop is not always visible in mean figures for the 1975-1985 period.

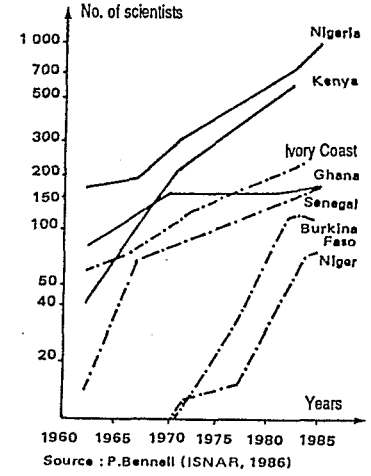

Figure 3. Growth in number of scientists (including expatriates) working on agriculture in a sample number of African countries.

Human resources

Figures 1 to 3 measure growth of scientific personnel over three decades. The overall effort is very sizeable, although most French-speaking African countries still rely heavily on French scientists (Medjomo 1987, Gaillard 1988), who still accounted for 30 to 40% of the total scientific strength in Ivory Coast and Senegal in 1988. This dependency is stronger within institutes than within universities.

The largest number of the most qualified scientists work in the universities. University scientists produce the most mainstream science and are the only ones to engage in exact sciences. The 1970s, and even more so the 1980s, have brought about some change. Increased enrolment, new faculties and a gradual move away from the capitals haved led to a Balkanisation of university education. Work conditions in the teaching profession have deteriorated. Overworked teachers, often obliged to structure courses at an elementary level, are judged on teaching rather than research. Resources for experiments are often largely insufficient. Hanlon (1979) quoted a Ghanaian university professor as saying that no responsible scientist with a family to feed could afford to spend time doing research. Salaries are so low that a university teacher often has to find a second job either as an international expert or a business consultant or has to create some enterprise that has relatively little to do with his scientific domain (Ehikhamenor 1988 and Gaillard 1991).

This situation has had rapid repercussions on the measurable effect of national scientific output. Eisemon has shown that in English-speaking Africa,

the "mandarin" psychology shifts the onus of teaching to young academicians, sparing the professors who still have some time to do research (Eisemon 1982). French-speaking Africa, by recruiting more professors, has unquestionably better accommodated the increase in student body. But the situation is critical there too. Will this lead to serious curtailment of university research? The question is of great immediacy. A keener analysis must be made before emulating countries such as India which has created a new panoply of *technological institutes* and *national university centres* reputed for their pockets of excellence. These new institutions are selective in their recruitment and provide close interaction between education and research.

The African national research system relies heavily on the network of specialized research institutes. These institutes are directly under the government and work full time on research in priority fields, which are usually technical areas related to agriculture and health. Their scientific staff has been growing at over 12% per annum, with a significant number of increasingly qualified Africans. Some of these institutes rank among the most productive, visible, and effective in Africa[8].

But that is not the end of the tale. Idachaba's study of Nigerian institutes is a good example of looming difficulties. Scientists in the institutes are less qualified, or have fewer diplomas, than the University scientists. They also have far fewer opportunities for scientific communication and refresher training. Their responsibility for a multitude of duties, ranging from supervising construction at an agricultural station to extension work, leaves them little time for recording their observations, even less time for analysing them in preparation for publication. As an example we need merely to note that scientists in institutes in Nigeria only produce one article every 10 to 25 years (Idachaba 1980). There are very few institutes that have their own journal. Grey literature (unpublished work) is poorly referenced and disseminated, or gets lost, and is often repeated (Idachaba 1980). Institute scientists have the status of a government employee, and are paid and esteemed less than a university scientist (even when they have the same qualifications). They are especially appreciated for their willingness to carry out the pressing demands that the institutes receive from their—often numerous—parent organisations (van Dijk 1986). Their reaction is to handle research themes and assignments as routines. One example can be seen by the fact that two-thirds of the agricultural breeding and trial experiments involved rice and wheat, two prime cereals that have already been well studied (van Dijk 1986, Idachaba 1980).

A point should also be made of the tendency for scientists to engage in parallel, more profitable and gratifying activities, and their escape to other functions. Low salaries and poor prospects for career development drive institute scientists to this way of life more than their colleagues at the universities. In an effort to show their appurtenance to the elite class, institute scientists often seek university posts or try to gain reputation among the intelligentsia. The result is a fast turnover. It is especially difficult to attract and/or retain highly qualified institute directors. In Nigerian institutes, 20 to 50% of the scientific

posts are vacant, the highest proportion of vacancies being, by far, at the most senior levels. For a five-year period the turnover is between 60 and 80%, and gets worse with time.

ISNAR (1988) looked at both English- and French-speaking Africa and came to the conclusion that, "It has not been possible to develop experienced and stable 'critical masses' of researchers in the key disciplines. Equally important, graduate recruits have frequently not received the kind of expert supervision and mentorship which is normally expected from experienced colleagues in scientific communities."

The constant turnover of scientists means that much work is slipshod, incomplete, and unrecorded, and that the available scientists are young, rather inexperienced, unmotivated, and reliant on scientific supervision. This has led to the growth of a management system that is both topheavy and sluggish. One of the main concerns is to find a solution by adopting a functional scientific management or even by creating new institutes. This situation is not unique to Africa. In many countries of Latin America, research divisions have been set up under ministries with technical portfolios. Their quality and dynamism are extremely variable and depend on how much autonomy they manage to obtain. The Latin American tradition has intellectuals coming and going between the universities, consultancy offices, and government services. The result is significant—but often precarious—success.

A very limited private sector

Normally, national research systems are complemented by private, generally, industrial research. This phenomenon is exceptionally limited in Africa[9]. Private research is generally found in countries with weak research systems and focuses on exact sciences and engineering, especially mine engineering in English-speaking Africa. We could also add agricultural engineering, often connected to major rural development projects[10]. All this work is adapted or adaptable, skilfully done and sometimes even innovative, but unfortunately, often kept confidential, unrecorded, and disjointed[11]. According to David (1983), the visibility of private undertakings is next to nil in Africa but clearly visible in the country of the corporate head office, i.e., United States, South Africa, EEC (except France and Great Britain). What lacks most is the echelons of development. This is because multinational firms, mainly oil, chemicals, and pharmaceuticals, after working through their R&D departments to support local exploration and experimentation programmes, finalise their "discoveries" in laboratories located elsewhere. Science that is useful to Africa, thus, is often produced outside the region, which creates the problem of availability and ownership[12].

All the sectors (institutes as well as universities) still have multiple causes for concern

— *Shortage of technicians.* The (too) few that have been trained are so underrated that the more quick-witted ones leave the country, work for industry, or establish their own business[13]. This leads to insurmountable, even crucial,

problems of ordering, delivering, installing, and maintaining equipment, be it sophisticated or simple, much of which, in any case, is underutilised or left idle (Gaillard and Ouattar 1988).

— *Too high an auxiliary/scientist ratio.* There are about ten typists, lab assistants, gardeners, messengers, watchmen, and drivers for every scientist[14]. The research budget required to pay their (albeit, small) salaries, is so heavily punctured that in some cases nothing is left for experiments. The extreme is in the case of agricultural stations that are converted into food crop plantations to feed the staff (van Dijk 1986).

— *Cruel shortage of qualified managerical staff.* Careers outside the national research system have more appeal which means that many positions remain vacant. The senior scientists and directors have to take time away from their scientific activities to discharge managerial duties (Idachaba 1980).

— *Communications problems.* Very few African countries have scientific publications. Journals are few in numbers and irregular in supply. National budgets and foreign aid neglect support for them. Distribution of international journals leaves much to be desired. The stimulation effect, feedback, and repercussions such as requests for reprints and incorporation in informal networks are weakened. Libraries are in a state of misery. In the poorest countries, journal subscriptions are not renewed, scientific personal meetings with colleagues receive even less support. To honour an invitation to go abroad commits the scientist to hurdling a veritable obstacle course: exit visas, foreign currency, depleted travel budgets, the administration's hint of suspicion that the trip is for pleasure, or an unjustified privilege for a senior civil servant. Organising scientific meetings in Africa is even more hazardous. And yet, such meetings are the most effective channel for durable scientific contacts and the establishment of societies of scholars (Chatelin and Arvanitis 1988).

This thicket of problems is leading national and international political decisionmakers and experts to explore a new "circumvention" strategy. In the more advanced countries thought is being given to the creation of institutes of excellence where problems of salaries, careers, scientist/technician and scientist/auxiliary ratios, operating budgets, and support for communications would be worked out on an entirely different basis. Considering the great differences between the countries, thought is also being given to institutes of excellence, as described above, which would have a regional mandate—centres of excellence supported by several states, based in different countries, specialised according to the ecological and economic requirements of their home zone. Experts feel dubious about this solution[15] because of past experience. Tremendous amounts of time, money, and energy have been spent on pacifying and mending relations between the founding states, not to speak of inter-state rivalry, intense pressure from each state to get maximum gain from its input, and accommodation of special requirements for particular regions and minority groups. Regional centres imbued with the success of their haloed formula tend to favour networks that have a hierarchical structure for various existing specialties, but leave the universities to fend for themselves. This system seeks to put every

existing institute in its rightful slot, according to its productive capacity measured in terms of the quality of its staff and the efficiency of its scientific management. In this system the regional centres would become leaders and conduct basic research. Certain national centres could work on application, most would work on adaptation. These are the key points of a very pithy political debate referred to again further on. The preceding chapter gives us an idea of what is at stake.

Budgetary resources

Efforts extended during the last three decades have developed considerably (Fig. 4). Progress and growth rates vary according to national size, wealth, and strategy (Fig. 5). Countries such as Zaire, Ghana, Uganda, and Ethiopia have barely been able to maintain, or are leaving untapped, what used to be a bright future. Other countries, the latecomers (Sahelian countries) are showing an exceptionally strong thrust. Certain French-speaking countries, viz., Cameroon, Ivory Coast, and Senegal, have not only built up a critical mass but have sustained a very steady, significant effort during the last two decades. Signs of slowing down have become somewhat noticeable since the beginning of the 1980s, however[16].

On the whole, up to the end of the 1970s, financial resources for R&D grew faster than the GDP. In the priority areas (health and agriculture) the R&D

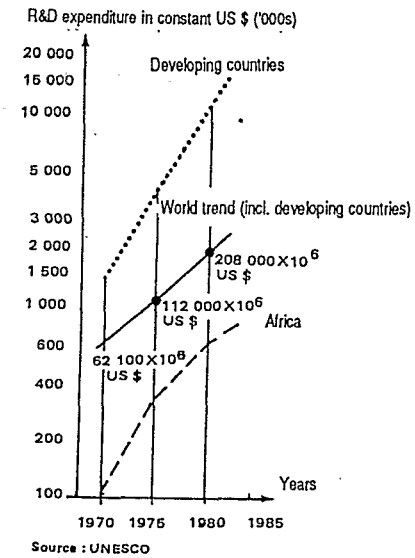

Figure 4. Total expenditure for R&D in Africa, in developing countries as a whole, in the world.

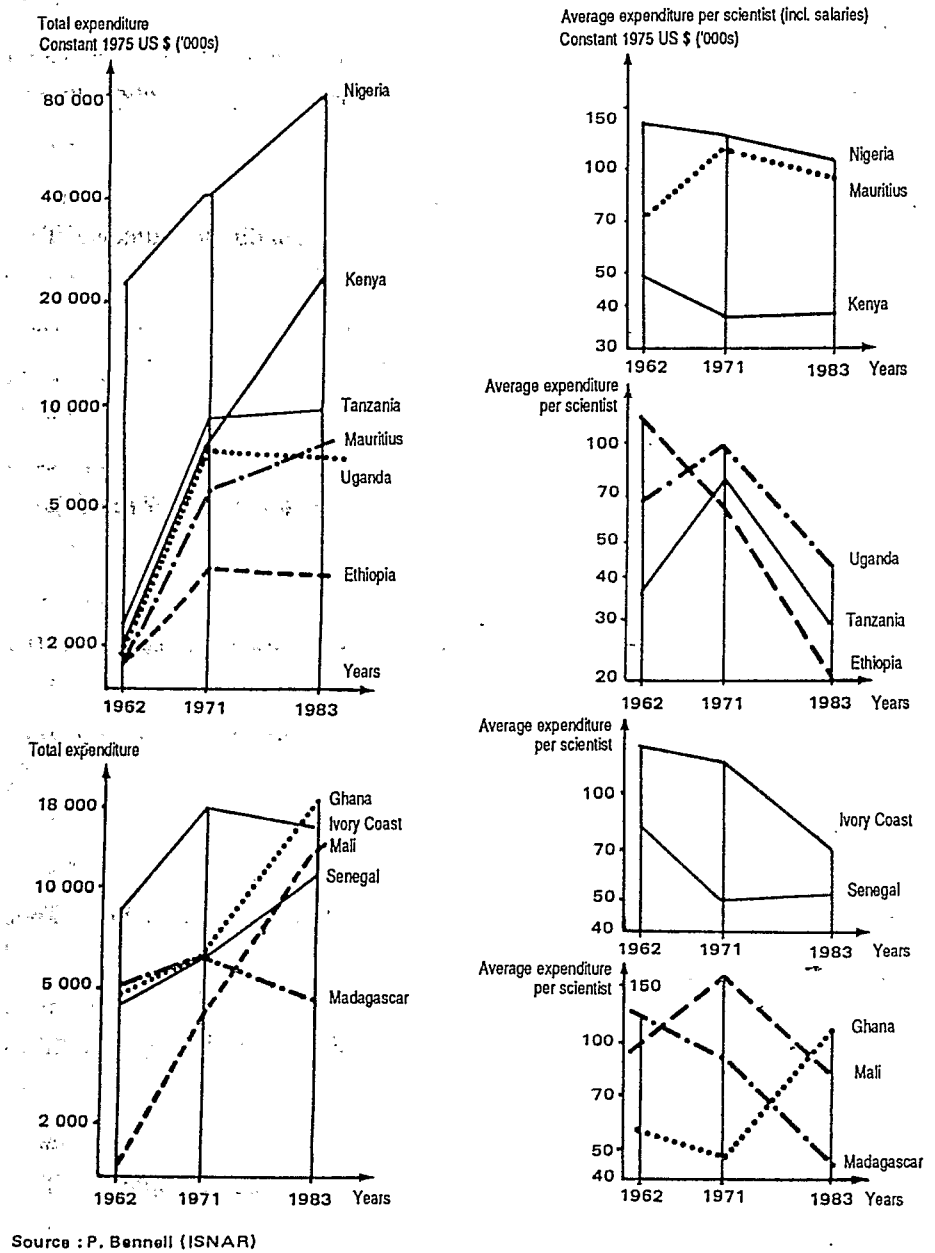

Figure 5. Growth of R&D expenditure in selected African countries.

budget had a respectable rank, even on the world scale[17]. But it would be wrong to think that funds were adequate since the percentage figures only give part of the truth. Further, the financial and economic crisis, especially service charges for the foreign debt, affect all public investments and often spell calamity for funding of national research systems. Setting aside the question of resources, there are several functional issues that need to be highlighted:

— The budgets focus excessively on (too) few fields of activity.

— Funding often comes from foreign aid, which pays for 70% or more of the national research budget in some African countries, e.g. Mali, Mozambique, Senegal, Lesotho, Swaziland, Zambia[18]. National funds are used to pay the salaries of the research scientists, technicians and national auxiliary staff. Whatever is left is used for the upkeep of oversized, scattered field stations. Botanical gardens, by tradition, ride the fringes of research budgets. The main hospitals in the national capitals, built in the 1960s, spend a goodly part of the national health budget for their operating expenses. Buildings, government-paid housing for civil servants which is a remnant, often a very hefty one, of the colonial system, large numbers of agricultural stations that, in some cases, have become inaccessible because of lack of roads or vehicles, all draw heavily on the natonal research budgets.

— Certain rather slight but directly productive costs, (reagents, experiments, travel to the field), and scientific communications costs (subscriptions, publications, conferences) are no longer funded. They are subject to uncanny fluctuation, or else rely, rather precariously, on foreign aid. In this scenario, the large, routine programmes are least affected. The jerks and jolts bring research to a grinding and premature halt with results left dangling. The present trend is the adoption of shortsighted programmes, with neither follow-up nor strategy, often carried out through a contract agreement with the World Bank or some other foreign body.

— A mention may also be made of the archaic budgetary procedures, a carbon copy of the ones used in the civil service, characterized by inadequate classification, a *priori* control methods, excessive centralisation, and administrative red-tape especially so in the research institutes[19].

Organisation

Institution-building has been an active process over the last twenty years in Africa. In the beginning, the governments tackled the problem of building up a state. Then, they slowly became aware of the strategic value of scientific research and decided to create specialised, supervisory institutions to ensure a single line of responsibility. The budgets, policies, and international negotiations that affected the research institutes were all centralised (Table 2).

With this structure, it became possible to apply a *bona fide* research policy in harmony with the development strategy and the related sectoral policies. Accidental (oft cited) dysfunctioning stemmed from excessive centralism. In this vein, Nigeria went the farthest. As of 1973, even the details of negotiations for foreign support were centralised. Local interests were poorly assessed. Pro-

Table 2. Modalities of Nationalization of Agricultural Research Institutes in Francophone West Africa.

Modality	Countries (Institutions)
1. Creation of one research Directorate under one or two ministries	-Benin (Min. of Rural Development) -CAR (Min. of Rural Development) -Chad (Min. of Rural Devt+Min. of Agric.) -Togo (Min. of Rural Devt) -Congo (Min. of Scientific Research)
2. Creation of specialized institutes to supplement existing research capacity	-Burkina Faso (CRTA) -Cameroon (IHS) -Senegal (ITA)
3. Creation of specialized institutes absorbing existing French research	-Ivory Coast (IDESSA) -Senegal (CNRA, CRODT)
4. Creation of various multiprogram national institutes	-Burkina Faso (IBRAZ, IRBET) -Cameroon (IRA, IRZ) -Mali (IER, INRZFH) -Mauritania (CNRADA, CNERU)
5. Creation of one multiprogram national institute	-Ivory Coast (INIRA) -Niger (INRAN) -Senegal (ISRA)

Source: Rochetau cited by Van Dijk (1986).

ducers' interest were neglected, and relations with extension services were too lax (Idachaba 1980).

It is advisable, and indeed most urgent, to change this unfortunate, abnormal way of functioning. The solution quite paradoxically may well lie in closer—and more qualified—political guardianship working with more autonomous institutions that have a genuine scientific management capability. Accepting unqualified patronage from special, regional or foreign, groups will not facilitate making national policy more coherent. Like centralism, it cannot guarantee that local needs will be properly met. The best solution seems to favour autonomy with qualified guardianship and scientific guidance, together with regular *a posteriori* evaluations.

Scientific production: proportion and disciplines

The number of publications registered for Africa in the main international database, ISI[20], has gone up significantly, over 9% per year during the last decade, i.e., at the same rate as the increase in the number of scientists. The percentage is higher for the universities and lower for the national institutes. Despite a real effort, the figure for agricultural sciences is going down. This reflects the exceptionally large contribution from countries whose national systems are of a good size and are not too fragile, in other words, systems with existing or emerging scientific communities: Nigeria and Kenya, with 1/3rd of the potential, generate more than 1/2 of the output; Ivory Coast, Tanzania, Senegal, and Cameroon appear to be significant; Ghana, Sudan, Uganda, and

Table 3. Variation in Scientific Production in a Single Field Depending on the Country (No. of Publications for n Scientists per Year).

	Africa					
	Nigeria	Senegal	English-speaking	French-speaking	Total	Brazil Chile
Tropical agricultural sciences	1/18 (a)	1/14 (a)	1/14 (b)	1/20 (b)	1/16 (b)	1/15 (b)
	Egypt	India	Philippines		Mexico	France
	1/25 (a)	1/25 (a)	1/40 (a)		1/60 (a)	1/13 (c)

Source: (a) Chatelin and Arvanitis (1988), Pascal database, 1983. (b) Davis (1983) SCI database, 1980. (c) Chatelin and Arvanitis (1988) personal database, average for 1950-1985 for one French joint research institute.

Ethiopia used to excel but are now on the decline. On the whole the African scientist's contribution to mainstream scientific production is scanty, although its productivity is not necessarily less than in other LDCs (Table 3).

Like certain other observers, we are concerned about the steady decline during the last 15 years (ISNAR 1986, Gaillard 1988). However, there are marked differences among the countries that reflect differences in research systems, publication strategies of scientific communities, disciplines, and the institutional framework of the home organisation (Table 2, 3, and 5). Each field of production is quite different (Table 6). Agriculture and health lead by far, accounting for over 80% of the total African output, which is higher than the percentage for the LDCs as a whole. The national profiles that Frame (1977) identified early in the 1970s moved closer to the Ghanaian model, which is characterised by strong emphasis on agricultural sciences. Medicine was a leader in the Anglo-Saxon tradition, but is dropping off. The exact sciences and engineering are progressing very slowly[21], essentially in the universities. Social sciences produce little (only about 1/4th of the amount that comes from exact and natural sciences), do little analytical work, and concentrate on rural problems.

Visibility: who feeds on African science?

The Science Citation Index (SCI) of ISI can be used to count citations of the articles it contains. Hence visibility can be measured, as Rabkin et al. (1979) and Davis (1983) tried to do for Africa. They reached the following conclusions:
— The citation rate for Africa throughout the world is "normal". This especially applies to the OECD countries, less for the eastern countries, Latin America and Asia. India and Pakistan are exceptions since they mainly cite

Table 4. Variation in Scientific Production per Discipline (No. of Publications for n Scientists per Year).

Country \ Science	Agriculture	Medicine	Exact sciences	Social sciences	All sciences combined
Nigeria	1/18 (a)			1/12 (b)	
Senegal (c)	1/12	1/5	1/3	1/15	1/6*
South Africa (d)	1/16	1/3	1/3	1/15	

Source: (a) Chatelin and Arvanitis (1988), Pascal database, 1983. (b) Ayiepeku (1975) local database, averages 1948-1974. (c) Gaillard (1988), Pascal database, 1980 * Davis (1983) obtained 1/8 1980. (d) Davis (1983), SCI database, average for 1970-1980.

Table 5. Variation in Total Mainstream Scientific Production (All Sciences Combined) Within a Country According to the Type of Institute.

Country \ Institute	University	National institute	International institute	Bilateral institute	Total
Senegal (a)	1/7*	1/20		1/4	1/6
English-speaking Africa (b)	1/5				
French-speaking Africa (b)	1/15				
Africa	1/7	1/15	1/4	1/6**	1/10

Source: (a) Gaillard (1988) Pascal database 1985. (b) Davis (1983) SCI database, average for 1970-1980 * Davis (1980) SCI database, obtained 1/12 for the year 1980.

Table 6. Production Per Main Scientific Discipline (By % of Publication).

	Medicine	Agriculture	Environment	Exact science	Engineering
Africa 1977*	55	30	7	5	3
Africa 70's**	38	44	7	11***	
DC average	39	35	5	13	8
World average	43	12	3	31	11

Source: * Frame et al. (1977), ** Davis (1983). *** combined total of Exact sciences and Engineering.

work from Kenya. Citations come from scientific communities of a certain size and age, e.g., Nigeria for physical science.

— Africa has an exceptional tendency for intra-African, more particularly intra-national citation. This trend is especially strong in Nigeria where it reflects the introspective attitude of the scientific community (and its extreme: scientific isolation). The same trend is noted in varying degrees everywhere: French-speaking Africa, except for the international agricultural centres, knows next to nothing about the science produced elsewhere on the continent.

— The degree of visibility and the publications strategy depend more on discipline than on institution. In universities in Nigeria, Kenya and Zimbabwe the exact sciences (mathematics and physics) have proven to be more cosmopolitan and internationally visible. Sciences more closely linked to site-specific observation (botany and zoology) enjoy a type of African (intra-national, but also intra-African) hypervisibility. Paradoxically, the former colonisers do not pay special attention to work conducted in their ex-colonies, except in sciences that require observation.

The "communications system" is somewhat more operational than expected, and the desire for scientific relations seems to grow as the scientific communities mature. This leads us to reverse the question in the title to this paragraph and to ask what science feeds Africa? To our knowledge there is no study that provides an answer[22] to this vital question. Science available to Africa quite clearly exceeds the science that is produced in Africa[23], but is it accessible? How can the network be built and kept up?

Impact on development

Is science going to be judged by its effects on daily life? Judging science is a risky undertaking. In the field of agriculture, the slight production increase in Africa is not considered to be the result of yield improvement; 80% of the increase in agricultural output in Africa between 1961 and 1980 came from the use of more lands. For world production during that period, 75% of the increase came from yield improvement. Global correlations between research efforts and socio-economic progress provide little information on the process. Each discipline needs to be analysed separately.

Agricultural sciences

Idachaba studied changes in agriculture in Nigeria by looking at yield increases, sustainability of yield increases per plant and per region over a 10-15 year period, and in relation to recommendations made by the research services. The results are varied.

— For certain plants such as rice, cotton, cocoa, and millet, significant success is related to the selection of high-yielding varieties[24]. Positive results can be obtained when political leaders, research scientists, and well-organised producers cooperate closely, and when research institutes have the right scientific ambition and proper management.

— Crop susceptibility to environmental factors has hardly changed. That is the other side of the coin. Breeders work on their own, rather than with plant pathologists and agricultural entomologists. The breeder is more concerned with increasing yields than with developing varieties that are adapted to difficult cropping conditions, such as lack of fertilizers.

— Research cannot be blamed for poor performance in fields that it has hardly touched, such as forestry, livestock, aquaculture (despite the fact that these fields are of national importance as potential remedies to certain urban shortages), and other fields not directly related to agricultural production such as industrialisation and social sciences[25].

A more recent study on Senegal (Sène 1985) stresses that results are better disseminated when researchers are concentrated in a given region, e.g. the

groundnut basin, for extended periods of time. Furthermore, since data from applied research become obsolete very quickly, discontinuity of work can lead to gross inefficiency. The role of the economic environment, social structures, and companion programmes have proven to be decisive. Because of cost of inputs and the difficulty of obtaining credit, recommendations made by the research services, too aloof from the socio-economic realities, have not been very practical. The amounts of fertilizers used, for instance, are often so far below what research recommends that they skim the "threshold of uselessness".

Medicine and health

This sector can be credited with at least part of the spectacular 12-year gain in life expectancy (from 36 to 48 years of age) Africa registered between 1955 and 1985. Yet despite the considerable effort made by medical research, the results, reflected in the public health, are often disappointing. The national health capability is concentrated in the main hospitals located in the capital cities leaving little room for clinical research, therapeutic tests, or application work except in difficult, rare cases that are investigated in the university hospitals. The international pharmaceutical industry has met with considerable success outside of Africa in developing new drugs. But the discontinuity and dispersal of national health care facilities result in the use of the same molecules everywhere, which may have side effects or may create resistance in the microbial strains. Great hope was placed in ambilar, for instance, because of its effectiveness in curing bilharzia, which formerly was uncurable. But repeated use of this drug, without any substitute, has led to serious kidney disorders. Malaria control measures need to be reviewed in many countries in spite of the new malaria pills that are now available. Discoveries are not keeping up with new challenges.

The most significant results come from epidemiological work carried out on diseases that are commonplace and are etiologically well studied and through local control measures that are organised to combine care and prevention[26]. Unfortunately national funds are devoted to running the hospitals and are not available for such programmes whose success can be credited essentially to the bi- and multilateral aid agencies, especially WHO[27].

It is difficult to measure the impact of science with a single yardstick since the most effective actions have often received the most severe economic judgement. In far-ringing reports to the World Bank or the EEC, Eliot Berg and others of his ilk measured, and, in the absence of productive support programmes, condemned the cost of saving (often handicapped) lives through a sustained vaccination programme or through the onchocerciasis eradication programme in West African countries with an economic growth rate much lower than the population growth rate.

Furthermore, it would be unwise to stigmatize clinical and basic research because, in fact, it keeps the country's sharpest minds alert. The public, rather than favouring preventive care, which seems dull and not visibly effective, favors a hospital for treating some extreme cases, or encourages discoveries by

the research services to cure some exceptional, terrifying affliction. After the transmissible diseases have been rooted out, there are other fields of research that are already well-targeted considering the growing morbidity rates caused by perinatal mortality, certain genetic diseases, or AIDS, the unexpected...

Efficiency and organisation of research

The preceding sections show the difficulty of assessing the usefulness of results generated by science. From the social angle, evaluations can be downright contradictory. Isolating effects is tricky, especially since some are delayed. Actually, up to now the African scientific system has had little effect on development, for reasons described above. One problem is that resources, including qualified staff, are assigned sparingly. Another problem is that since work is not carried out with regularity, and the research system suffers "outages", results quickly become obsolete and prove totally ineffective because they do not fit into a dissemination scheme and a world of innovation structurally connected to the world of research[28]. Lastly, development strategies that bear the mark of agriculture and tradition work essentially through applied routines, and are ill-prepared for the new situation created by urbanisation and industrialisation and for the world's innovative paths of development.

Idachaba (1980) listed seven factors needed for efficiency in the African research systems:

— the university-institutes linkage;
— regularity of funding;
— coherent planning;
— interaction between organised users, autonomous research institutions, and governments;
— strong political support, and stability of scientific communities;
— direction, leadership, and scientific management, and
— impetus from an active scientific community to replace a managerial approach by a scientific approach.

These lines of development underscore, once again, that the results of research are not "turnkey" consumer goods. Scientific research requires companion programmes, social recognition, and a link with the world of innovation. They may be partly state-driven, but only partly, and more indirectly than one might first think. A scientific society and its national orientation may have some intrinsic characteristics, invisible to the planners, which bolster the capacity for independent breakthroughs and the reproduction of science.

The uphill emergence of the scientific communities

Going beyond the availability of resources, the construction of institutions, and state orientations based on national goals, research needs a certain permanency through a place for science in the society, good management, and established scientific communities. Scientific ambitions, good choice of themes, innovations, and breakthroughs depend on such permanency, which relates to matters well outside of traditional planning techniques. Wherever scientific

systems have been set up—in some 15 countries already—the debate seems to centre on the quality of scientific output and the capacity of scientific communities to reproduce themselves and sustain their activity. The problem is to find the best system for supporting the emergence and reproduction of independent scientific communities[29].

Up to now nearly all science in Africa has been backed by government. In the beginning, the newly-independent states learned how to build a state and all its machinery. Priority was given to education, up through advanced diplomas, in order to train high-level employees for the state. This concept led to the engagement of graduates without specific majors whose careers took them up the ladder to the chambers of power. The profession or even the vocation of research scientist was nowhere to be seen. The career is avowedly not attractive, and there is a crying need for statutes and a social status for the research profession.

The social status of scientist can be improved when the profession of scientist is adopted by dominant groups in the society traditionally connected to wisdom. Using the example of western science that was brought to Bengal in the 19th century, K. Raj (1986) analyses the historical vicissitudes of members of the dominant Hindu castes, and particularly the Brahmans, who were the first and the biggest group in India to assimilate Western science. They constituted—and still do—the core of a brimming scientific community that enjoys its due social status. The social background of scientists in Africa is somewhat different; they come from a wider range of social classes[30]. The drive for social success has made students, from the time they select their major[31], more easily influenced by the planners' opinions and incentives. The rest of their career bows to the same forces. Research work orientation in Africa depends on budget allocations. Science as a profession is not independent of government and/or foreign agencies whose source of inspiration is utilitarianism; professional instability impedes the formation of scientific communities.

Conclusion

Do all these thoughts sidetrack us from practical questions concerning the state of science in Africa and the best way to support scientific development? Quite the contrary. We have seen that in many cases, the first steps of "institution building" have been completed, that significant, although insufficient, human and financial resources have been made available, and that from now on foremost consideration should be given to quality. The quality factor does not lend itself well to planning techniques and standard budgetary incentives. Part of the issue is institutional—what research system should be adopted, and what organisational procedures should be applied? Foreign aid as well as national policies (by discipline or even by scientific theme) will have to be redefined, and the instruments of evaluation will have to be refined. We mentioned the serious problems of redesigning agricultural research systems. We also mentioned the importance of sound scientific management. With decreasing productivity being the trend, both in universities and in institutes,

the main focus should be on the systems' functional quality rather than on quantitative expansion, on indicators of efficiency rather than on resources.

Ways need to be found to impact the scientific field itself, identify the most promising themes, help set up teams and sustain the best ones, and promote communication through national journals and conferences. The purpose would be to help develop a scientific nucleus with international ramifications.

In the developing countries, this requires constant implementation of a national science policy, which is unthinkable without a genuine professional status for the scientists, and greater autonomy for their institutions. From the vantage point of aid policy managers, this would require, with due consideration for the situation as a whole, relying less on aid packages and more on scientific leaders. This would also mean closer interaction between all parties concerned so that efforts are well coordinated and, consequently, resources are well used.

One could conceive of a regional African system, with a proper hierarchy, supported by national structures (of limited size) and intense regional cooperation, with a division of duties, the formation of networks, and the creation of inter-state research centres. We could however remain skeptical about that type of reorganisation, familiar as we are with the mishaps of regional research institutions, especially in East Africa, and the legitimate desire of each country to formulate its own research policy. In any case a regional strategy could only become truly productive if it were supported by consolidated national systems.

The operations described above obviously exceed the capability of administrators who have global responsibilities and must manage huge budgets. Institutional innovations and new parameters of action are needed. The most decisive new line of action would be to support emerging scientific communities as they develop their internal standards and their capacity to formulate proposals, negotiate, offer guidance and, at the same time, provide sound management for relatively autonomous institutions.

NOTES

1 At that time, however, and untill 1920 it belonged to the German East African Territories, before it was given over to the British Empire.

2 By way of example, during the second national development plan (1970-1974) in Nigeria, 63% of the agricultural research budget was earmarked for export crops, while food crops only received 33% (Idachaba 1980). Idachaba's study also explains reasons for the stagnation of food production in Africa, using Nigeria as an example. It especially flags the shortcomings of research.

3 For more information on the history of INEAC and the Belgian concept of agricultural research during the colonial period consult Cornet's book (1965).

4 It is regrettable that the main donors, who made it possible for thousands of young Africans to receive education, did not worry about what would become of them after graduation, nor about their place in the national economic fabric, especially in national research systems. In France it wasn't until the beginning of the 1980s that institutional innovations appeared, e.g., training-professional employment contracts negotiated between French research organisations and national research institutions in DCs such as Cameroon and Madagascar.

5 National figures are uncertain, often old, not uniform and are presented in incomplete series. In a world of numbers, facts may reflect the social—actually secondary—role the culture of the countries and their decision-makers (national, or assigned by development agencies) give to research. By matching sources we discovered logical aggregates, coherent magnitudes of size, and clear trends. The main sources were UNESCO, bi- and multilateral donor agencies (ISNAR adn FAO provided good quality data on specific sectors, targets and dates related to agriculture), and a few studies on scientometrics and science sociology (isolated but good quality).

6 Source: UNESCO (1985).

7 Source: Davis (1983) and Braun et al. (1988) African scientists often publish their work in local journals that are not included in the main international data bases. Much of their work remains unpublished, and hence unavailable to the international scientific community.

8 See Idachaba (1980) on Nigeria.

9 Ten to 20% of the resources devoted to private sector research in the ten African countries which extend the most significant effort, 50% in the OECD countries, and 60% in the newly industrialised countries and the fastest growing Asian countries (UNESCO 1986).

10 This is a specialty of French-speaking Africa where agricultural research is either turned over to CIRAD or, more often, to consultancy firms. Casas and Labouesse (1988) assess the potential at 1/5th years/agricultural research in West Africa. Research seems to come to a stop when the project to which it is connected ends. An average project "lives" five years.

11 An example would be trials in rural areas, crop diversification, analysis of production systems, and market studies.

12 Singapore and Taiwan have done a remarkable job in this regard by being pragmatic and not seeking total control of R&D done by multinational corporations. Kenya has been relatively successful. The more "dogmatic" African countries simply arrested all private research.

13 See Hanlon (1979) on Ghana.

14 See UNESCO (1986) for examples from 15 countries, also see Casas and Labouesse (1988).

15 The model has already been applied, e.g., the East African University which was created when the region became independent, and the Sahelian research institutes under CILSS.

16 In Senegal, for example, the funding for research dropped from 0.31% of the GDP in 1980 to 0.16% in 1985 (A. de Fondeville 1985).

17 According to Casas and Labouesse (1988) outlay for agricultural sciences in French-speaking sub-Saharan Africa represents 12.7% of the agricultural GDP (of which 0.6% is paid by the state) which puts the region slightly behind the North African countries (the Maghreb) but ahead of Greece, Spain, Italy, and Yugoslavia.

18 Here again there is great disparity since foreign aid in countries like Cameroon and Sudan represents less than 15% of the national R&D budget (Gaillard 1986).

19 One of the continent's leading hematologists said that in a country that does not suffer the worst from abnormal functioning, his main problem was importing certain vital reagents that are very rarely used. They are difficult to identify in the Customs nomenclature, and are valued 100 times higher than common laboratory products. The institute accountants and the public authorities, who issue the import licenses, do not accept or understand this situation (personal communication).

20 ISI is located in Philadelphia, Penn, USA, and analyses 4500 scientific journals from around the world.

21 It is striking that the Arab countries of North Africa produce ten times more in this field than the rest of Africa.

22 Preliminary results (Gaillard 1988) suggest that African scientists "feed" largely (80%) on mainstream scientific literature published in the northern hemisphere, but seem to receive it late; more than half the references used are over ten years old. Work published in local journals is more rapidly (but far less often) used.

23 In the field of soil sciences, our colleagues Chatelin and Arvantis (1988) have shown that 20% of the world's scientific output concerns the LDCs. Only half of this 20% is produced by or in the DCs.

24 IAR (rice and cotton) and CRIN (cocoa) have the most applicable and practical results. They publish (by far) the most, and their work is most often cited. Questionable results have been obtained on sorghum, chick peas, and groundnuts/ maize production has definitely dropped.

25 In Nigeria, the national rice harvest was so poorly husked, stored, and processed that urban consumers preferred paying a higher price and buying imported rice. Because of the increase in imports, increased local yields that had been obtained thanks to varietal improvement generated very little profit. A poor understanding of foreign markets, the social conditions of production, and the inefficiency of the extension services also hold back the development of national agriculture.

26 A study on Algeria (Waast 1981) reports a drop in infant mortality from 12.5 to 4.5% in five years following the sustained implementation of a vaccination-vitaminisation-water control programme backed by a care and prevention network.

27 WHO quite willingly and successfully turns over research work to French bilaterial institutes, especially ORSTOM and the Pasteur Institute.

28 From this point of view, medical research is in the best position since its research scientists are often also practitioners or service directors. Epidemiological research is not caught in a relay role since care and prevention are not separate activities. Agricultural research is less fortunate, mainly because the producers are less organised and the system designed to provide supervision for the rural areas is not all it should be. In other fields, research is expected to produce turnkey consumer products rather than to respond to local, social needs.

29 We do not mean professional associations or leagues but rather a naturally formed social group, with its own ethic, status-bound social conditions, vocation-dictated recruitment, and its own vision of the world.

30 J. Gaillard (1987) compiled substantial data on the choice of professions, but was not able to rank the preferences of the social groups. His conclusion is that after completing higher education, scientists do not enter research through a carefully planned choice, but rather because of some sort of serendipity and the possibility of obtaining a scholarship at the right stage in their training, even if it means going into a field that does not, *a priori*, interest them.

31 Eisemon (1982) cites many examples of students changing their majors during their studies to qualify for a position that fits in with a newly acclaimed national priority.

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ACRONYMS

CILSS	Comité Inter-Etats de lutte contre la sécheresse au Sahel (Inter-state committee for drought control in the Sahel)
CIMMYT	Centro internacional de mejoramiento de maiz y trigo (International centre for maize and wheat improvement)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (International centre for assistance in development-oriented agronomic research)
CRIN	Cocoa Resarch Institute of Nigeria
DC	Developing country
EEC	European Economic Community
FAO	Food and Agriculture Organisation
GDP	Gross domestic product
IAR	Institute of Agricultural Research, Nigeria
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
IFS	International Foundation for Science
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
IRRI	International Rice Research Institute
ISI	Institute for Scientific Information
ISNAR	International Service for National Agricultural Research
NIC	Newly industrialised countries
OECD	Organisation for Economic Cooperation and Development
ORSTOM	Institut français de recherche scientifique pour le développement en coopération (French Institute of cooperative scientific research for development)
SAREC	Swedish agency for research cooperation with developing countries
WARDA	West African Rice Development Association
WHO	World Health Organization