# Africa

JACQUES GAILLARD, MOHAMED HASSAN and ROLAND WAAST
IN COLLABORATION WITH DANIEL SCHAFFER

Africa is a rich continent: rich in biodiversity, rich in mineral resources, rich in precious stones. It is also a continent rich in traditional knowledge, especially knowledge associated with indigenous and medicinal plants. But Africa is also a poor continent; with roughly 13% of the world's population, it enjoys only 1% of the world's wealth. An estimated 50% of Africa's people live in poverty and 40% suffer from malnutrition and hunger. Two-thirds of Africa's land base is degraded and more than half of Africa's population is without safe drinking water. Malaria poses a serious threat in several regions and HIV/AIDS has devastated the youth of many African nations, including Botswana, the Republic of South Africa and Zimbabwe, where an estimated 25% of adults are now afflicted with this deadly disease.

What accounts for Africa's impoverished state? There are many political, socio-economic and environmental factors: centuries of colonialism followed by decades of home-grown authoritarian governments; a chronic lack of transparency in economic transactions, often accompanied by corruption; unsustainable use of natural resources; marginal participation in the global economy. However, there is another factor that may not be as visible or dramatic as those mentioned above but may nevertheless play a central role in the continent's inability to participate at the global economic level, protect its environment and devise sustainable strategies for economic growth. That factor is Africa's woeful shortcomings in science and technology (S&T) (UNESCO, 2000; *Current Science*, 2001).

Setting out from what was, in 1960, a very weak starting point in terms of home-based scientific potential (Eisemon, 1979), Africa went through a stage of rather intensive development of scientific institutions (research institutes and universities) during the 1970s and 1980s (Davis, 1983; Kolinsky, 1985; Gaillard *et al.,* 1997). Associated with this was an enormous increase in the academic population and a steady growth in the number of research scientists (Gaillard and Waast, 1993). This development was underpinned by aid, the amounts varying greatly according to the country involved.[1] Such programmes took on diverse forms: fellowships for training, research grants to individuals and teams, institution building, strengthening and twinning, North/South partnership research programmes and so on (Gaillard, 1999). By the end of 1980, the benefits derived from these investments were modest but tangible.

Since then, the state of S&T has deteriorated substantially in most African countries. Severe cuts in government spending have pushed institutions of higher education and research centres into steep decline. National educational and research coordinating bodies, once the focal points of reform for S&T, have lost much of their political power and influence. Indeed a significant number of these reform-minded bodies have been dissolved. Adding to the decade-long litany of problems that have fractured Africa's S&T infrastructure is the fact that virtually no recruitment took place throughout the 1990s and scientists' salaries are no longer adequate to live on. Recent assessments of African scientific research communities have detailed these prevailing dismal conditions time and again (Dahoun, 1997; Gaillard *et al.*, 1997[2]; Lebeau and Ogunsanya, 1999). Universities that once served as beacons of hope, including the universities of Ibadan in Nigeria, Dakar in Senegal, Dar-es-Salaam in the United Republic of Tanzania and Khartoum in Sudan, have been turned into shells of their former selves. Buildings are poorly maintained, modern laboratory equipment is rarely available, and faculty and staff go underappreciated and sometimes unpaid. Meanwhile, external funding for science and joint research initiatives with universities and research institutes in other nations have often declined. Given such circumstances, it should come as no surprise that the continent's best scientific talent continues to leave in large numbers, creating a chronic 'brain drain' problem.

In addition, official development assistance from the world's richest countries now stands at 0.22% of national gross



1. In some African countries, external 'aid' to research and scientific cooperation came to account for to 75% or more of the national research budget, for example in Senegal (Gaillard *et al.,* 1997).
2. See in particular the chapters on Egypt, Kenya, Nigeria and Senegal.

domestic product, far below the internationally agreed-upon target of 0.7%. No developing region of the world suffers more from this parsimonious level of aid than Africa. At the same time, it is true that the economic development and technology transfer strategies from the 1960s through the 1980s – often encouraged, if not devised, by Northern 'donors' – have not served Africa's interest well. Under these programmes, African nations with weak scientific infrastructures simply did not have the skills to evaluate the appropriateness of the technologies that were being introduced. At the same time, they lacked the critical mass of scientific and engineering talent necessary to add a great deal of economic value to the continent's vast wealth of natural resources by transforming them into products and processes that could command higher prices in the global market place than the unprocessed raw materials themselves.

Despite the unsettling trends resulting from a continuing crisis, there are reasons for hope about the future of S&T in Africa. Foundations and international organizations, for example, have recently launched ambitious programmes in consultation with African countries and institutions to rehabilitate higher education and research systems in a number of countries. Even more promising, initiatives taken by several African governments could boost the development of S&T on the continent. For example, a number of African science institutions have begun to recruit researchers again. Similarly, an increasing number of national research grant schemes have been established in recent years. More specifically, the government of Nigeria, after experiencing a staggering collapse of its scientific production during the last 15 years, has taken some important measures, including the establishment of an international board of science advisers and the granting of US$ 5 million to the African Academy of Sciences endowment fund. These measures could bring about positive developments for both Nigeria and the African continent as a whole.

This chapter of the *UNESCO Science Report 2005*, which examines the status of S&T on the African continent (including North Africa, the Republic of South Africa and the rest of Africa or 'Median Africa'), is divided into three parts. The first part offers a brief historical analysis of S&T development in Africa, a bibliometric panorama of African science through the 1990s and a brief inventory of S&T capacities. The second part analyses the extent to which the process of globalization has fundamentally altered what it means to be a scientist in Africa and changed the very nature of the scientific production. The final part examines perspectives and strategies for strengthening scientific and technological capabilities in Africa.

One of the main difficulties in writing about S&T in Africa is related to a lack of reliable data. This gap has been partially filled by a recent study on science and scientists in Africa at the end of the twentieth century.[3]

## THE COLONIAL LEGACY AND THE EMERGENCE OF NATIONAL SCIENCE

The first encounter with modern S&T in Africa was the result of European colonization. Many of the scientific pursuits in the colonies of Africa were confined to exploration, surveys, data collection and the application of techniques mainly to promote colonial economic policies. Nevertheless, the science taking place during this period left an important legacy inside Africa in terms of:

- **knowledge** (detailed inventories and recorded bodies of knowledge);
- **organizational models** (creation of specialized research institutes, full-time researchers employed as civil servants, etc.);
- **strategic choices** (agriculture and health, for example, emerged as research priorities).

This legacy grew even stronger after independence. In the 1960s, it was enriched by the development of national higher education systems. In the 1970s, it was bolstered by the 'nationalization' of research institutes, the 'Africanization' of

3. This study, coordinated by Roland Waast and Jacques Gaillard, and co-funded by the European Commission (DG Research), the French *Institut de Recherche pour le Développement* (IRD) and the French Ministry of Foreign Affairs, includes a comprehensive bibliometric study of science in Africa during the 1990s, country case studies carried out in 14 African countries (Algeria, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Madagascar, Morocco, Mozambique, Nigeria, Senegal, Republic of South Africa, Tunisia, United Republic of Tanzania and Zimbabwe) and some 400 interviews with scientists conducted in the same countries.





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

staff at both research institutes and universities, the expansion and multiplication of institutions, and the creation of national coordinating bodies mandated to define, implement and monitor national policies. In short, from 1965 to 1985, the African states put considerable efforts into developing national research systems with support from bilateral and multilateral cooperation schemes.

Such widespread trends fostered a mode of scientific development in which the state played a central role. That in turn propelled a new process of scientific production – 'national science' defined by the following principles:

- science is a public good;
- the main funding provider is the state;
- the researchers (and their scientific communities) have a nationalist ethos;
- research scientists are employed as civil servants;
- besides the peer community, the end-users consist principally of public authorities.

The era of national science in Africa resulted in some real success stories. In the mid-1980s, African scientific publications became visible on the international scene; eminent scientific figures emerged; centres of excellence acquired international reputations; and some celebrated innovations originated from home-grown scientific research (see box below).

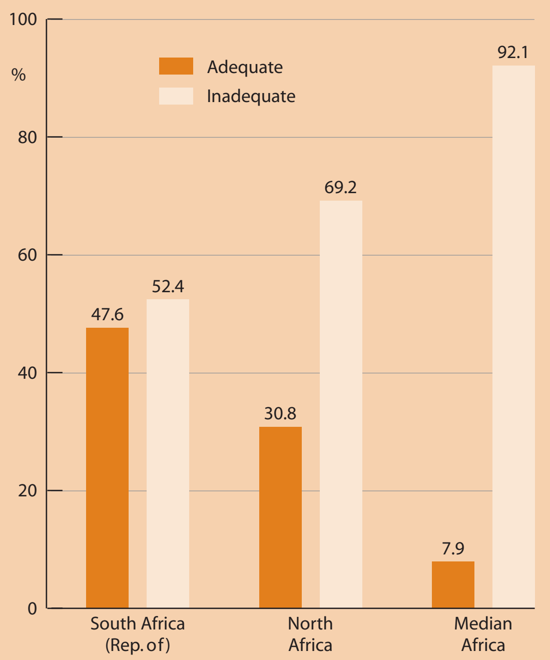
## A heterogeneous continent: North, South and Median Africa

When viewed from beyond the continent, there has been a tendency to see S&T in Africa as a single entity of concern. Although there is some truth in this perception, it is

## *Drugs from medicinal plants in Madagascar*

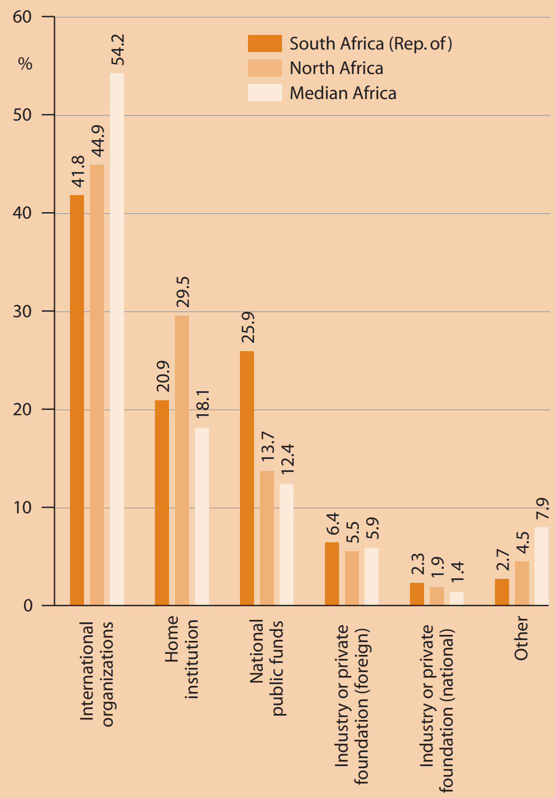
For more than 40 years, the Malagasy Institute of Applied Research, with a staff of 30, has sought to extract agents from indigenous plants to produce effective pharmaceuticals. For example, Madecassol®, derived from active agents of the Malagasy plant *Centella asiatica*, has been used to treat intense burns, leprous wounds and inflamed ulcers for more than a quarter of a century. Royalties earned by the institute for the critical role that its researchers played in the development of Madecassol® have generated thousands of dollars in annual revenues for the institute. The institute, however, does more than research the region's biodiversity for the purposes of developing pharmaceuticals. It also sells the drugs it helps create at subsidized prices to local populations, which allows them to enjoy the same health benefits as citizens residing beyond Madagascar's borders; it manages a health clinic that provides low-cost health care to nearby residents; it oversees a botanical garden to help preserve the region's rich biodiversity; it operates a small production facility that manufactures a variety of drugs for local distribution, including medicines to combat malaria, hepatitis and asthma; and it provides job opportunities to local residents in several different fields, both manual and technical, in a region where steady employment is hard to find. The Malagasy Institute of Applied Research was founded by Albert Rakoto-Ratsimamanga who continued to oversee its operations until his death in 2001. His wife, Suzanne Urverg-Ratsimamagna (an internationally recognized scientist in her own right), now heads the institute. She is expanding the scope and visibility of the husband and wife team's lifetime of work. Taking a long-term view, the institute's future rests on its ability to turn this family affair into a research institution that will continue to function long after its creators leave the scene. It is a challenge faced by many of sub-Saharan Africa's most successful scientific institutions.

Figure 1
ADEQUACY OF SCIENTISTS' SALARIES IN AFRICA, 1999
**By region and major country**




**Source:** Gaillard, J.; Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists. IFS Grantees and INCO Beneficiaries.*

Figure 2
SOURCES OF RESEARCH FUNDS IN AFRICA, 1999
**By region and major country**




**Source:** Gaillard, J.; Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists. IFS Grantees and INCO Beneficiaries.*

important to note that real differences exist between North, South and Median Africa in such critical areas as scientific infrastructure, budgeting, training and publication output. Moreover, it is important to keep in mind that not even the division of Africa into three scientific geographical regions conveys the diversity of experience that can be detected when closely examining the situation. For example, Median Africa, which today is the continent's most troubled region, is in itself far from being homogeneous.

A recent Africa-wide questionnaire survey (Gaillard and Furó Tullberg, 2001)[4] illustrates these disparities in relation to several key characteristics, three of which are briefly discussed below: salaries, self-sufficiency for graduate and postgraduate education, and the level and structure of research funding.

While African scientists acknowledge that they enjoy a high degree of job security, they also express strong dissatisfaction – indeed frustration – with their salaries and job benefits. However, scientists in the Republic of South Africa are much less dissatisfied with their salaries (52.4%) than their colleagues in North Africa (69.2%). Not surprisingly, scientists in Median Africa are the most dissatisfied with their salaries. A startling 92% of the survey respondents from this region said they were displeased with their earnings (Figure 1).

The number of students pursuing graduate and postgraduate education in African universities has increased considerably



4. 702 African scientists responded to the questionnaire.



UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

during the past three decades. Nevertheless, the higher the degree that is sought and ultimately earned, the more likely it is that a student will pursue his or her studies abroad – in Europe (mainly France and the UK) and to a lesser degree in Canada or the USA. While the Republic of South Africa's university system now allows it to be quasi self-sufficient in the awarding of all degrees, the university systems in North Africa and particularly Median Africa continue to depend on foreign institutions of higher education. This trend continues to take place despite recent statistics indicating an increasing number of Master's and Doctorate degrees received at home.

The structure of research funding also varies from region to region (Figure 2). Although international institutions or foreign nations remain the most important source of funding for science throughout Africa, Median Africa's scientific community depends more on outside donors than the Republic of South Africa and North Africa. Similarly, the Republic of South Africa and North Africa enjoy a higher percentage of funding from home-based institutions than Median Africa.

Other characteristics such as the relative importance of and trends in scientific output discussed below also show contrasting developments according to region. What such figures reveal is that there is not one but several Africas and that the scientifically weakest countries are located in Median Africa. All told, we estimate that there are about 10 000 full-time active researchers in Egypt and roughly the same number in Maghreb countries (Algeria, Morocco and Tunisia). Meanwhile, the Republic of South Africa has approximately 13 000 full-time researchers, which is comparable to the number of full-time researchers in the whole of Median Africa (Table 1).

## A BIBLIOMETRIC PANORAMA OF THE 1990s[5]

What can we say about scientific productivity in Africa today? An attempt to answer this question has been made by analysing the number of scientific publications in Africa indexed in the PASCAL database from 1991 to 1997.[6]

The PASCAL database shows that in 1991 African scientific production in terms of publications amounted to just 4% of the publications output of European scientists. In 1997, it fell to 3%. At the end of the period covered by the PASCAL database, the Republic of South Africa (the continent's main producer of scientific literature) had an impact comparable to Greece, and Egypt (the continent's second highest producer) had an impact comparable to Portugal.

Not too much significance should be placed on this comparison: Africa's research priorities are often substantially different from those pursued on other continents. Moreover, European researchers, particularly those working in smaller countries, have benefited from increased funding for science in the European Union as a whole. Such trends, which stand in stark contrast to the circumstances of researchers in Africa, have spurred spectacular growth in output among European countries which had previously lagged behind their neighbours. Despite all these qualifications, it is important to note that PASCAL figures for the output of scientific publications in Africa are low (Table 3).

With the Republic of South Africa representing approximately a third of the continent's scientific literature output, statistical analyses of the output of smaller African countries could be misleading and/or subject to substantial fluctuations from year to year. One or two articles could make a big difference. Lastly, the most recent trend (1991–97) shows that countries in North Africa now account for a higher percentage of scientific articles (37%) than the Republic of South Africa.

### Countries: the hierarchy

Scientific capacities are unevenly distributed in Africa and not always proportionate to a region's or country's wealth and/or population. Using 1991–97 publication scores as the basis of the analysis (excluding human and social sciences, which are not recorded by PASCAL), five main groupings can be distinguished:

5. This section draws on Arvanitis *et al.* (2000).
6. Despite its limitations discussed elsewhere (Arvanitis and Gaillard, 1992), we consider that the PASCAL database can be used with some degree of confidence to characterize the relative importance of the main science producers and to pinpoint shifts.

Table 1
RESULTS OF THE IRD SURVEY ON RESEARCHERS IN AFRICA, 1999
**Selected countries**

| | Staff in higher education | Researchers full time in the public sector | Researchers full time in the private sector | FTE[1] researchers | Researchers per million inhabitants |
|---|---|---|---|---|---|
| Algeria | 16 000 | 1 200 | 700 | 3 000 | 100 |
| Burkina Faso | 700 | 200 | 0[2] | 350 | 30 |
| Cameroon | 1 800 | 300 | 0 | 800 | 60 |
| Côte d'Ivoire | 1 200 | 500 | 0 | 600 | 55 |
| Egypt | 40 000 | 1 500 | 0 | 10 000 | 230 |
| Kenya | 1 800 | 600 | 0 | 1 000 | 35 |
| Madagascar | 900 | 260 | 0 | 300 | 35 |
| Morocco | 10 000 | 700 | 500 | 3 200 | 120 |
| Mozambique | 600 | 0 | 0 | 0 | 0 |
| Nigeria | 14 000 | 1 300 | 0 | 3 000 | 40 |
| Senegal | 1 000 | 435 | 0 | 600 | 80 |
| South Africa (Rep. of) | 17 000 | 8 500 | 5 000 | 13 000 | 350 |
| Tanzania, United Rep. | 1 400 | 0 | 0 | 600 | 70 |
| Tunisia | 9 000 | 800 | 400 | 3 000 | 350 |
| Zimbabwe | 1 100[3] | 300 | 0 | 600 | 30 |

1 Full-time equivalent. 2 0 = negligible. 3 Includes private.

**Source:** Waast, R. and Gaillard, J. (coord.) (2000) *Science in Africa at the Dawn of the 21st Century*. IRD, Paris.

**Group 1:** Two countries, Egypt and the Republic of South Africa, together represent half the continent's production (49%). In these countries of 'complete science', all disciplines (in our breakdown, 71 fields) are covered.

**Group 2:** Four countries account for a quarter (26%) of Africa's publication output: Kenya, Morocco, Nigeria and Tunisia. While these countries enjoyed well-established scientific communities in several fields at the beginning of the study period (1991), they are among those that experienced the most turbulent fortunes between 1991 and 1997.

The remaining 43 countries share 25% of the recorded production. They can be divided into the following groups:

**Group 3:** Seven countries – Algeria, Côte d'Ivoire, Cameroon, Ethiopia, Senegal, United Republic of Tanzania and Zimbabwe – regularly produce between 70 and 200 papers per year. This output is sustained either by groups or networks of scientists specializing in a few disciplines or by groups of scientists in a handful of cutting-edge institutes. Such people and places represent small pockets of research activity achieving modest levels of accomplishment (ranking seventh to 13th according to the classification).

**Group 4:** Some 14 other countries publish between 20 and 70 references on average each year: Benin, Burkina Faso, Congo, Gabon, Gambia, Ghana, Madagascar, Malawi, Mali, Niger, Sudan, Togo, Uganda and Zambia. Production in these countries often depends on a few eminent figures of science. As a result, the scientific infrastructure remains extremely fragile, highly sensitive to political change and dependent on external sources of funding.

**Group 5:** The remainder of the African continent consists of scientifically small countries whose performance in terms of scientific production is erratic and closely tied to a few authors or visiting scientists. This group contains countries that have recently experienced fundamental political change, international isolation, civil war and massive destruction of infrastructure.





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

## Countries: trends (1991–97)

While different databases provide different perspectives on trends in scientific publication output among African countries over the past decade, they agree at least on one point: in five years (1991–96), compared with Europe or with the rest of the world, Africa has lost 20–25% of its relative capacity to make contributions to world science. Furthermore – and this is the salient point – the paths of different countries have diverged enormously. Whereas in the 1970s and 1980s middle-sized scientific powers had been seen regularly to grow and become established (Groups 2 and 3 as already defined), the 1990s brought abrupt changes in fortune, completely upsetting previous classifications. The main changes are summarized below:

- The continent's two science giants – Egypt and the Republic of South Africa – encountered difficulties in maintaining their previous level of performance. The data from both PASCAL and the Institute for Scientific Information suggest that the relative contribution of both Egypt and the Republic of South Africa remained stationary.

Table 2
SCIENTIFIC ARTICLES PUBLISHED IN AFRICA, 1998
**Selected countries**

| | Number of scientific articles | Articles per million inhabitants | Articles per billion US$ GNP |
|---|---|---|---|
| Algeria | 241 | 8 | 5.5 |
| Burkina Faso | 72 | 7 | 26.0 |
| Cameroon | 167 | 12 | 18.0 |
| Côte d'Ivoire | 87 | 6 | 8.0 |
| Egypt | 1 313 | 120 | 17.0 |
| Kenya | 506 | 17 | 53.0 |
| Madagascar | 50 | 3 | 13.5 |
| Morocco | 510 | 20 | 14.5 |
| Nigeria | 450 | 4 | 14.5 |
| Senegal | 106 | 12 | 21.0 |
| South Africa (Rep. of) | 2 738 | 72 | 21.0 |
| Tanzania, United Rep. | 196 | 6 | 30.0 |
| Tunisia | 491 | 55 | 26.0 |
| Zimbabwe | 176 | 16 | 21.0 |

**Source:** Science Citation Index (North, South and East Africa); PASCAL (West Africa).

- Scientific output rose among Maghreb countries. In five years, Morocco doubled its score, to become the third-ranking producer on the African continent. Tunisia has also shown a strong surge. Even Algeria managed to improve its performance, despite disruptions caused by civil war and the persecution of its intellectuals. The portion of Africa north of the Sahara (including Egypt) now accounts for more than a third of African publications (catching up and even overtaking the output of South Africa).
- Nigeria experienced a staggering collapse in scientific ranking. In five years, Nigeria's scientific community experienced a 50% decline in output of scientific literature. In the absence of career prospects and faced with the dilapidation of establishments paralysed by large budgetary shortfalls, and with high staff turnover, a large number of research scientists have emigrated or changed profession. Many, while remaining scientists, also devote themselves to other activities.

Among Groups 3 and 4 – countries in which science rests precariously on the shoulders of a few teams of specialists – changes have often been sudden and unpredictable. Here are some noteworthy developments in this classification:

- Among countries experiencing an upswing in scientific output, Cameroon is now the leader of Group 3. While ranked 16th in 1981, it climbed to tenth place in 1987 and eighth in 1996. None of the primary indicators of the state of science in Cameroon (budgets and salaries have remained flat and scientific institutions have actually closed) help to explain these encouraging trends. Similarly, both the United Republic of Tanzania's and Senegal's scientific literature production continues to grow despite severe restrictions in operating budgets and poor working conditions (Gaillard and Waast, 2000).
- The most marked changes in direction are seen in figures recorded for the smallest countries in Africa. Ghana has recovered somewhat. In Malawi and Uganda, aid and cooperation from the USA and, to a lesser extent, the UK have stimulated a revival. The ebb and flow of aid and cooperation schemes can explain the progress of Burkina

Table 3
SCIENTIFIC PRODUCTION IN AFRICA, 1991–97
**By main linguistic and geographic area**

| | Scientific publications | Articles only | % of all scientific publications | % of all articles |
|---|---|---|---|---|
| English speaking (excl. South Africa) | 10 639 | 9 155 | 21 | 22 |
| French speaking (excl. Maghreb) | 5 938 | 4 958 | 12 | 12 |
| North Africa | 18 906 | 15 542 | 37 | 37 |
| South Africa (Rep. of) | 13 997 | 11 813 | 28 | 28 |
| Median Africa | 881 | 759 | 2 | 1 |
| **Total** | **50 361** | **42 227** | **100** | **100** |

**Source:** Publications indexed in PASCAL (1991–97).

Faso, uneven yet one of the most impressive cases. Its science leapt 20 places in ten years, 16 in the course of the past six years. Such an achievement has been possible thanks largely to sound support from government authorities, and the considerable ability of the authorities in charge of science.

- In contrast, Gabon, Mozambique and Niger, which were sustained not long ago by vigorous external support programmes, recently began to sink again into deep recession. The Republic of Congo, which in the 1980s was showing great promise, has slumped since 1994. The Democratic Republic of Congo (formerly Zaire) slips further into the depths of scientific obscurity, although 30 years ago the prowess of its universities would not have augured such a sad fate. It is hardly necessary to mention how insignificant scientific output has become for those countries ravaged by civil war, or confronted with famine, population exodus or obscurantism, such as Angola, Burundi, Liberia, Rwanda or Somalia. Sudan, which at one time occupied a significant position, is in a state of incessant decline.

As a general rule, the scientific performance of other countries is haphazard, subject to the whims of rulers and the instabilities of international cooperation. It would be unwise to comment extensively on their erratic courses. An exception is found in some small countries with an often limited scientific expertise skilfully run or serving as a platform for multinational research. Gambia's Medical Institute in Banjul and the Institute of Geophysics in Djibouti are two bright instances in an otherwise bleak scientific landscape.

## GLOBALIZATION: TENSIONS AND REORGANIZATION

Nowhere did globalization alter the ways in which science is structured as much as in Africa. This is no trifling paradox, as such a modification is mainly expected in developed countries and high-technology sectors. After 1980, the signs of a profound change began to emerge. It was, however, by no means confined to Africa. The free market ethos meant that governments everywhere reduced their intervention. The expected source of progress became innovation in private companies and no longer the discoveries of science.

In Median Africa, this disaffection for science (and indeed for education) occurred against a background of severe and enduring economic crisis. Research and higher education, in spite of the growing number of students (up 15% per year before 1990 or 1995), lost their priority. Buildings, facilities and conditions for working deteriorated at an accelerated pace. Budgets from the state were soon to serve only to pay the devalued salaries of S&T personnel.

In parallel, the intellectual professions and the civil service, often regarded as parasites, had their pay reduced. Not only were cuts in salary imposed by emergency economic measures




UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

(e.g. in Cameroon in 1993), but devaluations and runaway inflation (Madagascar: 20% per year between 1985 and 1996; Nigeria: 34% per year) led to a massive drop in researchers' purchasing power. To avoid humiliation, and a huge downgrading of their social position, many academic figures emigrated. They entered an international market of scientific work, first heading for countries of the industrialized North then, as such opportunities dried up, for other African countries where pay was higher (especially in southern and francophone Africa). Changes of profession without leaving the country are also common. Banks and industrial companies attracted many researchers in the years 1975–85 and international organizations and political positions did so a little later. Informally many teaching staff have a second job, which prevents them from devoting much time to scientific research. According to a recent study carried out in Nigeria, 40% work on farms, and 20% in shops (Lebeau *et al.*, 2000). Through this process of deprofessionalization, the pool of active people in science has significantly decreased in a decade. Parallel jobs are necessary to live decently. Among these, the practice of research can, for some, become an acceptable way of earning a living, provided it is carried out on a consultancy basis.

Many foreign clients – corporations, foundations and international organizations – interested in public health, resource development, nature conservation, population trends and good governance, as well as a wide range of smaller grassroots organizations concerned about such issues as women in development and poverty alleviation, often have job openings for scientifically trained personnel. Few such bodies, however, are interested in science for its own sake. Instead, they seek to use science in ways that have a direct impact on society. While such employment opportunities create valuable career paths for African scientists who have few alternatives, these opportunities often come at the expense of the continent's universities and research centres which are in desperate need of skilled personnel.

All told, the changing nature of scientific work in Africa has spurred professional and institutional crises marked by the following characteristics:

- Policies have become increasingly driven by laissez-faire principles (Waast, 2001).
- Deprived of budget and power, the national coordinating bodies have lost direction and become ineffective.
- Many scientific institutions have floundered. For example, agricultural research institutes, which had become accustomed to reliable earmarked funding, have found it difficult to adjust to a competitive funding environment that requires them to tailor their agendas to donors' expectations and goals. Universities, meanwhile, have failed to meet the challenges posed by dramatic increases in student populations and have failed to respond effectively to policies that have degraded – and in some cases abandoned – higher education's research responsibilities.
- There has been an erosion of academic oversight and direction. As national scientific communities become too impoverished or too small to function effectively, science as a profession has become increasingly individualized.

All these trends suggest that, while scientific research has not disappeared in Africa, in many countries its mode of production has been radically altered. Much closer to development than to investigation, it is less geared towards education and does not much lend itself to publications. In brief, the principles now driving research can be summarized as follows:

- the profession is practised within a system depending on orders for research work and on time-bound contracts (not in the context of a career);
- the activity is exercised in a worldwide network;
- international, not national, demand shapes programmes and objectives;
- benefits and profit, rather than knowledge, define the axioms for action;
- the system is increasingly regulated by the market, not peer assessment.

This cultural revolution is carrying tensions. A rift has opened up between the researchers attached to their old national ethos and researchers open to the market. A certain number of African researchers are hired virtually full-time on

## Scientific institutions across Africa

### NORTH AFRICA

Egypt has established a strong research apparatus. The country currently has 18 universities (six of them private), with a total enrolment of 1 200 000 students, including 250 000 in the sciences; a national centre and 35 institutes, staffed with full-time researchers and dependent on several ministries (research, agriculture, health, mining); and a few research units maintained by the industrial sector. The Maghreb countries, which developed their national research systems later than Egypt (since the 1970s), now enjoy the highest rate of growth in scientific output on the continent (10% per year since 1980). There are some strong points. Egypt remains the second highest African producer of science, with strong abilities in chemistry and engineering. Meanwhile, the Maghreb countries have developed good capacities in medicine and agriculture, physics and chemistry, and engineering.

### MEDIAN AFRICA

Compared with the other two sub-regions, the academic and scientific institutions in Median Africa are of more recent origin. The very first university to be established was the University College of Ibadan in Nigeria where the first science degrees were awarded in 1950. Following independence, in the 1970s and 1980s, the number of scientific institutions, professors and research scientists increased very rapidly. According to our survey (Waast and Gaillard, 2000), in early 2000, out of an estimated total of 13 000 full-time equivalent scientists in Median Africa, 5 000 are in Nigeria, 1 000 in Kenya and 800 in each of Cameroon, Côte d'Ivoire, and the United Republic of Tanzania. The top ten countries contribute some 90% of S&T resources. Efforts bear heavily on medical and agricultural sciences and there is much less work in engineering, social and fundamental sciences.

### REPUBLIC OF SOUTH AFRICA

The Republic of South Africa possesses a solid research system, combining 36 universities and teknikons, and seven councils (specialized agencies employing full-time researchers in agriculture, medicine, industry, mining, etc.). The private sector manages its own research units (for research and development), and contributes half of national expenditure on research. The system has wide experience of cooperation schemes between the private and the public sectors and its capabilities range from aeronautics to nuclear engineering, from chemistry to metallurgy, from agriculture and food to specialities at the forefront of medicine. Although it has not yet totally recovered from the fall brought about by an international scientific boycott (during the last years of apartheid), it alone produces approaching a third of the continent's publications and is the leading African country for many disciplines.

---

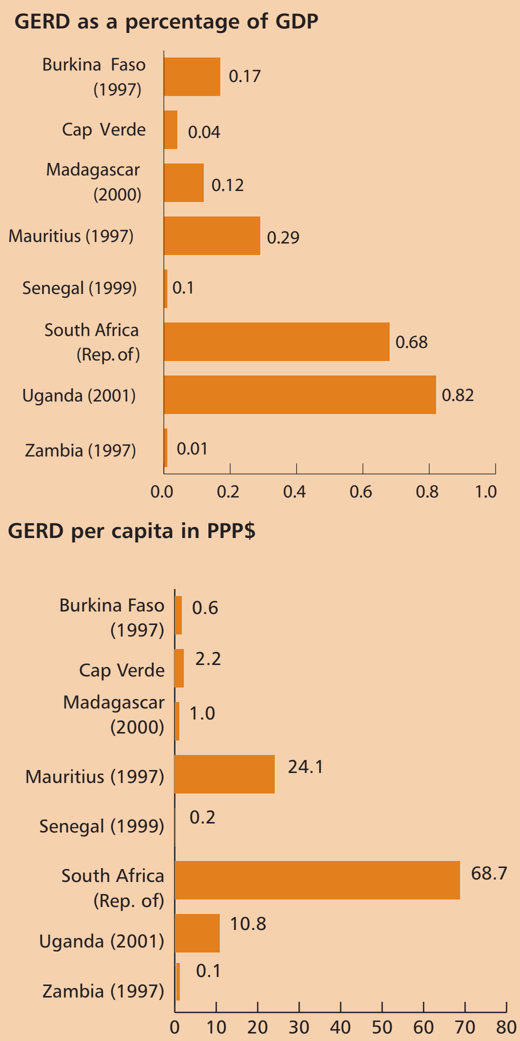
a consultancy basis. Some of them have at their disposal research laboratories almost tailor-made for them, equipped and built off the university campus with money from abroad. Others have created simultaneously a non-governmental organization (NGO) for research and another for action. Most researchers are employed more sporadically, by development institutions and small NGOs. A few establishments have been able to adapt themselves; through their quality label, they attract orders and ensure their researchers a continuous flow of work and a share of the profits.

However, the anarchy of a free market satisfies no one. One problem is that it ruins the institutions, and




UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

Figure 3
GERD IN AFRICA, 2002 OR CLOSEST YEAR
**Selected countries**




**Source:** UNESCO Institute for Statistics.

uses the available talents without ensuring their eventual replacement. Some donors are worried, and offer to support new programmes of capacity or institutional rehabilitation. The hired researchers feel a need for security. As for governments, although they contribute little, they complain of being short-circuited by sponsors, who negotiate directly with the laboratories and individual scientists of their choice. Suppliers and clients alike are therefore seeking new regulatory frameworks and some reconstruction is now under way. The new fledgling institutions are local or regional rather than nationally based.

The Republic of South Africa appears to be poles apart from Median Africa. In spite of the economic crisis, the country remains deeply committed to science and education. Salaries have remained attractive. Facilities and maintenance are generally excellent. But the post-apartheid regime brought a strong thrust of institutional reform to realign research to better serve basic human needs and promote industrial competitiveness. For example, a Council for Innovation, which includes representatives from large corporations, has been set up. The relative decline in research funding (which fell from 1.04% of gross national product (GNP) in 1987 to 0.68% in 1995) has been halted. In 2002, real spending was 0.68% of GDP (Figure 3). In parallel, the nation's system for financing S&T activities has changed radically, towards a competitive system closely linked to strategic goals. Several incentive funds have been established and have tripled in volume in five years. They currently represent a quarter of all public expenditure on research.

In a similar vein, councils (specialized agencies employing full-time researchers in agriculture, medicine, industry, mining, etc.) are instructed to rely more on self-financing. As a result, these agencies have increasingly turned to the provision of products and services (including new services to the poorer populations). A division of labour is also taking shape, between the councils and the private sector (which are involved more with research and development (R&D)) and the universities (active in basic research, but more and more in strategic areas linked to the productive sector). In 1999, 3 000 leading academics categorized their work as one-quarter basic research and three-quarters strategic and/or applied research. Their work was financed 40% by incentive funds, 22% through contracts with industry and government, 25% from cooperation schemes and 12% from their university's core funding (taking into account the number of articles published by the staff in high-ranking journals). The thrust toward innovation now looks like the main concern (Mouton *et al.*, 2000).

Yet other challenges remain. The proportion of 'Africans' between the ages of 20 and 24 attending university is expected to double in coming years. This would entail the creation of 300 000 new places, which is equivalent to the number of students currently attending university in Nigeria. Some councils, moreover, have had difficulties serving new clients (poor farmers, civilian industry) and others manage to do it by remaining in rather traditional fields. Higher salaries in the private sector have made it more and more difficult

Table 4
KEY EDUCATION INDICATORS FOR AFRICA, 1990 AND 2000
**Selected countries, in descending order of human development index**

| | Public expenditure on education as a % of GDP 1990 | Public expenditure on education as a % of GDP 2000 | Public expenditure on tertiary education (as a % of all levels) 1990 | Public expenditure on tertiary education (as a % of all levels) 2000* | Tertiary students enrolled in science, maths and engineering (% of all tertiary students ) 1998–2003 |
|---|---|---|---|---|---|
| South Africa (Rep. of) | 6.2 | 5.7 | 21.5 | 14.5 | 17 |
| Gabon | – | 3.9 | – | 25.5 | – |
| Namibia | 7.6 | 7.9 | – | 12.0 | 9 |
| Botswana | 6.7 | 2.1 | – | 18.6 | 19 |
| Ghana | 3.2 | 4.1 | 11.0 | – | 26 |
| Cameroon | 3.2 | 5.4 | 29.5 | – | – |
| Togo | 5.5 | 4.8 | 29.0 | 17.4 | 8 |
| Congo | 5.0 | 3.2 | – | 32.6 | 11 |
| Lesotho | 6.1 | 10.0 | – | 16.7 | 6 |
| Uganda | 1.5 | 2.5 | – | – | 8 |
| Zimbabwe | – | 10.4 | 12.3 | – | – |
| Kenya | 6.7 | 6.2 | 21.6 | – | 29 |
| Madagascar | 2.1 | 2.5 | – | 11.9 | 20 |
| Nigeria | 0.9 | – | – | – | – |
| Gambia | 3.8 | 2.7 | 17.8 | – | – |
| Senegal | 3.9 | 3.2 | 24.0 | – | – |
| Rwanda | – | 2.8 | 16.7 | 34.7 | – |
| Guinea | – | 1.9 | – | – | – |
| Benin | – | 3.3 | – | 16.4 | 25 |
| Tanzania, United Rep. | 3.2 | – | – | – | 22 |
| Côte d'Ivoire | – | 4.6 | – | 25.1 | – |
| Zambia | 2.4 | 1.9 | – | – | 30 |
| Malawi | 3.3 | 4.1 | 20.2 | – | 33 |
| Angola | 3.9 | 2.8 | 3.7 | – | 18 |
| Chad | – | 2.0 | – | 16.6 | – |
| Ethiopia | 3.4 | 4.8 | 12.1 | – | 19 |
| Mozambique | 3.9 | 2.4 | 9.9 | – | – |
| Burundi | 3.4 | 3.6 | 22.0 | 26.9 | 10 |
| Mali | – | 2.8 | – | 14.6 | – |
| Burkina Faso | 2.7 | – | – | – | – |
| Niger | 3.2 | 2.3 | – | 16.2 | – |

* For some countries, data may be for 1999 or 2001.

**Source:** Data provided by UNESCO Institute for Statistics in October 2005 and for: UNDP (2004) *Human Development Report*.





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

for institutions in the public sector to retain professors, researchers and good students in competitive activities. In higher education, tensions have increased between teaching duties and the necessary research tasks, between top-class, elitist departments (especially if they provide training for specialities in high demand) and others devoted rather to mass education.

Indeed, three distinct groups of institutions are emerging:

- a few councils and five or six elite universities that excel in most areas: these institutions are cultivating a strong research tradition and/or opening up new fields and are eager to forge new partnerships and to market their programmes aggressively;
- some universities and councils of average performance refocusing their activities on several specialities in which they are particularly strong, without excessive risk taking;
- institutions, including most historically disadvantaged universities, which confine themselves to the basics, where there is no tradition of research and where it is sometimes too late to build one up (Mouton *et al.,* 2000).

Other major challenges confronting science in the Republic of South Africa relate to incorporating science in the overall culture and society by addressing problems of illiteracy and scepticism ('Is modern science "white" science?' 'How can "indigenous knowledge" be incorporated?'). Finally, there is a need to establish a new 'contract' between researchers and the state, leaving room for grassroots initiatives and avoiding scientific activity being dissolved in political issues.

Despite the dramatic changes and continuing uncertainties surrounding S&T in the Republic of South Africa, scientific activity is brimming with health and even vibrancy in several sectors, thanks largely to the nation's scientific tradition, solid institutional capacities, a sturdy critical mass of scientists and ample number of centres of excellence. No doubt there has to be added the emphatic support of the government and the backing of socio-cognitive groups (linked to industry and trade unions) which, although not representing all of society, are nevertheless powerful.

Independence in North Africa has stimulated a national-based science, which at first was solidly propped up by the state. However, by the early 1980s, that support began to waver in some countries while picking up momentum in others, leading to an increasingly diverse situation. While some governments banked on the virtues of science (Tunisia since 1990, Morocco since 1996), others did not (e.g. Algeria, Egypt). Cooperation schemes (especially with the USA in Egypt and with France in the Maghreb) have been instrumental in keeping science growing and improving. But the secret of scientific stamina is elsewhere. Ensconced in two distinct professional branches, education and the higher technical civil service, the practice of science became part of respective professional profiles. Scientific activity was divided between two fields: the academic and the technological, maintaining and advocating completely opposed scientific styles. The university system, in no way engaged in the transfer of technology, subordinated research to the tasks of instruction and training. Teaching staff had to publish, but only to further their careers. In the technological camp, the science practised is *for doing*; but concrete demands from local companies are missing.

In spite of its strength and success, the scientific apparatus is now at a crossroads. Its social stance has to be redefined. Modern science, the resulting technology and the way of life it imposes are perceived as 'immoral' and 'foreign' by significant sections of society. Islamism has given the question a highly political significance. Is S&T in conflict with religion? What kind of science do the people need? If social demand remains low, can commercial demand take over? Scientific forces are highly advanced over the concerns of the economic apparatus (based on rents or cheap labour). Only the state can get involved in programmes bolder than commonplace engineering. And the scientists hesitate between academic endeavours, the daring ventures of audacious applied research (such as desalination of sea water, automatic translations into Arabic or agricultural biotechnology) and straightforward projects of technological adaptation, intended to win over the firms that already exist.

Table 5
PATENT APPLICATIONS FILED BY AND GRANTED TO AFRICAN COUNTRIES, 1999

| | Applications filed | | Patents granted | |
|---|---|---|---|---|
| | By residents | By non-residents | To residents | To non-residents |
| Algeria | 34 | 248 | 0 | 0 |
| Botswana | 0 | 54 | 0 | 26 |
| Egypt | 536 | 1 146 | 38 | 372 |
| Ethiopia | 0 | 12 | 0 | 1 |
| Gambia | 0 | 7 903 | 0 | 26 |
| Ghana | 0 | 80 028 | 0 | 17 |
| Kenya | 28 | 80 516 | 3 | 91 |
| Lesotho | 0 | 80 315 | 0 | 43 |
| Liberia | 0 | 41 120 | 0 | 0 |
| Madagascar | 9 | 41 237 | 6 | 29 |
| Malawi | 1 | 80 430 | 0 | 84 |
| Morocco | 0 | 3 649 | 0 | 0 |
| Rwanda | 0 | 4 | 0 | 4 |
| Sierra Leone | 0 | 72 449 | 0 | 1 |
| South Africa (Rep. of) | 116 | 26 354 | 0 | 0 |
| Sudan | 2 | 80 424 | 0 | 0 |
| Swaziland | 0 | 40 673 | 0 | 57 |
| Tanzania, United Rep. | 0 | 14 467 | 0 | 0 |
| Uganda | 0 | 80 421 | 0 | 74 |
| Zambia | 5 | 87 | 0 | 66 |
| Zimbabwe | 1 | 80 167 | 0 | 34 |

**Source:** World Intellectual Property Organization.

How these contradictory impulses are sorted out will depend to a large extent on the future course of government policies and on the relationships between science and scientists and the societies in which they live. In Egypt, researchers have poor living conditions and few opportunities to innovate. Export of 'surplus' brain power is structural. In Algeria, education and teaching staff have lost half of their purchasing power during the last 20 years. Since 1991 threats and murders have caused a mass exodus of highly experienced professors, doctors and engineers. The younger generation who take over are lively, but they frequently lack international networks to keep their knowledge up to date.

In other Maghreb countries, the profession has suffered less from recession. In Tunisia, for example, the state has embraced science as a symbol of rationality, competence and modernity. In Morocco, the government has recently praised scientists for their dynamism and is striving to derive maximum benefit from their research. In both cases, government interest is translated into action with great political determination: the creation of an office at secretary-of-state level with real political power; a law that ensures good funding over the medium term; the undertaking to build the whole sector (including universities) into a structure based on laboratories; and encouragement of industrial demand. It has the backing of a new generation of technicians, who wish to promote new tools and areas of research such as transplant medicine, computing, telecommunications and biotechnology.

Thus, some governments in the region are now convinced that globalization, and the prospect of an association with the European market, will require upgrades in their productive system, technical innovation, and a new consensus within their societies of the relationship between science and society. Meanwhile, such considerations are barely on the political agendas of other nations. Not only does this disparity lead to different economic development environments among nations, but it also hampers regionalization and the building of a critical mass of scientists in strategic areas. Science continues to operate under an umbrella of highly nationalist values. The intervention of the state remains necessary, however, both to stimulate demand for research and to reaffirm the legitimacy of science within society. Yet, a leap forward demands tricky reforms to reconcile the two separate fields of academic and technological research, avoiding excessive state control that could antagonize the professionals. The winning cards of governments prepared to enter this challenge lie in the strength of the institutions and the energy (and high skills) of the scientists. Such a wide range of concerns poses serious challenges for both government and the scientific community.

## WHAT PROSPECTS FOR AFRICA?

The way scientific research is structured and carried out has changed greatly during the last 30 years. This is as true for Africa as it is for the rest of the world (Krishna *et al.*, 2000). S&T activities are more and more dependent on international





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

cooperation. They are part of a global market spurring the mobility of people and knowledge. Furthermore, science, particularly in Median Africa, has lost the hitherto dependable trust of societies and governments. However, S&T is essential for human and technological development, for global trade and for being part of the knowledge society. It is what society depends upon for a sustainable development and future.

Our dependence on S&T for sustainable development necessitates for Africa, and particularly Median Africa, a genuine rehabilitation of activities, including providing future career prospects and compensation for those involved in S&T. African states must reinvest in S&T activities. In part, this necessitates the re-establishment of the people's trust in science. A few African states like Nigeria have recently seized the initiative and are clearly aware of what is at stake (see box on page 192).

While efforts like those in Nigeria are significant and should be applauded, it is important to remember that Africa's shortcomings in S&T remain immense and will not be resolved by six or so isolated measures, however significant each of these measures may be. At a May 2001 workshop on capacity building among science academies in Africa, organized by the Inter-Academy Panel on International Issues (IAP) which is headquartered in Trieste, Italy, participants observed that, of the 53 nations in Africa, only nine had science academies and many of those academies were starved of cash, recognition and influence. A tenth academy has since been launched in Zimbabwe, in October 2004, but it is faced with the same problems. For its first year of operations, the Zimbabwe Academy of Sciences received a government grant of US$ 120 000 but no assurance of future government funding.

The same observations should be applied to other aspects of the continent's scientific enterprise, including the work of individual scientists, the capabilities of scientific institutions and the efforts of scientific ministries.

## Six interdependent approaches

In light of these daunting challenges, a clear vision of the necessary steps to take for a sustainable revival is a must. The approaches outlined below may seem utopian and prescriptive, given the present context and conditions. Yet, we feel they are realistic ones, particularly for Median Africa, assuming that the African governments, the scientists, the grassroots actors and the donors can agree on practical measures to ensure a revival.

**First**, *develop, sustain and utilize local capacities and leadership in efforts to advance S&T.* The truth is that developing scientific and technical capacity is less difficult than sustaining it, and sustaining it is less difficult than utilizing it. That is why it is important for African nations to invest in the education and training of scientists and technologists, and that is why it is important for each nation to develop an economic strategy that offers scientists and technologists employment opportunities once they obtain their degrees. A single talented scientist can make a difference. That is the

## The 10 African national academies

| | |
|---|---|
| Cameroon Academy of Sciences | Cameroon |
| Academy of Scientific Research and Technology (ASRT) | Egypt |
| Ghana Academy of Arts and Sciences (GAAS) | Ghana |
| Kenya National Academy of Sciences (KNAS) | Kenya |
| *Académie Nationale Malgache* | Madagascar |
| Nigerian Academy of Sciences | Nigeria |
| *Académie des Sciences et Techniques du Sénégal* (ASTS) | Senegal |
| Academy of Science of South Africa (ASSAf) | South Africa |
| The Uganda National Academy of Sciences (UNAS) | Uganda |
| Zimbabwe Academy of Sciences | Zimbabwe |

## Science makes a fresh start in Nigeria?

At the request of the Government of Nigeria, an international advisory board for the reform of the country's science, technology and innovation system was established by UNESCO in October 2004. A core activity of the reform programme is a joint review of investment, industry and innovation in Nigeria involving UNESCO, UNCTAD, UNIDO and WIPO. Financed in equal shares by the Government of Nigeria and UNESCO/Japan Funds-in-Trust to the tune of US$ 1 million, the review is part of preparatory work for a donors' conference Nigeria is planning to call to fund implementation of a multi-year plan of action on science, technology and innovation. Other international agencies expected to join the reform programme are the United Nations Economic Commission for Africa, the World Bank and the International Association of Universities.

Could science be making a fresh start in Nigeria? Since the transition to civilian rule in 1999, consolidated in 2003 with the election of the second Obasanjo government, Nigeria has certainly given signs of renewed interest in S&T. In October 2003, it launched a low Earth orbit remote-sensing micro-satellite to monitor the environment and provide information for infrastructure development. This prowess has enabled Nigeria to join a Disaster Monitoring Constellation grouping Algeria, China, the UK and Viet Nam.

President Obasanjo has since announced that his country is establishing, within UNESCO, a US$ 1 million Nigeria Special Funds-in-Trust for Science. This Special Fund will 'not only benefit Nigeria but also assist other African countries in designing project proposals for the reform of their national science systems and in developing managerial capacities', Nigeria's Minister of Science and Technology, Professor Turner T. Isoun stated in October 2004.

Nigeria has considerable human potential. It counts 60 universities, 44 polytechnics and 65 research institutes for a population of 133 million. However, there are also deep-rooted problems; these include insufficient funding of research and development, poor management, inadequate macro-level coordination and a lack of linkages between industry and research institutes or universities.

The need for reform is patent after four decades of military rule marked by state corruption and spiralling foreign debt, following independence in 1960. The rewards of reform could also be immense, for Nigeria is potentially a wealthy country. The world's 13th largest oil producer and the 6th largest in OPEC, Nigeria also has gas reserves which, when fully exploited, will place it among the world's top ten gas producers. However, 'in the 1980s, the country failed to use productively the oil windfall to improve social conditions and encourage the non-oil economic sector', writes the UK Department for International Development (DfID) in its Nigeria Draft Country Assistance Plan (2004). 'Between 1980 and 2000, Nigeria's per capita income plummeted to about US$290, well below the Sub-Saharan average of US$490.'

The reform comes at an auspicious time. After sluggish growth initially following the end of military rule, GDP rose by nearly 10% in 2003, driven by strong oil receipts and agricultural growth of 7%. Public spending has climbed markedly, from 19% of GDP in 1997 to 50% in 2001 (DfID). One aim of the science system reform will be to use this growth to diversify Nigeria's economy, in order to reduce the country's dependence on fluctuating oil prices: oil exports accounted for 95% of foreign earnings in 1998, compared with 58% in 1970 (UNDAF).





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

good news. The troubling news is that past experience indicates that educating and retaining scientists and technically skilled workers is much more difficult than it seems. Yet small programmes with relatively limited resources can make a difference (see box below). Two critical prerequisites of sustainability are a vibrant educational system and an enduring, yet flexible, job base (World Bank, 2000).

**Second**, *mobilize the best and most relevant S&T in Africa and elsewhere to address critical social and economic problems*. The food, health and environmental issues faced by people in poor countries, and especially in the least developed ones, are of a different dimension (and often a different kind) from the food, health and environmental issues faced by people in rich countries. Such differences help to explain why S&T initiatives in developed countries have rarely targeted Africa's most critical problems: those related to poverty, food and energy deficits, inadequate and unsafe drinking water, tropical diseases and the HIV/AIDS pandemic.

As a result, if Africa expects to use S&T to tackle its most pressing problems, it must develop its own scientific and technical capacities. Otherwise, it will be forever beholden to second-hand science that will likely never quite fit the continent's circumstances. For this reason, it is important that the governments of Africa engage the continent's scientific leadership in providing authoritative and independent opinions on current scientific issues of critical importance. That, in turn, means strengthening Africa's scientific academies in those countries where they now exist and establishing new scientific academies in countries where they do not. As stated above, only ten of Africa's 53 countries currently have merit-based science academies. Such numbers indicate that there is much room for improvement on this front.

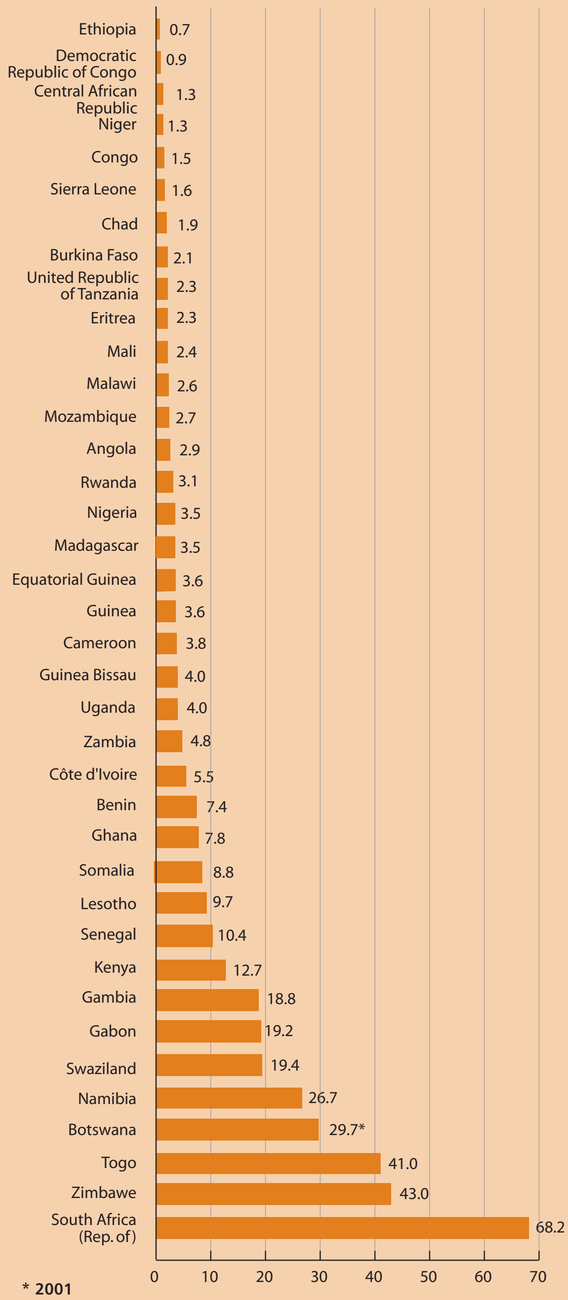
That is not to say that African nations should turn their backs on research taking place beyond their borders. North–South collaborative efforts have already contributed to strengthening and internationalizing African science. Yet, while they should be continued, care must be taken to recognize inequalities between partners from the start of collaboration so that such inequalities can be addressed and hopefully overcome (Gaillard, 1994). At the same time, Africa should seek to engage the private sector in its efforts to

## IFS and TWAS support programmes in Africa

The International Foundation for Science (IFS) and the Academy of Sciences for the Developing World (TWAS) have supported many African scientists over recent decades: in sciences related to the management, conservation and sustainable use of natural resources for IFS and in the basic sciences, including biology, physics, chemistry and mathematics, for TWAS. Since 1974, IFS has supported some 1 250 African scientists in most African countries and TWAS close to 1 000 since 1986. As part of the Monitoring and Evaluation System for Impact Assessment (MESIA) being established at IFS, a tracer study of IFS grantees has been conducted in a selected number of countries including Cameroon, Morocco and the United Republic of Tanzania. Paradoxically, very few cases of true brain drain were found in the surveyed population. Out of 262 scientists surveyed some 30 years after the first grant was approved, only four had emigrated permanently to Europe and the USA. Most of the remaining scientists were still active in their respective countries except for the United Republic of Tanzania where some 10% were found to contribute to a regional circulation of scientists in Southern Africa. This shows that support well targeted to young scientists at the beginning of their research careers can be instrumental in retaining them in their national scientific communities.

See www.ifs.se and www.twas.org

Figure 4
SUB-SAHARAN INTERNET USERS PER 1000 POPULATION, 2002




* 2001

**Source:** http://unstats.un.org/unsd/mi/mi_series_results.asp?rowId=605

boost S&T on the continent. While such efforts may prove difficult to pursue in a climate of political and economic uncertainty, Africa's wealth of natural resources, particularly its treasure trove of indigenous and medicinal plants with potential commercial value, may be particularly attractive to private pharmaceutical firms. The continent's untapped demand for new information technology (barely 1% of Africa's population is currently connected to the Internet compared with 40% in North America) may prove to be another area ripe for public/private partnerships, especially if Africa can nurture a sufficient number of well-trained information technologists allowing African nations to forge balanced partnerships. At the same time, African nations should continue to pursue cooperative projects with constituencies that have special ties to the continent. For example, African scientists should seek to tap the distant yet potentially strong ties that exist between them and expatriate scientists of African origin in the North.

**Third**, *build a strong case at home and worldwide for supporting indigenous development of S&T.* This is a critical challenge for African scientists given the competing demands that are constantly being exerted on the continent's limited financial resources. African scientists have not only an obligation but a self-serving interest to convince governments of the value of science and the need to support such endeavours. Such efforts must include a willingness to engage the public in discussions on science-based issues, a desire to lobby the government for support and, perhaps most importantly, a commitment to pursue research agendas that focus on critical social and economic problems. The development of national research grant schemes or the strengthening of already existing ones could be a powerful tool to pursue such research agendas. Such efforts will also require serious and sustained investments in education from primary grades through graduate studies at universities. Educational initiatives, in fact, could prove the most productive long-term elements of all governmental S&T strategies.

**Fourth**, *share innovative and successful experiences in the development and application of S&T.* Africa's successful experiences in the application of S&T for development have





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

all too often been drowned out by the din of dismal news concerning the current state of affairs on the continent. Identification of genetic molecular markers for improved tea harvests in Kenya, ongoing efforts to examine alternative treatments for river blindness in Uganda (see box on page 198), research on sickle-cell anaemia in Ghana, and detailed assessments in Madagascar of the effectiveness of medicinal plants (see box on page 179) are examples of science-based initiatives that deserve greater recognition both within the larger scientific community and among the public (UNDP and TWNSO, 1998 and 2001).

**Fifth**, *strengthen and build centres of excellence in Africa.* Despite the generally gloomy condition of scientific and technological institutions in Africa, small pockets of strength can be found. For example, such national and regional centres of scientific excellence as the Immunology Laboratories in Cameroon, the African Centre for Meteorological Applications in Niger, the African Centre for Technology in Senegal and the Tanzania Industrial Development Organization could eventually be transformed into international centres of excellence capable of functioning more effectively than they do now. Such a transformation would not only boost science in Africa but could serve as a model for the development of other institutions across the continent. These efforts will likely require both strong political will on the part of Africa's governments and reliable help from bilateral concerted support, regional development organizations such as the African Development Bank and international development organizations such as the European Commission and the World Bank.

**Sixth**, *strengthen and build regional programmes and networks in Africa.* Many such networks and regional programmes do already exist, particularly in medical and agricultural sciences. In agricultural sciences three sub-regional programmes (*Conseil Ouest et Centre Africain pour la recherche et le développement agricoles* (CORAF), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), and Southern African Center for Cooperation in Agricultural and Natural Resources Research (SACCAR)) have been established to coordinate activities in the three main sub-regions. While more efforts should be made to strengthen African sub-regional research systems, the legitimate desire of each country to formulate and develop its own research policy should also be taken into account. In any case, a regional strategy can only become truly productive if it is supported by consolidated national systems.

## *Sustaining biology*

The East Africa Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Research (Bio-Earn) was founded in 1999 with funding from the Department for Research Cooperation of the Swedish International Development Agency (Sida-SAREC). Four countries – Ethiopia, Kenya, United Republic of Tanzania and Uganda – are members. The organization's principal objectives are to 'build capacity in biotechnology' among its member states and 'to promote appropriate research and related policies'. Equally important, Bio-Earn seeks to foster programmes and policies that enable biotechnology to be used 'in a sustainable manner ... to help improve livelihoods, ensure food security and safeguard the environment'. While biotechnology and genetic engineering may hold great promise for addressing questions of food security in sub-Saharan Africa, applications of these technologies have generated a great deal of controversy and concern. The most critical issues involve questions of property rights, corporate control of the research agenda and the risks posed to non-transgenic crops and the environment. As recent controversies over the distribution of genetically engineered maize in Zimbabwe show, these concerns cannot be ignored in the name of science or even in the name of feeding the hungry.

See www.bio-earn.org

## THE ROAD AHEAD

There is no doubt that the major problems that afflicted Africa during the last 30 years of the twentieth century remain stubbornly in place at the beginning of the twenty-first century. Yet, recent events and discussions suggest that Africa has the best opportunity in the coming decades to break its well-entrenched logjam of problems and make significant advances in scientific capacity building. To seize these opportunities, however, Africa must devise new long-term visions and strategies that enable it to sustain economic

### NEPAD

The New Partnership for Africa's Development (NEPAD) was launched in 2001 as a comprehensive, integrated initiative for the revival and sustainable development of Africa. NEPAD is a programme of the African Union grouping 53 countries.

Within NEPAD, African statesmen are calling for greater investment in S&T. Were the target set by NEPAD in 2003 of devoting 1% of GDP to R&D within five years to be realized, it would constitute a mini-revolution for the African continent, where most countries devote less than 0.3% of the public purse to R&D.

It is not the first time that Africa's leading politicians have voiced their 'unflinching' support for such efforts. In 1980, there was the Lagos Plan for Action; in 1987, the Kilimanjaro Declaration; in 1988, the Khartoum Declaration; and, in 1998, the Addis Ababa Declaration. All called on sub-Saharan African nations to turn to S&T as primary sources of economic development.

What makes NEPAD's strategy different? First, the times. A steep decline in many economic and social indicators is a stark reminder that urgent action is needed now more than ever before. Second, the strategy lays heavy emphasis on human resources development as a prerequisite for science-based development and thus takes a long-range view of how progress should be defined and achieved. NEPAD emphasizes sensible goals and makes provisions for on-going evaluations and adjustments. Although the language may not be as dramatic as the statements associated with previous reform efforts, the prospects for success – albeit modest success – are greater. Third, NEPAD views the development of S&T as a tool rather than a goal, directly tying investments in S&T to such immediate needs as poverty elimination, improvements in public health, access to safe drinking water and environmental protection.

NEPAD's plan of action for S&T acknowledges that African science and scientists are currently cut off from the economic system. The plan of action consequently focuses on science policy development and flagship programmes that include biotechnology, indigenous knowledge and technologies, ways of developing university–industry partnerships, technology incubators, innovation hubs and training in science policy. This plan of action was adopted by a ministerial conference in Johannesburg, South Africa, in 2003, which in parallel established a Council of Ministers to serve as NEPAD's policy-making body.

NEPAD is encouraging both a dialogue between stakeholders in S&T and the elaboration of an appropriate regulatory and policy environment to nurture private investment in R&D. Regional centres of excellence are being promoted as a key strategy for boosting African collaboration. At the same time, NEPAD is fostering a genuine spirit of partnership which revolves around South–South and North–South collaboration. The Memorandum of Understanding signed in 2004 between NEPAD and the International Agricultural Research Centres of the CGIAR points in that direction.

See www.nepad.org





UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

growth and compete in a world where development is becoming increasingly dominated by scientific knowledge and technical skills. In short, African nations must build and sustain their own capacities in modern S&T and then use the knowledge and skills that are acquired through such efforts to devise problem-solving strategies. Such strategies, in turn, must put the best of S&T in Africa and elsewhere to work in ways that will build and sustain local and regional capacities as well as address real-life concerns.

The recent history of Africa has shown that we cannot inject heavy doses of outside technology into the continent and hope that this infusion of external know-how somehow takes hold in the years ahead. Instead, efforts to build S&T capacities in Africa must be driven by a long-term strategy founded on the principle that each country, no matter how poor, needs to develop its own science and, moreover, that scientific knowledge can serve as one of the primary forces behind sustained economic development. Put another way, like speed in sports, there is no substitute for science in development.

All assessments of the state of science in Africa concur that not just the buildings, communication systems and laboratory equipment (that is, the hardware of scientific institutions) are in a desperate condition but so too the teaching and training programmes (that is, the software of scientific institutions). As African nations and outside donors seek to bolster the capacity of the continent's scientific infrastructure, they must devote a great deal of attention not only to the construction and maintenance of physical structures and access to computers and electronic networks, but to a host of basic personnel issues of prime importance to scientists, including the availability

## *Future harvests today*

The Consultative Group of International Agricultural Research (CGIAR) is a worldwide consortium of 15 research organizations, collectively known as the 'Future Harvest' institutions. Four of these research institutions, each with its own history of scientific excellence and specific mandate, are located in sub-Saharan Africa:

- Africa Rice Centre (WARDA), based in Bouakè, Côte d'Ivoire, has pioneered the development of Nerica (New Rice for Africa), which is expected to make Africa self-sufficient for rice by 2010.
- International Livestock Research institute (ILRI), based in Nairobi, Kenya, which works at the crossroads of livestock and poverty, bringing high-quality science and capacity-building to bear on poverty reduction and sustainable development for poor livestock keepers and their communities.
- International Institute for Tropical Agriculture (IITA), based in Ibadan, Nigeria, which focuses on crop management and improvement, especially for such small landholder crops as cassava, cowpea, plantain and yam.
- World Agroforestry Centre, based in Nairobi, Kenya, which conducts research on overcoming land depletion in the smallholder farms of the sub-humid and semi-arid regions of Africa, and searching for alternatives to slash-and-burn agriculture at the margins of the humid tropical forests.

The diverse mandates of these institutions – and the fact that other Future Harvest institutions based elsewhere are also collaborating to help solve some of Africa's agricultural problems – provide a network of scientific excellence. The reach of this network is extended through a host of regional centres distributed throughout sub-Saharan Africa that also assist in disseminating research results and 'best practices' to Africa's farmers.

See www.cgiar.org

of journals and monographs, the timeliness of teaching materials, and adequate pay levels and reasonable opportunities for career advancement.

All of these problems are well known but deserve to be repeated for two reasons.

First, *acknowledging the full range of the problems facing science in Africa is just a first step.* By no means do these expressions of concern ensure that an effective strategy will follow. No region of the world is more cognizant of this fact than Africa, whose problems have been discussed at length for decades without much progress to show for it.

Second, *history indicates that basic bread-and-butter issues often lose out to more glamorous visions of progress.* One reason for the decline of Africa's universities over the past 30 years, after a period of promising steps forward in the 1960s and early 1970s, is the fact that Africa's governments often chose to expand their university systems to new campuses at the expense of adequately supporting their existing institutions of higher education. The reason for this was that clearing and construction in new areas provided more tangible signs of progress. The same 'monu-mentality' helps to explain the persistence of the World Bank's 'bricks and mortar' programme during the post-Second World War era long after library shelves filled with assessment reports largely conveyed a story of failure.

In any circumstances, Africa has to help itself first by its own forces and resources and must remain wary of other people's money no matter how well intentioned and how effective new international funding strategies may prove to be. Donor fatigue, after all, is just another name for human nature.

Even the most diplomatic of ventures, for example, the first (1970–79) and second (1980–89) Industrial Development Decades for Africa, which were sponsored by the United Nations Industrial Development Organization (UNIDO), barely left an imprint, either positive or negative, on the S&T landscape in Africa. And, as much of the literature on economic development has since concluded, the United Nations Conference on Science and Development, held in Vienna in 1979, falsely raised expectations for rapid progress by confidently promising funding mechanisms and follow-up actions that never materialized. The World Conference on Science (WSC) in Budapest in 1999, sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Council for Science

## Sighting blindness

Just a decade ago, it was not uncommon for one in every three villages in parts of Burkina Faso, Ghana, Nigeria and other nations of sub-Saharan Africa to be afflicted with river blindness. Today, virtually no villages are. The progress that has been made in combating the disease represents one of the most triumphant public health campaigns ever waged in the developing world. But will this success continue? Nobody is sure. The reason for the concern is that the parasites causing the disease are likely to build resistance over time to the successful drug therapies that have been in put in place. For this reason, Thomas G. Egwang and his colleagues at the Med Biotech Laboratories at Makerere University in Kampala, Uganda, with the help of a grant from the Howard Hughes Foundation, USA, are seeking alternative treatments based on the medical community's rapidly advancing knowledge of molecular biology and, more specifically, biochemical pathways. Such knowledge could help researchers devise carefully targeted strategies designed to disrupt the disease-causing parasites' basic molecular functions. That, in turn, could serve as the basis for undermining the parasites' vitality and disrupting their reproductive cycles.

See www.mblab.or.ug




UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

(ICSU), was developed with much more modest expectations than its predecessor meeting in Vienna. While follow-up WSC activities on a regional scale have been encouraging, however, the initiatives continue to lack the resources and staffing commitments necessary to make a dramatic difference to the pace of scientific progress in the developing world.

## Models and mechanisms

There are, however, models and mechanisms in place to advance the cause of S&T in the developing world. According to the United Nations Development Programme, the Republic of Korea, for instance, recently rose to the ranks of high human development (UNDP, 2001), with an average per-capita income greater than that of the Czech Republic, Hungary and Poland.

Other potential examples include Brazil, China, India and Mexico. None of these nations, except perhaps China, has achieved the spectacular economic success of the Republic of Korea. Nevertheless, each has built a sturdy scientific infrastructure that promises to provide an enduring framework for sustained economic growth.

The strategies that have been pursued by these nations are not difficult to decipher: sustained investment in education at all levels; long-term government commitment to the nation's scientific enterprise; reasonable and reliable funding; the ability to access the most current scientific literature through electronic communications and ample opportunities to interact with the international scientific community; and strong encouragement to compete at the highest levels of excellence in the global scientific community.

These strategies, however mundane they may seem, represent science policy at its best. On the one hand, the strategies provide a clear and coherent blueprint for institutional capacity building based in large part on domestic funding; on the other hand, the strategies offer mechanisms for the development of knowledge and skills by individual scientists. These scientists – at least an increasing number of them – are then given opportunities to apply their talents at home.

Scientific ministries, research centres and universities in Africa would be wise to follow the S&T path laid out by the most successful developing countries. The road map that

## *African initiative*

Launched in 1998 with financial assistance from the World Bank, the Millennium Science Initiative (MSI) strives to build capacity in modern science and technology in developing countries. To date, MSI institutes have been established in Brazil, Chile and Mexico, and have reached the implementation stage in Africa. With the aid of an African MSI task force, organized jointly by the Academy of Sciences for the Developing World (TWAS) and the Science Initiative Group (SIG), an independent non-governmental organization that advises the MSI, three priority areas have been selected: biology and biotechnology; mathematics; and instrumentation and information technology. MSI's strategy involves linking the work of local researchers, teachers and programmes to activities and institutions that are already in place.

Among the institutions acting as focal points for the initiative are Med Biotech Laboratories in Uganda; and the University of Dar es Salaam and the Tanzania Industrial Research and Development Organization (TIRDO), which are the primary nodes for the information technology and instrumentation facilities respectively. In contrast, the mathematics component is 'multi-centred', with hubs in such countries as Benin, Cameroon, Kenya and the Republic of South Africa.

See www.msi-sig.org

they have devised is as likely to advance S&T in Africa as it has in parts of Asia and Central and South America. The bottom line is this: S&T alone cannot save Africa but Africa without S&T cannot be saved. Recent history tells us so.

*This chapter was prepared in 2001 and has been partially updated.*

## REFERENCES AND FURTHER READING


Arvanitis, R. (2001) Introduction. *Encyclopedia of Life Support Systems EOLSS. Section: Science and Technology Policy.* UNESCO, Paris.

Arvanitis, R. and Gaillard, J. (1992) *Science Indicators for Developing Countries*. Collection colloques et séminaires. Institut de recherche pour le développement, Paris.

Arvanitis, R., Waast, R. and Gaillard, J. (2000) Science in Africa: a bibliometric panorama using PASCAL database. *Scientometrics*, 47(3): p. 457–73.

Current Science (2001) Science in the Third World. *Current Science* 81, 25 October 2001, special issue, Bangalore, India.

Dahoun, M. (1997) *Le statut de la science et de la recherche au Bénin.* Logos-Verl., Berlin, 320 pp.

Davis, C.H. (1983) Institutional sectors of 'mainstream' science production in subsaharan Africa, 1970-1979: a quantitative analysis. *Scientometrics*, 5(3): p. 163–75.

Eisemon, T.O. (1979) The implementation of science in Nigeria and Kenya. *Minerva*, 12(4): p. 504–26.

Gaillard, J. (1994) North–South research partnership: is collaboration possible between unequal partners? *Knowledge and Policy*, 7(2): p. 31–63.

Gaillard, J. (1999) *La coopération scientifique et technique avec les Pays du Sud, peut-on partager la science?* Karthala, Paris.

Gaillard, J. and Furó Tullberg, Anna (2001) *Questionnaire Survey of African Scientists, IFS Grantees and INCO Beneficiaries.* IFS: MESIA Report No. 2, Stockholm, 90 pp.

Gaillard, J., Krishna, V.V. and Waast, R. (eds.) (1997) *Scientific Communities in the Developing World*. Sage, New Delhi and London, 398 pp.

Gaillard, J. and Waast, R. (1993) The uphill emergence of scientific communities in Africa. *Journal of African and Asian Studies*, 27(1–2): p. 41–68.

Gaillard, J. and Waast, R. (2000) L'aide à la recherche en Afrique subsaharienne: comment sortir de la dépendance? Le cas du Sénégal et de la Tanzanie. *Autrepart* 13: p. 71–89.

Hassan, M.H.A. (2000) Can science save Africa? *Science* 292 (1 June), p. 1609.

Hassan, M.H.A. and Schaffer, D. (2001) The Third World Academy of Sciences: celebrating two decades of progress. *Current Science,* 81, 25 October.

Kolinsky, M. (1985) The growth of Nigerian universities, 1948–1980. *Minerva*, 23(1): pp. 29–61.

Krishna, V.V., Waast, R. and Gaillard, J. (2000) The changing structure of science in developing countries. *Science, Technology & Society*, 5(2): pp. 209–24.

Lebeau, Y. and Ogunsanya, M. (eds.) (1999) *The Dilemma of Post-Colonial Universities.* IFRA/African BookBuilders, Ibadan.






UNESCO Science Report 2005 - ISBN 92-3-103967-9 - © UNESCO 2005

Lebeau, Y., Onyeonoru, I. and Ukah, F.K. (2000) Nigeria country report. In: Waast, R.; Gaillard, J. (coord.) *Science in Africa at the Dawn of the 21st Century*. IInstitut de recherche pour le développement, Paris.

Mouton, J., Boshoff, S.C., Ravat, E. and Ravjee, N. (2000) Science in transition. In: Waast, R; Gaillard, J. (coord.) *Science in Africa at the Dawn of the 21st Century*. IInstitut de recherche pour le développement, Paris.

UNDP (2001) *Human Development Report 2001: Making Technologies Work for Human Development*. UNDP/Oxford University Press, New York–Oxford.

UNDP and TWNSO (1998) *Sharing Innovative Experiences: Examples of Successful Initiatives in Science and Technology in the South.* UNDP and Third World Network of Scientific Organizations (TWNSO), New York.

— (2001) *Sharing Innovative Experiences in the Conservation and Wise Use of Medicinal and Indigenous Plants.* HEJ Research Institute of Chemistry, Karachi, for UNDP and TWNSO, Karachi.

UNESCO (2000) *World Conference on Science: Science For The Twenty-First Century World: A New Commitment*. UNESCO, London.

Waast, R. (2001) Science and technology policies in Africa, *Encyclopedia of Life Support Systems EOLSS. Section: Science and Technology Policy.* UNESCO, Paris.

Waast, R. and Gaillard, J. (coord.) (2000) *Science in Africa at the Dawn of the 21st Century*. IRD, Paris.

World Bank (2000) *Higher Education in Developing Countries: Peril and Promise.* World Bank, Washington DC.

**Mohamed H.A. Hassan** is Executive Director of the Third World Academy of Sciences (TWAS), President of the African Academy of Sciences (AAS), Secretary General of the Third World Network of Scientific Organizations (TWNSO) and serves on a number of committees in other organizations worldwide.

He holds a PhD in plasma physics from the University of Oxford, UK (1974). A former professor and dean of the School of Mathematical Sciences at the University of Khartoum, he received the order of scientific merit of Brazil. He is a fellow of TWAS, AAS and the Islamic Academy of Sciences as well as honorary member of the Colombian Academy of Exact, Physical and Natural Sciences and corresponding member of the Belgian Royal Overseas Academy of Sciences. His research areas include theoretical plasma physics, physics of wind erosion and sand transport.

**Roland Waast** is a Senior Researcher at the French Research Institute for Development (*Institut de Recherche pour le Développement*, IRD).

As a sociologist, he spent numerous years in developing countries (including Algeria and Madagascar). While he was head of the Department of Development Strategies at IRD, he set up a research team specializing in the sociology of sciences and an international network (ALFONSO) dealing with the same topic in developing countries (with the main nodes in Algeria, Argentina, Brazil, India, the Republic of South Africa and Venezuela). He has authored numerous papers in French and international journals. He is the founder and co-director of the journal *Science, Technology and Society*, and the series editor of *Les sciences hors d'Occident au 20° siècle/Science beyond the Metropolis* (IRD-UNESCO: 7 volumes).

**Jacques Gaillard** is Director of the Office of Policy and Coordination of the Department of Technical Cooperation at the International Atomic Energy Agency (IAEA) in Vienna, Austria. Before joining the IAEA, he served as Acting and Deputy Director of the International Foundation for Science (IFS) in Stockholm, Sweden, on secondment from the French Research Institute for Development (*Institut de Recherche pour le Développement* (IRD), formerly ORSTOM).

A trained agricultural engineer with a doctorate in science, technology and society, he has published over 30 papers, six books as author and six books as editor in his field.

**Daniel Schaffer,** Public Information Officer for the Third World Academy of Sciences (TWAS) and the Abdus Salam International Centre for Theoretical Physics (ICTP), has written extensively on issues related to science, technology and economic and urban growth for the popular and academic press. His writings have been published by Johns Hopkins University and Temple University Press and his documentary films have been shown on public television stations in the USA.

The designations employed and the presentation of the material throughout this publication do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The ideas and opinions expressed in this book are those of the individual authors and do not necessarily represent the views of UNESCO.

Editor-in-Chief: Mustafa El Tayeb
Editor: Susan Schneegans

Thanks go to Michiko Tanaka, David McDonald and Eric Frogé for their professional advice.

Published in 2005 by the
United Nations Educational, Scientific and Cultural Organization
7 place de Fontenoy, 75352 Paris 07 SP, France

ISBN 92–3–103967–9

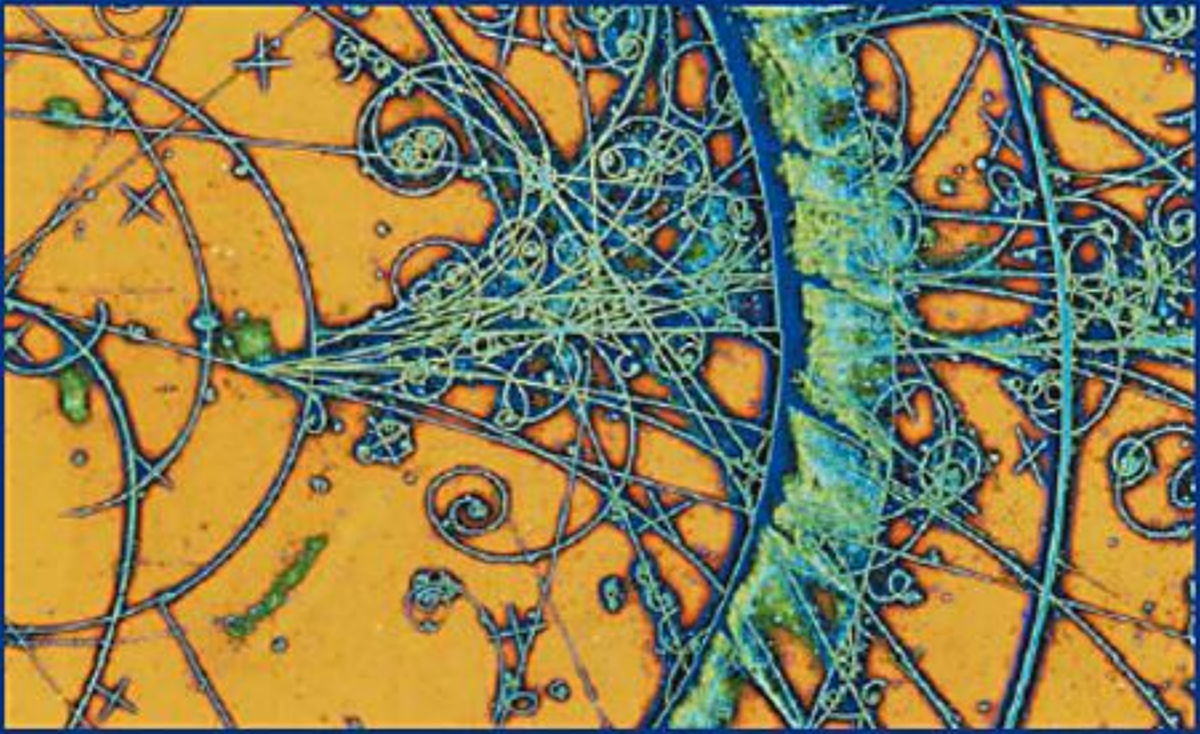
www.unesco.org/publishing



Typeset by Curran Publishing Services, Norwich, UK

Printed by Darantiere, 21809 Quetigny
*Printed in France*

# UNESCO SCIENCE REPORT 2005



United Nations
Educational, Scientific and
Cultural Organization

UNESCO Publishing