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Study on National Research Systems

A Meta-Review

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REGIONAL REPORT ON AFRICA

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SECTION 1: INTRODUCTION

Our review of sub-Saharan African countries produced country reports for 17[1] countries: Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mali, Namibia, Rwanda, Senegal, Tanzania, Uganda, Zambia and Zimbabwe[2]

Although these countries were selected because they met the criteria (relatively poor developing countries and not well-researched) of this study, there are still significant differences in their science and technology systems. These differences are due to many factors: socio-political histories, geography, political and economic (in)stability, different legacies of colonial science influence and subsequent science institutionalization development and so on.

One example of the differences between the seventeen countries is illustrated by differences in scientific output as measured by articles published in the ISI-indexes. In terms of this measure, one would distinguish between three clusters of countries: those countries (Kenya) that produced more than 2000 publications between 2001 and 2004 (Tijssen, 2006); another cluster of countries (Cameroon, Tanzania, Ethiopia, Zimbabwe, Uganda, Ghana and Senegal) who produced at least 500 publications and then the remaining countries who produced less than 500 or – stated differently- less than 100 articles on average per year. The African picture of scientific production is no less skewed than any other region of the world!

However, publications in ISI-journals are not necessarily the best indicator of science in a country, especially in developing countries, where there are many "informal" scientific institutions who produce science in various non-standard dissemination media. Also, it is well documented that journals in "marginal countries", such as the case for all African countries, are not well-represented in ISI-indexes. Unless one also takes into account scientific production in local African journals, one still has a very biased and restricted view of science in such countries.

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[1] It was, in the final analysis, not possible to compile reports for Benin, the Gambia and Nigeria.

[2] This regional report is based on the individual country reviews contained in the Africa compilation as well as some additional references. The authorship(s) of the individual countries in the Africa compilation are clearly identified and acknowledged in the compiled report. In summary, therefore, I only list here the individual authors of the country reviews: Nelius Boshoff, Simone Esau-Bailey, Jacques Gaillard, Hocine Khelfaoui, Mziwandile Madikizela, Johann Mouton, Nya Ngatchou, Mluleki Nkwelo, Nomahlubi Shezi & Frank Teng-Zeng, Florence Verlhac, Roland Waast and Erin Zink. I also wish to acknowledge very useful comments and corrections by Roland Waast and Jacques Gaillard to an earlier version of this report.

SECTION 2: SUMMARY INDICATORS AND DESCRIPTORS

Table 1: General demographic and S&T indicators

Country	Total Pop millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national income/ Per capita $/ 2003(WdI 2005)	PPP gross national income/ Per capita / Rank 2003(WDI 2005)	GERD/% GDP	Head-count of researchers	Nr of researchers per million of pop	ISI-papers (2002 – 2004)	ISI Rank	Average ISI papers per 100 000 pop (2002 - 4)	SCI pubs per 100 000 of pop
SMALL											
Botswana	1.7	131	8370	83	0.4%	2165	1270	329	97	6.5	6.89
Lesotho	1.8	149	3100	144	N/a	196	109	24			
Namibia	2.0	125	6660	95	<0.1%	N/a	N/a	146			
MEDIUM0											
Rwanda	8.4	158	1290	182	0.5%	1016	121	30			
Senegal	10.2	156	1620	177	N/a	4800	470	470			
Zambia	10.4	165	850	194	0.1%	2098	202	206			
Malawi	11.0	166	590	207	N/a	N/a	N/a	305			
Mali	11.7	175	960	192	N/a	276	24	155			
Burkina Faso	12.1	174	1170	183	0.17%	1319	109	290	100	0.8	0.99
Zimbabwe	13.1	151			0.2%	1400	30	536			
Cameroon	16.1	144	1990	161	N/a			727	77	1.5	1.7
Cote d'Ivoire	17.6	164	1400	180	0.90%	1840	104	352	95	0.7	1.65
Ghana	20.7	136	2190	155		1840	89	477	89	0.8	0.69

Country	Total Pop millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national income/ Per capita $/ 2003(WdI 2005)	PPP gross national income/ Per capita / Rank 2003(WDI 2005)	GERD/% GDP	Head-count of researchers	Nr of researchers per million of pop	ISI-papers (2002 – 2004)	ISI Rank	Average ISI papers per 100 000 pop (2002 - 4)	SCI pubs per 100 000 of pop
Uganda	25.3	145	1430	178	0.81%	1480	50	558	86	0.7	0.78
Kenya	31.9	152	1030	189		2400	35	1588	61	1.7	1.84
Tanzania	35.9	162	620	206	0.35%	1400	70	663	78	0.6	0.72
LARGE											
Ethiopia	68.6	170		201		4070	59	595	84	0.3	0.09

Table 2: Higher Education Indicators

	Total HE enrolment 2004[3]			*Teaching staff (2004)*[4]		*Total number of graduates (2004)*[5]		*Total public expenditure on education (2004) as a % of GDP*[6]
	MF	*%F*[7]	*% Private*	*MF*	*%F*	*MF*	*% F*	
Botswana	10 197	46	100	827	30	3417	...	8.0.
Burkina Faso	Ca. 15 000							
Cameroon	60 500							
Cote d'Ivoire								
Ethiopia	172 111	25	23	4 803	9	41 364	29	4.6
Ghana	69 968	32	-	3 933	14	…	...	...
Kenya	102 798	38	...	...	...	…	...	7.0
Lesotho	…	…		…	…	…	…	9.0
Malawi	5 089	35	-	418	32	…	...	4.7
Mali	25 578	35	-	975	...	…	...	
Namibia	12 197	53		…	…	…	…	7.2
Rwanda	25 233	39		1 738	12	3595	42	..
Senegal	52 233	...	21	...	...	…	...	4.0
Tanzania	42 948	29	...	2 516	16	4 028	...	...
Uganda	88 360	38	10	4 168	19	21 164	38	5.2
Zambia	...	...	...	...	...	…	...	2.8
Zimbabwe	55 689	39	10	...	...	…	...	...

Source: Global Education Digest 2006; UNE SCO Institute for Statistics; Web Page: http://www.uis.unesco.org/TEMPLATE/pdf/ged/2006/GED2006.pdf

[3] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - accessed 3 August 2007
[4] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 4; - accessed 3 August 2007
[5] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 16; - accessed 3 August 2007
[6] Source: Global Education Digest 2006; UNE SCO Institute for Statistics; Web Page: http://www.uis.unesco.org/TEMPLATE/pdf/ged/2006/GED2006.pdf - Table 13; - accessed 3 August 2007
[7] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 14; - accessed 3 August 2007

Table 3: General science "system" descriptors

Country	*S&T Policy Document*	*Ministry of S&T*	*Research Funding Agency*	*Nr of public universities*
Botswana	Yes (1998)	Ministry of Communications, Science and Technology (MCST)	Botswana Research, S&T Investment Agency (BRSTIA)	2
Burkina Faso	No info	Ministry of Higher Education and Scientific Research	None	2
Cameroon		Ministère de la Recherche Scientifique et Technique	None	6
Cote d'Ivoire		Ministry of Higher Education and Scientific Research	Direction de la Programmation, du Financement, de la Formation et de la Promotion du Personnel de la Recherche Scientifique	3
Ethiopia	Yes (2007)	Ethiopian Science and Technology Agency (ESTA)	None	15
Ghana	Yes (2000)	Ministry for Education, Science and Sport (MOESS)		7
Kenya	Yes (1980)	Ministry of Education, Science and Technology (MOEST)		5
Lesotho	Yes (2003)	Ministry of Communications, Science and Technology	MCST, Lesotho Innovation Trust Fund (LITF)	1
Malawi	Yes (2002)	Ministry of Education, Science and Technology	National Research Council	2
Mali	No info	Ministry for Secondary and Higher Education and Scientific Research (MSHESR)		1
Morocco	Yes (2000)	Ministry of National Education, Higher Education, Professional Training and Scientific Research	National Centre for Scientific and Technological Research	15
Namibia	Yes (1999)	National Commission on Research, Science and Technology (NCRST)	Foundation for Research, Science & Technology (FRST)-	1
Rwanda	Yes (2005	Ministry of Science and Technology	Innovation & National Research Fund	6
Senegal	Strategic Plan 2006-2010	Ministry of Scientific Research	Fonds d'Impulsion de la Recherché Scientifique et Technologique (FIRST)	2
Tanzania	Yes (1996)	Ministry of Science, Technology and Higher Education (MSTHE)	Commission for Science and Technology (COSTECH)	3
Uganda	Draft (2006)	Uganda National Council for Science and Technology (UNCST)		5
Zambia	STDP (2002)	Ministry of Science, Technology and Vocational Training (MSTVT)	Ministry of Science, Technology and Vocational Training (MSTVT)	2
Zimbabwe	Yes (2002)	Ministry of Science and Technology Development (MSTD)	Research Council of Zimbabwe (RCZ)	2

SECTION 3: SUMMARY FINDINGS FROM THE COUNTRY PROFILES

In this section, we discuss a number of themes that build on the detailed country profiles. This is done under the following headings:

1. Recent trends in governance and policy development in S&T
2. The institutional landscape: institution-building or de-institutionalization?
3. Current state of human and infrastructural resources
4. Information scientific structures and scientific communities

3.1 Recent trends in governance and policy development of S&T

Our meta-review of seventeen countries would suggest that it is possible to discern at least three very different trajectories as far as science policy development is concerned within the African countries studied.

- The first trajectory refers to those countries which have gone though two waves of science policy development: during the first wave (not too long after acquiring independence) a first S&T policy was developed but during the subsequent years was allowed to become dormant and ineffectual. A second wave of policy revision was instigated more recently (1990's and after) in order to recapture the essence of the science policy goals. However, not all countries managed to revise their policies effectively with the result that there is now a very evident policy vacuum in some countries (e.g. Kenya). This category of countries includes Ghana, Kenya and Senegal.
- The second category consist of countries that established their first S&T policy documents in the 1990's and even more recently (after 2000): These include countries such as Botswana, Lesotho, Malawi and Namibia.
- A third – and small category of countries in sub-Saharan – still do not have a S&T policy, e.g. Mali and Swaziland (not covered in this survey).

We elaborate on each of these trajectories with reference to illustrative examples.

Trajectory 1: Two waves of science policy development

The more well-developed science "systems" in sub-Saharan Africa invested in the establishment of a science governance framework with associated science policy statements soon after achieving independence. However, very few of these relatively early efforts to establish the desired S&T governance framework were successful

which led them to revisit and reformulate the first versions of their science policy frameworks in more recent years.

One of the earliest attempts in this regard occurred in Ghana which published its first "seven year plan for national reconstruction and development" in 1964, which firmly placed science and technology as central to the country's development efforts. However a fairly long period elapsed before the earlier policy was revisited. Since 2001 there has been a reorganization of various ministries, including the line ministry for S&T (Ministry of Environment and Sciences), with the latter being dissolved in April 2006. Responsibility for Science was then shifted to the Ministry of Education and Sport, where after the name of the ministry changed to the Ministry of Education, Science and Sports (MOESS). During the 1990s the Government of Ghana adopted Ghana-Vision 2020, aimed at making Ghana a middle-income country by the year 2020. The Government published the first medium-term development plan based on what it called *Ghana-Vision 2020 (The First Step: 1996-2000)*, in which S&T fell under the heading of 'Enabling environment' and formally formulated a draft National Science and Technology Policy in December 2000. At present the Ministry of Education, Science and Sports (MOESS) is in the process of finalising a Strategic Plan for Science and Technology Development and Usage to support the implementation of major Government programmes such as the Ghana Poverty Reduction Strategy (GPRS II). This process is scheduled for completion in 2007 (GoG, 2006).

The first Kenyan Science and Technology Act Chapter 250 was formulated in 1977 with a revised version in 1980. Some of the key institutions established in accordance with this act were the National Council for Science and Technology; Advisory Research Committees and Research Institutes with various functions to promote the application and development of science and technology for socio-economic transformation. Since then different sectoral policies including education and ICT have been drafted but the national S&T Policy is yet to be revised. It hence became one of key areas of Kenya Vision 2030 policy document drafted in 2006. In line with achieving the goals of Vision 2030, the science and technology system is currently under review with the intention of formulating a new science, technology and innovation policy and strategies.

Senegal created its first Ministry of Scientific and Technical Research in April 1983 only for it to be abolished three years later in January 1986. A substantive ministry

was recreated in 1995, only to be merged with the Ministry of Higher Education and Scientific Research in 2000. This merger of Higher Education and Scientific Research did not last because the current government re-established the Ministry of Scientific Research and Technology in 2002

Trajectory 2: Late establishment of science policy and governance frameworks.
The majority of the countries in our study have only very recently established either a science policy document or proper science governance framework (dedicated Ministry for S&T) or both. The timeline below illustrates this clearly:

Year of Science Policy Enactment	***Countries***
1993	Ethiopia (Revised in 2006)
1996	Tanzania
1997	Zambia
1998	Botswana
1999	Namibia
2002	Malawi, Zimbabwe
2003	Lesotho (first draft; final version 2006)
2005	Rwanda
2006	Uganda (first draft)

Two interesting trends emerge from a cursory inspection of these science policy documents:

- The tendency to imitate – rather slavishly and uncritically – science, technology and innovation policy approaches and paradigms from elsewhere. Some examples; This is evident in the Ethiopian S&T policy document where there are uncritical and fairly inappropriate comparisons with the science systems in South Korea and Malaysia. It is also evident in many African documents that aim to emulate and adopt the concept of “national systems of innovation” (NSI) to their own science systems. Such an emulation is highly inappropriate given the early developmental state of local science systems. A derivative of this tendency has recently manifested itself in Southern Africa where some Southern African countries (most notably Lesotho, Namibia and Botswana) are currently emulating the science and technology policies of the South African government. This is perhaps not surprising given that experts from South Africa have been called in to assist in the development of these

policies and plans (e.g. Botswana) and because of the closer relations amongst these countries.

- A second pattern that has emerged is found at the substantive level where one finds a large degree of similarity in the content and emphasis in these documents. Again, this should not be that surprising as most of these science policy documents have originated in a globalizing world where national boundaries and national goals are increasingly subsumed under inter-national interests. Most of the science policy documents crafted over the past decade or so therefore have very similar contents and identified priorities, e.g. focus on science and technology for development and economic growth, the adoption in many cases of the notion of a "national system of innovation", linking science and technology with poverty reduction strategies and (more recently) with the Millennium Development Goals and at the substantive level, identifying biotechnology, ICT and nanotechnology as priority areas.

Trajectory 3: No science policy

A few countries in sub-Saharan Africa do not have as yet a science policy framework. In our sample, this would refer to Mali. Other countries, not included in this review, such as Angola and Swaziland, also do not have such policies. It is clear that the non-existence of a science policy framework is explained by different reasons in these countries. In Angola the devastating effects of a lengthy war, has meant that attention to S&T has not been fore grounded until very recently.

In Mali it seems that a lack of a clear "driver" of this process is the reason for its non establishment. A national seminar was organized on the formulation of a National Scientific and Technological Research Policy in 1999 but no decision was taken on the subject of this seminar, because no one at the Ministry for Secondary and Higher Education and Scientific Research really occupied themselves with giving direction to the programme and tabling exact proposals in Parliament.

Swaziland has one of the smallest science bases on the continent with a very small and concentrated research capacity at the University of Swaziland. Research for the two main industries in the country – forestry and sugar – is outsourced to institutes in South Africa. This might be a case where a science policy framework was never deemed to be sufficiently urgent or required to deserve attention! There are now signs of an intention to develop such a policy.

A concluding comment: The existence of science policies in many countries in our study does not of course mean that these are either effectively pursued or very clearly manifested in actual S&T performance. As our country studies show, in many countries these policies are still rather "empty" documents with little or no effect, mainly because of a lack of resources and (in some cases) lack of will to give expression to the goals and objectives of these documents. Perhaps the best illustration of this phenomenon is the fact that many of these policies and associated plans have set themselves the target of expending 1% of GDP on R&D. As Table 1 above shows not a single country in sub-Saharan Africa has achieved this target yet.

On a more positive note it is worth pointing out that there is great interest in many of the smaller countries for assistance and expert advice on further science policy development. Countries such as Ethiopia, Tanzania, Malawi, Lesotho – to mention a few only – have reached out to international agencies (including UNESCO) for assistance in the further development and articulation of their science policy and governance frameworks and structures. This is certainly an area that deserves more concerted effort in the future.

3.2 The institutional landscape: institution-building or de-institutionalization?[8]

Different science systems have very different institutional arrangements and forms. Modern science systems have evolved very differently in different parts of the globe and have produced very different types of research institutions.

In their pioneering studies on this theme Waast and Gaillard[9] discuss the emergence of "national modes of scientific production" and how these manifested itself in some African countries (Kenya, Nigeria and South Africa) after having achieved independence. .For them a "national mode of science" (Gaillard and Waast, 2003: 160) has the following characteristics:

1. Science is for the public good

[8] Interesting studies on this theme are found in the special issue of the Journal "Science, Technology and Society", 8:2 2003, about Nigeria, Tanzania, Madagascar and Mozambique as well as Morocco or Tunisia.

[9] J. Gaillard et al (1997) *Scientific communities in the developing world*, New Delhi: Sage; R. Waast & VV Krishna "Science in Africa; From Institutionalisation to Scientific Free Market- What Options for Development ?", *Science, Technology and Society*, 8(2): 153 -182, 2003.

2. The state assumes a major responsibility for financing research and development activities
3. The direction of that science is determined by the country's most pressing needs
4. Research scientists and particularly the scientific elite are mostly civil servants and have the right to pursue careers
5. They are imbued with national values as well as professional ones
6. Besides the peer community, the recipients of the products of research are principally the public authorities. The direct users of the products are hardly involved.

In their assessment, by the 1990s much of African science stood at a "very delicate position of crumbling both professionally and from the perspective of institutionalization of science as we conventionally understand it"(op cit. p. 161)

We would agree with these sentiments and add that most modern science systems have a number of typical features:

- There is a core of relatively stable and well-resourced scientific institutes
- There is consistent government and industry investment in these institutes
- Scientific institutions (both formal and informal) flourish under conditions of economic and political stability and within a science governance system that allows for their autonomous and relatively independent operation

Unfortunately, few or none of these "conditions" apply consistently to the seventeen countries in our study. Many of the scientific institutions in the developing countries of sub-Saharan Africa are:

- Fragile and susceptible to the vagaries of political and military events
- Severely under-resourced
- Suffer because of a lack of clarity and articulation of science governance issues (demonstrated by constant shifts in ministerial responsibility for science)

In fact, one could even refer to some of these science systems and the associated institutions as operating in a "subsistence" mode where they struggle to even reproduce themselves. By a "subsistence mode" we mean a system that basically produces knowledge for its own use only and does not export knowledge and in fact

does not make a significant contribution in the global game of knowledge production. In fact, it is debatable whether one can talk of a science "system" in many of these countries as they do not exhibit typical "systemic" characteristics. Institutions are not typically aligned through input, process and output flows and there is no typical systemic behaviour in response to external changes and demands. Rather, the image of an "assemblage" of fragile, somewhat disconnected and constantly under-resourced institutions is perhaps a more apt metaphor to describe the science arrangements in some of these countries.

But one should be cautious of over-generalization and over-simplification, as there are also instances of small but robust institutions that have survived the vagaries of political and economic instability, of universities that are still producing high quality graduates and supporting pockets of significant science. Before elaborating on these, we turn to a discussion of a few factors that have in the past and still continue to shape and affect the (de) institutionalization of science in these countries.

Our discussion commences with a focus on four major historical influences on the nature of scientific institutions in sub-Saharan Africa:

- The continuing legacy of colonial science in many countries
- The destabilizing influence of political events and civil wars
- The devastating influence of World Bank policies on higher education in Africa
- The role of international agencies in shaping African sciences

Colonial science legacy

Many of the research institutes that were established during colonial rule still exist in African countries. It is now well documented that the role of different colonial powers in the formation of scientific institutions varied greatly across continents. This is both a function of the nature of the institutions that were established as well as the "model" of "colonial" science pursued.

The British model of colonial science privileged the establishment of botanical gardens in many of the colonies as sites to conduct plant and other related research. This model was shaped by the influence exerted by the Royal Botanical Garden at Kew in London. At Lagos (Nigeria) a botanical garden was established in 1887; the

Royal Niger Company also founded a garden for the distribution of plants at Asaba in 1888 and established four other agricultural stations at various locations between 1889 and 1890 for experiments with coffee, cocoa and other crops. Ghana (then Gold Coast) also had a government botanical garden in 1890 at Aburi (McKelvey 1965:319).

Interestingly enough the British did over the years attempt to give more responsibility to the colonies in steering their own research agenda's. According to Sir Charles Jeffries (1964), three main principles guided the development of scientific institutions (facilities) in British colonial Africa:

- the facilities should be in the colonies rather than in Britain;
- research should be organised on a sub-regional rather than on a territorial basis and;
- colonial administrations should share in supporting the costs of research facilities and eventually bear complete responsibility for them (Eisemon & Davis 1997:108-109 in Teng-Zeng, 2005).

Therefore, to accomplish this regional approach to colonial S&T, research councils were created in British Africa which formulated regional research policies and priorities and then made recommendations on the allocation of research funds, as well as on projects assigned to institutes.

The French approach to colonial science was very different. Research done in the colonies had to be done through the mediation of institutions based in Paris such as the *Musée National d'Histoire Naturelle*, which had a section devoted to tropical agriculture and the *Ecole Supérieur d'Application d'Agriculture Tropicale*, which provided the training for Colonial Agricultural Officers. It was only with the Pasteur Institute which pioneered the organisation of research activities in the region when it established local branches (Hailey, 1956:918). Gaillard *et al.* (1997:28) confirm this, noting that the major translocation of French science in Francophone Africa from the late nineteenth century until the 1950s was the "institutional radiation" of, for example, the establishment of six local Pasteur institutes in Saigon (1890), Algiers (1894), Nhatrang (1895), Madagascar (1902), Tunis (1903), Brazzaville (1910) and Dakar (1913) (also see Forje, 1989:21; Eisemon *et al.,* 1985:193). According to Eisemon *et al.* (1985:193), these institutions performed extensivee experimental research, produced vaccines and provided routine diagnostic services. Thus far the

work which was sponsored by the Pasteur Institute in North Africa has produced the only two Noble Prizes for medicine in Africa, one to Laveran in 1907 for his work on malaria and the other to Nicolle in 1928 for his work on typhus. It was not until 1938 that the French established the *Institut Français d'Afrique Noire* (IFAN) to conduct research into all African problems, including those in the social sciences (Hailey 1957:1608; Forje 1989:21). Meanwhile, at this point these research activities were never co-ordinated at either the inter-territorial or metropolitan level (Teng-Zeng, 2005).

The creation of the *Office de Recherché Scientifique Coloniale* in October 1943 marked the first attempt at research co-ordination in the French colonies[10]. Thereafter French colonial authorities operated mainly through the *Office de la Recherche Scientifique Technique Outre-Mer* (ORSTOM – Office for Overseas Scientific and Technical Research) and through a group of applied research organizations (GERDAT) for agriculture in Francophone Africa. These included the Institute for Research in Tropical Agriculture (IRAT), the Institute for Research on Oil and Oil-bearing Plants (IRHO), and the Institute for Research on Cotton and Textiles (IRCT). Generally, ORSTOM was responsible for basic research (hydrology, soil science, entomology and virology) and GERDAT for applied research carried out in the various areas of coffee, cocoa, tea, tropical forests, rubber, rice, etc. (Forje 1989:195; see also Gaillard & Waast 1992:43)[11]. Most of these institutions had been established to extract and promote exports crops as raw materials for industrial production in Europe to the detriment of basic food crops (Teng-Zeng, 2005).

Unlike the British case, "only modest effort was accorded by French colonial or metropolitan authorities to the development of research activities in African colonies" (Eisemon *et al.,* 1985 as cited in Forje, 1989:21)[12]. Of course this is a partial (and biased: English) point of view. In fact, some areas were of crucial political importance, as the control of peasants and agriculture. In this field, public S&T utilities were soon set up and managed by a body of professionals who were often ahead of scientific practices in France. See C. Bonneuil 1999 a & b). But it can be argued that there were fewer institutional

[10] C. Bonneuil & P. Petitjean, « Recherche scientifique et politique coloniale: les chemins de la création de l'ORSTOM », in P. Petitjean ed. *Les sciences coloniales, Figures et institutions*, Paris : Orstom, 1996, p. 113-161

[11] For a more detailed discussion of this early history, see J. Gaillard and Lawrence Bush, "French and American agricultural science for the third world", *Science and Public Policy*, 20 (4): 222 – 234, 1993.

[12] For a deeper and well documented point of view, see : C. Bonneuil "Penetrating the Natives: Peanut Breeding, Peasants and the Colonial State in Senegal (1900-1950)" in *Science, Technology & Society*, 4:2 (1999): 273-302 and C. Bonneuil (1998): *Villages on Trial: Agricultural Scientists and the Building of the Developmentalist State in Tropical Africa, 1930-1970*, paper given at the Conference on African Studies and the History of Science, Oxford, 7 March .

linkages and less co-operation among Francophone colonies in the field of science and technology. According to Forje (1989:21), there was no co-ordination of French colonial policy on scientific and technological activities up to the Second World War (cf. Bonneuil & Petitjean op.cit.) Hence, the S&T activities of each institute or territory were explicitly and implicitly assimilated and undertaken by research institutions in metropolitan France that had African branches. Moreover, the regional centres so established were controlled by the French in terms of central management and staffing, as these centres were dominated by expatriates and no concrete efforts were made to develop the local capacity for independent research in the colonies. (Source: (Teng Zeng, F*. Science, Technology and Institutional Co-operation in Africa: From Pre-colonial to Colonial Science)*

What is perhaps not so clear is how the continuing legacy of colonial scientific institutions in many African countries should be assessed. On the one hand, such institutions had the negative effect of creating a long-term dependency by the African country on the colonial power – long after independence, which led to a neglect in establishing local institutions (Cf. Gaillard's interesting thesis in this regard in his study of the Tanzanian science system[13]. On the other hand, some of the institutes (such as the Pasteur institutes in Francophone countries) remain sites of significant capacity and provide a stabilizing continuity within the scientific landscape of these countries.

Political stability and civil wars

The destabilizing influence of many regional and local political events have led to the closing of scientific institutions (universities) in many countries and effectively put science back many decades. Events such as the civil war in Rwanda/Burundi, the Mengistu regime in Ethiopia, Amin's dictatorship in Uganda, the civil wars in Mozambique and Angola are examples. These events have had different negative impacts on institution building in these countries. In many cases it led to the suspension of overseas research funding (e.g. Sida/SAREC suspending its support to Ethiopia in the late 1990's), the closing of institutions because of lack of government funding and perhaps most notably the huge flight of top academics and scientists to other parts of the world. A good example of the devastating impact on a single institution is that of the University of Makerere in Uganda. Once a major site

[13] J. Gaillard "Tanzania: A case of dependent science" in *Science, Technology and Society* 8:2 (2003): 317 – 343.

for internationally recognized good research in the 1950s and 1960s, it suffered because of civil war and lack of government funding in the 1980s and beyond. This has forced the University in the 1990s to take in many more students than it could support (in order to raise some fees) with the result that by the beginning of this millennium it has more than 30 000 students for a campus built for less than 15 000. It is only in recent years that student growth has been capped and a decline in student numbers has materialized.

Structural adjustment policies and economic decline

Various international forces associated with globalization and internationalization of trade in the 1980s and 1990s have had a devastating effect on the economies of many African countries: the decline in export volumes as well as the relative decline in the price of primary products in world trade in the 1980s and 1990s, combined with the mishandling of exchange rates and of external reserves, and the huge external debt overhang together created major resource gaps for the countries of Africa. This put serious pressure on their import capacity and the availability of resources for essential economic and social investment. The results included increased dependence of the typical sub-Saharan Africa country on aid from the developed countries.

As Sawyer summarized it aptly:

> *The reality of globalisation - deriving from movements in economy and production - erodes the capacity of the typically marginalised and dependent sub-Saharan African state to generate enough production, savings and investment to ensure sustainable development. For its part, the ideology of neo-liberalism and the institutional arrangements that promote it, limit the policy instrument available to the state for intervening in the market place to ensure the provision of the basic needs of its people, thereby restricting the state's capacity to fulfill its principal function.* (*Challenges facing African universities: Selected universities*, n.d.)

He continues:

> *The collapse of many national economies in Africa under these forces and the accompanying destabilisation of social structures threw all institutions, including those of higher education, into a prolonged crisis. A variety of structural adjustment programmes (SAPs) were introduced in the 1980s and*

1990s to reverse the economic and social crises. The programmes were intended, first, to give freer reign to market forces by removing rigidities in the production, pricing, marketing and exchange rate regimes. They also sought to cut back the role of the state, downsizing it and reducing its reach. All this was to be combined with the rapid opening up of the economy to international competition. The results are yet new challenges to Africa's universities - the downgrading of university funding (in favour of basic education) and the pressure on them to adjust to the severe austerity regimen imposed by the various economic stabilisation policies, at the same time as they were pressured to increase enrolment and maintain quality levels, without commensurate increases in resources …A further factor was the policy of privileging expenditure on basic education at the expense of higher education, a posture reflecting the policy positions of the World Bank and leading donor agencies, and the argument that the social rate of return on investments in basic education was higher than in higher education.

To summarize: At the same time as university enrolments increased exponentially in many African countries, both government support and external donor aid to higher education was dramatically reduced. The result was quite predictable with many universities thrown into financial crisis, laboratories and libraries not receiving any maintenance, overcrowded class rooms and huge flight of the top academics from these institutions. It was only towards the end of the 1990s that these trends were being reversed and government and international aid (most notably through the Partnership Foundation in the USA) to universities in Africa being restored. However, it should be evident that research and scholarship would be one of the main losers during these years!

International research and funding agencies

The role of international agencies in shaping and steering science on the African continent cannot be underestimated. In this regard we include both the role of international development and aid organisations such as Sida, Norad, Carnegie, Ford, Rockefeller, USAID, IDRC and many others as well as the presence of international research bodies such as the CGIAR institutes, WHO research institutes and so on. On the positive side, these institutions and agencies, have to a large extent, managed to sustain a minimal scientific production in many countries where the formal S&T structures (universities and government research laboratories) have failed or seriously declined. So, for example, it is clear that the continuing support of

SIDA to Addis Ababa University in Ethiopia since 1976, has sustained a minimal scientific output in the natural and health sciences. On the negative side, it could be argued that some of these organisations and agencies have been more interested in pursuing their own (international) research agenda's and have not done enough to ensure the long-term sustainability of a local science base in Africa.

What have emerged from our seventeen country studies on scientific institutions? Although somewhat "untested" a first typology of institutional strength and scope can be proposed:

Type 1: The smallest science systems on the continent often rely heavily on the role and contribution of one (or a few) public universities as the main producers of knowledge. In countries such as Namibia, Botswana and Lesotho there are no significant research institutes outside of the national universities and 80 – 90% of the small research output is generated by academic staff at these institutions.

Type 2: Some countries have – in addition to a fairly strong public university (Makerere in Uganda, Dar es Salaam in Tanzania, Addis Abeba University in Ethiopia and so on) also some government funded research institutes and/or international research institutes based in these countries. However, it is not always evident that there is a strong connection and collaboration between staff at these universities and research workers in the local institutes of international agencies (CGIAR or WHO institutes).

Type 3: A few countries – Kenya, Ghana and Senegal – have a larger array of scientific institutions (a number of public universities, government funded laboratories and institutes and internationally based agencies).

The critical role of international research organisations in Africa

Although not always evident from the individual country studies, the very important contribution that international research organizations make to scientific research in Africa cannot be ignored or underestimated. It is also very clear that countries which house the headquarters of these organisations or significant institutes thereof, benefit immensely from their presence. As an illustration of the extent and range of these innternational centres, we discuss in Appendix A a sample of these centres. The examples are mainly from the field of agricultural research which is dominated by the presence of these organisations.

The significance of international institutes such as those listed in Appendix A is manifold:

- They provide some continuity in research programmes in the countries where they are located
- They are conduits for R&D funding through their international donors
- They form networks of collaboration and expertise that cut across national boundaries
- They provide employment to local scientists in countries where research employment is limited
- They usually have much better facilities and laboratories for conducting research than the local universities and research institutes of the host country.

On the downside, except in very general terms, one could not speak of a close alignment between the research priorities and programmes of these institutes and the national R&D priorities of individual countries. These institutes do not fall under the governance of the national science system of the host country and cannot be said to contribute in any strong sense to national institution-building. The research agenda's and priorities of these institutes are usually set at a supra- or inter-national level. So although their presence in these countries has a positive impact on science in those countries and in the regions and there have been well-documented success stories, in the final analysis they remain disconnected "from the "national science systems" of these countries.

Concluding comment: "Assemblages" of science

What kind of science is being practised in African countries? Our analysis, based on the meta-reviews, suggests a three-fold typology[14].

- Academic science in the universities
- Consultancy science for international (overseas and locally based) organisations
- Mission-oriented science mostly in international agencies (WHO, CGIAR institutes), but also in some cases, in government-based laboratories.

[14] This typology is similar to an earlier analysis by R. Waast and J. Gaillard R. Waast & VV Krishna "Science in Africa; From Institutionalisation to Scientific Free Market- What Options for Development ?" in *Science Technology and Society* 8(2) 2003: 153-182.

"Academic" science refers to science done by individuals or groups of scientists within universities. Our sense is that much of this science is under-funded, driven by the individual's scientists priorities and interests and is ultimately aimed at advancing the career of the individual academic. This kind of scientific endeavour rarely converts into building institutional capacity since it is not linked, for example, to a group of doctoral or even post-doctoral students. It is therefore not accumulative over time and does not culminate in the building of a programme or centre of excellence that can act as a node for future research and post-graduate training. Again, there are exceptions such as the highly successful Ethiopian Flora project that has been supported by Sida/Sarec since 1975. But it is precisely because of the international support that one has seen the development of a niche area which accumulated expertise over time.

"Consultancy" science is self-explanatory and refers to the wide-spread occurrence of academics engaging in consultancy work – mostly for international agencies and governments – to augment their rather meager academic salaries. This is perhaps more prevalent in certain disciplines – health sciences, business studies, ICT, monitoring and evaluation work – but is still widespread and on the increase.

Mission-oriented science conducted within the frameworks of international agencies as described above. This is typically Mode 2 science driven by concerns of application and innovation, where the research agenda's are set by non-academics (including foreign boards).

The end result of this picture is clear: lack of funding and interest in classic fundamental science which builds a knowledgebase in a discipline, very little output in academic journals and insufficient attention to the reproduction of scientific capacity through doctoral and post-doctoral programmes.

3.3 Current state of human and infrastructural resources

General concerns in the human resource area include poor pay and conditions, resulting in a serious and continuous brain drain problem, within the sector, to other non-science sectors and abroad to developed countries and increasingly also to South Africa as a preferred destination. Research infrastructure is often in a poor state with obsolete laboratories and equipment at many research universities. International support is still mainly aimed at human resource development and less

directed at funding laboratories and research infrastructure. One of the continuing and sustained challenges for human resources development in science and technology is the persistent brain drain. The continuing seriousness of this issue is illustrated again by the fact that the Association for African Universities (AAU) devoted its most recent meeting in Tripoli in October 2007 to an extensive discussion of this matter. We elaborate on some of the issues and challenges below.

On the brain drain

Of the 150 million migrants in the world, more than 50 million are estimated to be Africans. However, a recent report submitted to the United Nations suggests that there are 191 million international migrants in 2005, with those living in Africa accounting for only 9%. In terms of skilled migrants the report notes that there were about 20 million migrants with tertiary education and aged 25 or over living in OECD countries in 2000, which is up from 12 million in 1990 (UN, 2006). The extent of human capital outflow from Africa has been described as staggering given that the level of training and research infrastructure and resources available in most African countries is not comparable to the developed and newly industrialising countries. (Mouton, J.; Kulati, T. & Teng-Zeng, F. [2007] *Scientific mobility and the African diaspora. Working Paper)*

Studies sponsored by the Research and Development Forum for Science-Led Development in Africa (RANDFORUM) reveal that up to 30% of African scientists – i.e. excluding other professionals – are lost due to the brain drain (see Adeboye, 1998). Given the gravity of the situation, therefore, the brain drain of scientists and other professionals from Africa was the subject of a discussion at a "Regional Conference on Brain Drain and Capacity Building in Africa" organised by the United Nations Economic Commission for Africa (UNECA-ECA) in the Ethiopian Capital, Addis Ababa, in February 2000 (ECA, 2000). According to the ECA and the International Organisation for Migration (IOM), an estimated number of 27,000 skilled Africans left the continent for industrialised countries between 1960 and 1975. During the period from 1975-1984, the figures increased to 40,000. Since 1990, at least 20,000 qualified people have left Africa every year (*Education Today*, 2006:4). Accordingly, Alex Nunn of Leeds Metropolitan University notes that this situation makes Africa 20000 fewer people who can deliver public services and articulate calls for greater democracy and development (cited in *Education Today*, 2006:4).

While migration affects all professions and sectors of socio-economic importance, the brain drain in the health and higher education sectors in most developing countries as well as the so-called emerging economies is now receiving much critical worldwide attention. For instance, it has been estimated that about 60% of doctors trained in Ghana during the 1980s have left the country, with 200 of them leaving 2002 alone. [15] Also, a study of the 1995, 1996 and 1997 graduate cohorts from the College of Medicine of the University of Nigeria totalling 468 of which 416 graduates were located shows that 40% of the medical graduates were presently living abroad (including 50% of the female graduates).[16] In 2003, the United Kingdom alone-approved work permits for 5880 health and medical personnel from South Africa, 2825 from Zimbabwe, 1510 from Nigeria, and 850 from Ghana even though these countries have being included among those proscribed for the UK National Health Service (NHS) recruitment.[17]

However, some scholars and analysts are now emphasising the importance of the brain gain in Africa, but there is still a long way to go before Africa can reverse its brain drain into positive brain gain. The irony is that with the current outsourcing of certain industrial activities and therefore jobs in some developed countries to developing countries, it is countries with high-level scientific manpower such as India and China that stand to benefit most. Few African countries can take advantage of the situation, because of limited fields of knowledge and limited capacity for rapid expansion as a result of the poor educational and research infrastructure in both the public and private sectors.

Although studies on the size and extent of the African brain drain are constrained by the absence of reliable and systematic data on international migration - something that is made more difficult by the fact that countries use different methods for recording migrants (Carrington & Detragiache, 1999) - the following figures are provided in order to give a flavour of the scale of the outflow of highly skilled personnel (HSP) from developing countries.

- The Commission for Africa (2005) estimates that around 70% of Ghanaian medical officers trained in the 1990s have left the country. Further, it has

[15] Sagoe K as cited in Eastwood, JB, RE Conroy, S Naicker, PA West, RC Tutt and J Plange-Rhule 2005. "Loss of health professionals from sub-Saharan Africa: the pivotal role of the UK", the *Lancet* 365: pp. 1893-900.
[16] Chikwe Ihekweazu, Ike Anya and Enyinnaya Anosike 2005. "Nigerian medical graduates: where are they now? The *Lancet* (May 28): pp1847-8.
[17] JB Eastwood *et al* 2005, p1893.

been estimated that there are more African scientists and engineers working in the USA than in the whole of Africa (Nunn, 2005).

- The Zimbabwe National Association of Social Workers estimates that 1,500 of the country's 3000 trained social workers emigrated to the UK during a period of 10 years (Mutume, 2003)
- On a more personal, Teferra (2000) has mentioned that of the 20 members of the physics faculty at Addis Ababa University who left the country (the majority for leaving for the US) to undertake their PhD studies, none have returned
- Among the immigrant populations living in the US, those from Sub-Saharan Africa are among the groups with the highest proportion of higher education qualifications (Carrington & Detragiache, 1999):
- The United Nations Development Programme (UNDP) estimates that up to 100 000 professionals leave India each year to take up jobs in the US (Mashelkar, 2005)

To give an indication of the scope and impact of these migration trends, we discuss in some more detail two African countries: Ghana and Botswana.

GHANA: The migration of skilled labour has long been a source of concern for most developing countries, but Africa in particular because it is regarded as a major impediment to national and regional development. For instance, although remittances to Ghana from non resident Ghanaians over the years have increased tremendously reaching $4.25bn (with $1.2billion from Ghanaians in the Diaspora) there are serious concerns about the impact on Ghana's human resources capacity development and sustainable development efforts. A recent World Bank report on census and population titled International Migration, Remittances and Brain Drain, indicated that 47 percent of Ghana's college-educated citizens live abroad. In fact it has been estimated that about 90% of all Ghanaian graduates have attempted at one point or the other to travel overseas. Although remittances are growing, in the words of Kwesi Andam, "nations are built with brains, not with absentee dollar remittance" (quoted by *Adomako, Appiah Kusi 2006 Ghanaweb Feature, 29 August 2006)*.

Also a new United Nations report on International Migration presented before the 61st UN General Assembly in August 2006 points out that "Between 33 and 55 per cent of the highly-educated people of Angola, Burundi, Kenya, Mauritius,

Mozambique, Sierra Leone, Uganda and the United Republic of Tanzania live in the countries of the Organisation for Economic Co-operation and Development (OECD). The report notes that about 50% per cent of the 'highly-educated' Ghanaians have migrated - mainly to more developed countries such as the United States, Britain and others within the OECD. Although brain drain cuts across sectors of the Ghanaian economy the health sector has received much attention in recent times. For example, Samuel Owusu-Agyei, Ghana's Deputy Minister of Health, expressed regret that out of the over 73 members of the Class of 1986 medical graduates, only 23 were currently working in Ghana with the rest working abroad. Table 1 shows the brain drain of medical and health personnel from Ghana in recent years with about 448 doctors leaving the country between 1999 and 2004.

Furthermore, an important aspect of scientific mobility in Ghana is internal, with more researchers at the public research institutes opting to join the higher education sector due to worsening conditions of service and poorer remuneration in the research institutes (Ayensu, 2005). For instance, the CSIR researchers went on strike in late 2004 upon failure to reach an agreement with government over salary and wage negotiations for better conditions of service.

Table 4: Brain Drain Health Personnel in Ghana, 1999 – 2005

Category of personnel	1999	2000	2001	2002	2003	2004*	Total
Doctors	72	52	62	105	117	40	448
Pharmacist	49	24	58	84	95	30	340
Allied Health workers	9	16	14	12	10	8	69
Nurses/Midwives	215	207	235	246	252	82	1,237

*Provisional

Source: ISSER 2006, p181 based on MOH

BOTSWANA: A 1987 review of the state of conditions of experimental research in the agricultural, engineering, life and physical sciences in Botswana, suggested that outward brain drain was not a major problem in the country. The report noted that Botswana professionals who studied abroad also readily returned home. However, the assessment was that there was internal brain drain at that time from research institutes by Botswana professionals to join other parastatals and the private sector mainly due to general unsatisfactory terms of service in research and teaching but

there was a net gain in migration with most research institutes staffed by expatriates in key positions (see Tebicke, 1987). The key question here is how different is the current situation in Botswana regarding scientific mobility two decades later?

Available figures from Botswana indicate that over 90% of doctors, 61% of pharmacists, and 64% of radiography cadre in the health sector facilities are expatriates. As a result the country is making great efforts to expand local training capacity and to increase the number of health students to address the problem (Gaolathe, 2005). At the University of Botswana, which is one of the key research performing unit in the country, 77% of the professorial rank is international staff, while only 23% of the citizens are at the same level. The senior lecturer level international staff represents 64% of this category, while 36% are Botswana nationals (University of Botswana, 2006:7).

In view of the net gains from migration inflow of the highly-skilled, the government has realised the importance of the inflow of skilled labour into the country and to speed up the processing of work and residence permit, it has established a second Regional Immigrants Selection Board in Gaborone. Since the Board started its work in May 2005, the turn around time for processing of work and resident permits has reduced from about 12 moths to 2 months. This of processing permits still longer than some of the industrialised and newly industrializing countries mentioned earlier in Section A of this report.

On reproducing the next generation of academics and scientists

In a recent paper, Teng Zeng (2005, *Research infrastructure and innovation systems in Africa: Enhancing higher education sector research*) has highlighted the challenges that many countries in Africa face as far as post-graduate research training is concerned.

For example, on the issue of foreign postgraduate training, he refers to a recent Universities UK report which reveals that over 13,000 students from Africa were engaged in postgraduate research and taught programmes in the UK alone in 2003/2004. In all, African students accounted for the second highest number of international students outside the European Union (EU) enrolled in the UK higher

education institutions, as seen from Table 5 below. In addition, Table 6 shows the ten top African countries supplying students to the UK universities system[18].

Meanwhile, during a recent ceremony for first year students at the University of Cape Coast (UCC) (one of the three largest and first-generation universities in Ghana), the Vice-Chancellor Prof. EA Obeng announced that for the 2005/06 academic year the university has enrolled 5,170 fresh students, the highest number in the history of the university. This brings the total to 31,229 enrolled students for all programmes. However, there were only 17 students enrolled for doctoral, 172 for masters and 229 for diploma programmes.

Table 5: International students domiciled outside the EU, by level 2003/2004

World region	Postgraduate Research	Postgraduate Taught	First Degree	Other Undergraduate	Total
Africa	3,315	10,415	9,505	3,545	26,780
Americas	6,230	10,450	5,505	3,850	26,035
East Asia and Pacific	12,140	37,890	40,750	8,560	99,340
Europe (non-EU)	1,940	4,970	5,385	810	13,105
Middle East	3,600	4,025	4,435	930	12,990
South Asia	2,595	13,695	6,305	1,215	23,805

Source: Universities UK Patterns of higher education institutions in the UK - Fifth Report, p. 31.

[18] "France should be mentioned too, as it is "the most popular host country in Europe, which receives 34 % of the African people studying abroad… This situation is particularly marked in doctoral studies, whose graduates very often remain in the host country…75 % of the citizens of developing countries attending doctoral studies in France are Africans (i.e about 1500 peoples per year), and 77 % of those obtaining post graduate vocational qualifications… Barré & Meyer, *Scientific diasporas*, Paris: IRD (2003) p. 129

Table 6: African countries supplying significant numbers of students to UK HE institutions

World region	Postgraduate Research	Postgraduate Taught	First Degree	Other Undergraduate	Total
Nigeria	470	2,795	2,210	470	5,940
Kenya	205	965	1,710	200	3,085
Ghana	270	1,610	645	275	2,800
Zimbabwe	125	395	810	1,410	2,740
Mauritius	105	365	960	220	1,645
South Africa	320	600	315	175	1,410
Libya	455	595	75	95	1,220
Tanzania	90	515	380	70	1,055
Uganda	110	445	240	90	885
Egypt	435	225	115	25	800

Source: Universities UK Patterns of higher education institutions in the UK- Fifth Report, p. 31

Despite the good intentions of overseas training, the usefulness of the acquired knowledge to the local research and innovation systems has sometimes been questioned. And at times such overseas training has also served as a conduit for the migration of the scientific workforce, particularly in many developing countries, weakening the already fragile knowledge base due to the lack of a critical mass in many sub-fields in the research and innovation systems. However, this situation is not helped by the immigration policies formulated by developed nations, including Australia, Canada, United Kingdom and the United States, etc., which have sought to attract highly educated professionals in order to boost their competitiveness and to fill domestic skills gaps.

3.4 Informal S&T structures and scientific communities

The “health” of a national system is sometimes gauged not so much by the formal policies, governance arrangements or robustness of research performing institutions, but by informal structures and organisations. In fact, the question is whether there is a discernible scientific community of scholars (for an early statement of these issues

see Gaillard and Waast, 1993[19]) which is active and vigorous. “Indicators” of the activity of such communities are not difficult to identify:

- A strong culture of national conferences and seminars
- A sustained tradition of scientific journals published within the country with strong science communication networks
- Active national societies, professional associations and national academies

In addition one could mention programmes and initiatives around promoting science (science awareness campaigns) and rewarding and recognizing scientific excellence (prizes, medals) and so on. Most well-established and well-articulated science systems comprise such scientific communities and the associated features listed above.

Our country studies for sub-Saharan Africa have shown, on the whole, however, that very little of these features are present in these science systems. We will elaborate on one issue - scientific journals.

Very few countries have sustainable capacity for local journal publishing. In fact our research has shown that the only ways that these countries seem to be able to sustain some national local journals is (1) through international funding (e.g. Sida support of 26 Ethiopian journals) or the presence of international institutes in the host country which have the resources to publish a journal or (2) the publishing in-house university journals that mostly cater for the university staff. In the latter case, such journals have no aspirations to becoming international journals. Our studies have also shown that many journals typically start at some point, but eventually run out of resources for its sustained continuation.

As an example of a poor country with a rather active science base, one can refer to Burkina Faso where researchers have at their disposal several journals that they try to maintain even if funding is very low.

Most of the Journals listed below are national journals. The “international” ones are issued by regional African bodies. The fact that Burkina Faso has managed to attract these journals points to some strengths in their science system. As Khelfaoui has

[19] J. Gaillard and R. Waast, “The uphill emergence of scientific communities in Africa”in Aqueil Ahmad (Ed.), Science and technology policy for economic development in Africa, International Studies in Sociology and Social Anthropology, pp. 41- 67, 1993.

shown in his country study Burkina Faso (Cf. the African compilation) has indeed long standing support to science.

Publications depending on the CNRST

- *"Revue Sciences et Technologies";*
- *"EUREKA!,* journal of popularisation;
- *"Série Colloques et Séminaires".*

Publications depending on the University

- *"CEDRES-Etudes",* half-yearly journal of the Centre d'Etudes, de Documentation et de Recherche Economiques et Sociales of the FASEG;
- *"Résultats de la Recherche",* series, FASEG
- *"Documents de Travail",* series, FASEG
- *"Revue Burkinabè de Droitt",* half-yearly journal of the FDSP
- *"Le Burkina Médical",* journal of the Société Médicale of the BFA (3 first issues financed by Presidential and Prime Minister Offices)
- *"Annales de l'Université: séries "Sciences et Techniques"*
- *"Annales de l'Université: séries "Lettres et Sciences Humaines"*

Regional publications (Western Africa) in Burkina Faso

- *"Journal de la Société Ouest Africaine de Chimie"*, bulletin de la SOACHIM.
- *"Bulletin de l'OCCGE"*, bulletin de l'Organisation pour la Coordination et la Coopération pour la lutte contre les Grandes Endémies.
- *"Revue du CAMES: séries Sciences et Médecine",* scientific journal of the Conseil Africain et Malgache pour l'Enseignement Supérieur.
- *"Revue du CAMES: séries Sciences Sociales et Humaines",* scientific journal of the Conseil Africain et Malgache pour l'Enseignement Supérieur.
- *"Revue et Perspectives, Document de Travail ILRI/CIRDES"*, journal of both the International Livestock Research Institute (ILRI) and the Centre International de Recherche-développement sur l'Elevage en zones Subhumides (CIRDES).
- *"SUD Sciences et Technologies"*, Journal of the Ecole Inter-état d'Ingénieurs de l'Equipement Rural (EIER)

The pre-eminence of regional publications can be explained by the important activity of international institutions (mainly African and scientific bodies) which had settled in the country. These journals are very much in demand because of their international scope.

But another example – that of a relatively "rich" country with a very small science system – Botswana – which is able to sustain (successfully it seems) a number of journals. Although most of them were only established in the last few years, the *Botswana*

Notes and Records, which had been published by the Botswana Society, has been appearing since 1969. Most of the local journals are published at the University of Botswana and include:

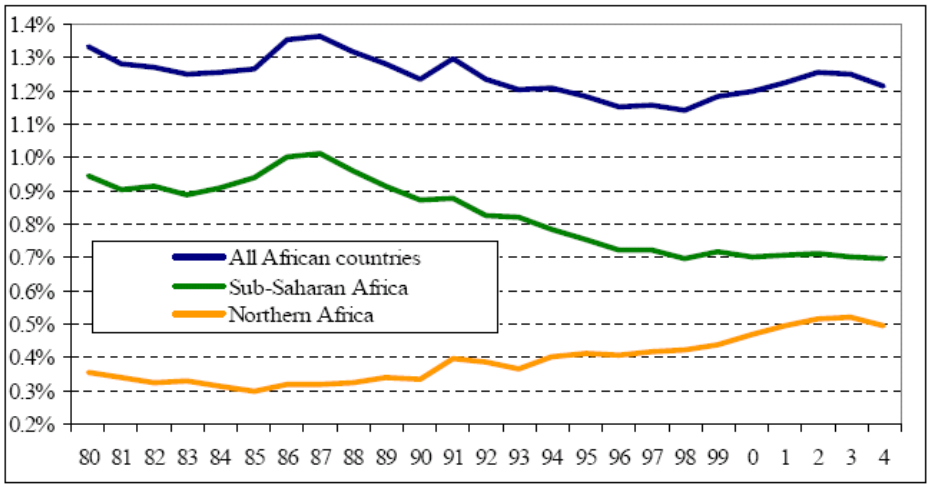
- *Botswana Notes and Records,* first published in 1969 (Botswana Society)
- *Pula: Botswana Journal of African Studies* first published in 1979 (UB).
- *African Journal of Library, Archives and Information* (UB) (indexed in AJOL)
- *Botswana Journal of Technology* 1993(UB) (indexed in AJOL)
- *Botswana Journal of Agricultural and Applied Science* (BCA)
- *Botswana Journal Business* 2002 (UB)
- *Botswana Journal of Economics* (UB)-launched 2004
- *University of Botswana Law Journal* (UB)–launched 2004
- *Southern Africa Journal of Mathematics and Science Education* 1994 (UB)

3.5. Knowledge production and output

It is by now well known that Africa's share of world science as measured in papers published in ISI-indexes have been declining steadily over the past decade. Various earlier studies by Gaillard, Waast and other have looked at this issue, but arguably the most comprehensive and up to date bibliometric analysis of these trends is captured in Robert Tijssen recent 2006 article in *Scientometrics* (*Africa's contributions to the worldwide research literature: New analytical perspectives, trends, and performance indicators)*

In his analysis, Tijssen shows how sub-Saharan Africa has fallen behind quite dramatically from 1% in 1987 to 0.7% in 1996 with no sign of recovery (Figure 1). These diminishing shares of African science overall do not reflect a decrease in absolute sense, but rather an increase in publication output less than the worldwide growth rate. Africa has lost 11% of its share in global science since its peak in 1987; Sub-Saharan science has lost almost a third (31%).5 The countries in Northern Africa; Egypt and the Maghreb countries (Algeria, Mauritania, Libya, Morocco and Tunisia) accounted for the modest growth of the African share of the worldwide output during the years 1998-2002. Part of this decline of Sub-Saharan science can be attributed to discarding African journals from the *Citation Indexes*. Notably, the number of South African journals dropped from 35 to 19 during the years 1993-2004.

Figure 1. Trends in African research article output in the international journal literature (1980-2004): % of worldwide publication output in the international peer-reviewed journal literature.



Source: CWTS/Thomson Science Citation Index database (excluding the Arts and Humanities Citation Index).

Table 7. Bibliometric performance profiles of African countries: summary statistics (2001-2004)*,** (Source, Tijssen, 2006)

Country	Arco	Total publ output	% int co-publ	Citation rate per publ	% cited publ	Relative citation scores (Field)	Relative citation score (Journal)
South Africa	0.37	14809	39	1.56	40%	0.63	0.90
Egypt	0.27	9895	29	0.81	31%	0.45	0.78
Morocco	0.22	3535	56	0.82	30%	0.43	0.69
Tunisia	0.29	2857	48	0.75	26%	0.44	0.68
Nigeria	0.14	2309	30	0.86	24%	0.47	0.78
Kenya	0.20	2067	74	1.89	45%	0.8	0.80
Algeria	0.28	2028	58	0.73	23%	0.51	0.70
Cameroon	0.19	896	73	1.28	37%	0.64	0.80
Tanzania	0.16	855	78	1.84	46%	0.87	0.85
Ethiopia	0.07	767	61	1.19	35%	0.53	0.69
Zimbabwe	0.28	735	66	1.40	42%	0.64	0.82
Uganda	0.13	724	74	2.23	46%	0.95	0.97
Ghana	0.20	641	65	1.68	39%	0.78	0.86
Senegal	0.15	618	74	1.42	38%	0.74	0.82
Ivory Coast	0.14	449	73	1.46	37%	0.75	0.81
Botswana	0.26	422	41	0.98	30%	0.53	0.75
Malawi	0.13	413	73	2.08	49%	0.76	0.78

Burkina Faso	0.05	364	80	1.50	40%	0.69	0.82
Sudan	0.14	315	63	1.44	40%	0.68	0.92
Zambia	0.24	286	80	2.03	49%	0.75	0.71
Madagascar	0.12	284	83	1.52	40%	0.75	0.87
Gambia	0.12	273	87	3.35	64%	1.07	0.89
Benin	0.11	257	81	1.13	34%	0.68	0.79
Gabon	0.23	240	87	2.74	55%	0.85	0.89
Mali	0.07	190	84	3.87	42%	1.09	0.83
Libya	0.31	161	51	0.81	27%	0.58	0.32
Mauritius	0.29	153	53	1.56	26%	0.63	0.43
Namibia	0.22	145	56	1.93	34%	0.48	0.31
Congo Rep	0.21	135	79	1.26	34%	0.75	0.53
Niger	0.03	126	66	1.53	40%	0.87	0.56
Mozambique	0.10	118	82	2.63	36%	0.85	1.06
Togo	0.15	101	66	0.99	33%	0.63	0.47

Source: CWTS/Thomson Science *Citation Index* database (edition 2005, excluding the Arts and Humanities Citation Index).

* Selected countries with at least 100 publications in CI-listed journals in the period 2001-2004.

** All citation statistics refer to cited and citing publications in the years 2001-2004.

*** The relative citation scores refer to the extent in which a specific set of journal publications are cited more (>1) or less (<1) than the average citation rate of all publications worldwide within either the same set of journals, or the corresponding set of fields of science. These fields are equivalent to the *Journal Categories* defined by Thomson Scientific for its Citation Index (CI) databases. Fieldnormalized relative citation score is defined as the average citation frequency per paper of an entity's publication output is compared to the weighted average citation rate of the set of fields in which the unit has published (excluding author self-citations in all computations). The worldwide citation rate per field is set at unity; scores above 1 indicate a citation impact rate above field average. Journalnormalized relative citation scores: similar to the field-normalized relative citation rate, but at the level of the collection of CI-listed journals in which the entity has published.

In a detailed analysis of the individual citation profiles of a selection of countries (Cf Table 7 above), Tijssen shows how unequal knowledge production is across the continent. It is also interesting to note that there are rather significant deviations between countries occupying the same size category or development level (as measured by the ArCo index, Archibugi & Coco, 2004; 2005).

For example, within the group of the seven largest countries, South Africa and Kenya are clearly out-performing the other five in terms of average citation rates, the share of publications cited, and the field-normalized citation scores. As Tijssen argues, it seems reasonable to assume that this performance is partly a cultural heritage from their English-language science systems that help to sustain or enhance their visibility

in English-language dominated international research literature. The Northern African countries, traditionally more focused on the Arab world and the French-speaking scientific world, are at a disadvantage.

And finally, Tijssen also show that there is surprisingly not a strong correlation between the country's level of technological development and any of the scientometric indicators. A positive correlation coefficient exists between the ArCo index value and the level of publication output (r=0.51), but all other indicators show negative coefficients (ranging from r=-0.28 to r=-0.50). In other words, size is inversely related to citation impact; the smaller African countries are receiving relatively large numbers of citations compared to the largest countries, in large part owing to their international co-publications in fields of the medical and life sciences.

This is especially true for countries such as Gambia, Mali and Mozambique who recorded above average citation scores albeit with small production. In cases such as these, it would be essential to look more closely at (1) who these authors co-author (as this is a huge factor in citation visibility) and (2) the nature of the institutions where these scientists are based. In terms of our earlier discussion on scientific institutions, it is more than likely that some of these scientists are based in international research organisations based in the host country and that they are benefiting from long-established networks with scientists in France, Sweden, the UK and other northern countries.

In the final analysis, however, it remains the case that both the output of African science in international journals is declining and that its overall visibility globally is minimal. African science in many respects is science on the margin: invisible and unrecognized.

SECTION 4: CONCLUDING ASSESSMENT

Our seventeen country reviews have raised a number of critical issues and highlighted many challenges that African research faces. Without repeating the main findings discussed in this report, I conclude with some summary points:

- Our country reviews have utilized and exploited as much of the available information and documentation of these countries possible. Some country visits were possible (although not required under the Brief) which augmented

the available statistics. However, there is a dire need to conduct follow-up country visits not only to improve the quality of the statistical data, but also to gather more qualitative and narrative information on scientific communities in these countries, the social inscription of science and status of scientists in the countries and so on.

- Our review of African research systems has reiterated the need for support in policy development. It is evident that many countries and ministries of science and technology require capacity building and technical support in various aspects of policy development, implementation and monitoring and evaluation.
- The quality of national statistics and indicators on higher education and science and technology needs to be prioritized. We strongly suggest that the possibility of establishing a network of observatories for science and technology in African be investigated. Such a network would perform not only a data gathering, validation and analysis function but could also act as sites for support and capacity building.
- Ways and mechanisms should be investigated of raising the visibility of African science. In addition to support for local journals and journal development, it would be advisable also to investigate the more intensive use of advanced web-based solutions such as virtual repositories, a knowledge commons for peer-reviewed materials and so on.

Appendix A

Overview of selected international research centres based in Africa

International Centre for Insect Physiology and Ecology (ICIPE)

Established in Kenya in 1970, ICIPE's founders recognised that the developing countries in the tropics had special problems that were not being adequately addressed by scientists and organisations in the North. Furthermore, there was a serious lack of indigenous expertise to resolve these problems. It should come as no surprise therefore that ICIPE's objectives for this millennium are essentially the same as they were three decades ago:

- To help ensure food security and better health for humankind and its livestock;
- To protect the environment;
- To conserve and make better use of natural resources

ICIPE's mission is to help alleviate poverty, ensure food security and improve the overall health status of the people of the tropics by developing and extending management tools and strategies for harmful and useful arthropods, while preserving the natural resource base through research and capacity building. (www.icipe.org.) A consortium of donors, the Sponsoring Group for ICIPE (SGI), and other private charitable organisations, United Nations organisations and governmental aid agencies funds ICIPE. ICIPE unrestricted donors for 2004 included:

- Danish International Development Agency (DANIDA)
- French Government
- Japanese Society for the Promotion of Science (JSPS)
- Kenya Government
- Norwegian Government
- Swedish International Development Agency (SIDA)
- Swiss Government

ICIPE conducts research to develop methods for managing pests and disease vectors in environmentally friendly ways and to enhance the useful effects of arthropods. This work is structured under the operative 4-Hs paradigm of improving human, animal, plant and environmental health:

- Human health research contributes to the reduction of malaria and other vector-borne diseases by developing tools and strategies that control the vectors and break the cycle of transmission, and that can be integrated with other disease management efforts;
- Animal health research aims to increase livestock productivity through development of integrated strategies and tools for livestock vector control, thus leading to greater availability of meat, milk, hides and draught power;
- Plant health research contributes to improved sustainable food security and environmental health through the development of integrated pest management (IPM) in field and horticultural crops and storage pests;

- The environmental health agenda concentrates on conservation and sustainable utilisation of the agricultural production base and important natural ecosystems by encouraging and utilising arthropod diversity; cataloguing and sharing biodiversity data and discovering endemic wealth by bio prospecting for useful natural products. (www.icipe.org.)

International Livestock Research Institute (ILRI)

The International Livestock Research Institute (ILRI) works at the crossroads of livestock and poverty, bringing high-quality science and capacity building to bear on poverty reduction and sustainable development. ILRI works in Africa, Asia and Latin America and the Caribbean, with offices in East and West Africa, South and Southeast Asia, China and Central America. (www.ilri.org.) ILRI is a non-profit-making and non-governmental organization with headquarters in Nairobi, Kenya, and a second principal campus in Addis Ababa, Ethiopia. It employs over 700 staff from about 40 different countries. About 80 staff is recruited through international competitions and represents some 30 disciplines, and around 600 staff is nationally recruited, largely from Kenya and Ethiopia. (www.ilri.org.)

ILRI places poverty at the centre of an output-oriented agenda. ILRI's strategy focuses on three livestock-mediated pathways out of poverty: (1) securing the assets of the poor, (2) improving the productivity of their livestock systems and (3) improving their market opportunities. ILRI's research portfolio comprises four issue-oriented themes: Targeting and innovation; Improving market opportunities; Using biotechnology to secure livestock assets; and People, livestock and the environment. ILRI also coordinates the System wide Livestock Programme of the Consultative Group on International Agricultural Research (CGIAR). (www.ilri.org.)

International Council for Research in Agroforestry (ICRAF): Eastern and Central Africa Regional Programme

The International Council for Research in Agroforestry (ICRAF) was establishment in 1978 to promote agroforestry research in developing countries. During the 1980s ICRAF operated as an information council focused on Africa. It joined the Consultative Group on International Agricultural Research (CGIAR) in 1991 to conduct strategic research on agroforestry at a global scale, changing its name from Council to Centre. After joining the CGIAR, the Centre explicitly linked its work to the goals of the CGIAR—reducing poverty, increasing food security and improving the environment—through two means: overcoming land depletion in smallholder farms of sub humid and semi-arid Africa, and searching for alternatives to slash-and-burn agriculture at the margins of the humid tropical forests. In implementing this strategy, the Centre expanded into South America and Southeast Asia while strengthening its activities in Africa. (www.worldagroforestrycentre.org). In 2002 the Centre acquired the brand name the 'World Agroforestry Centre'. The 'International Centre for Research in Agroforestry' remains the legal name and the Centre continues to use the acronym 'ICRAF'. The new name reflects the fact that the Centre is now recognized as the international leader in agroforestry research and development. (www.worldagroforestrycentre.org)

ICRAF's headquarters are in Nairobi, Kenya, and the Centre has altogether seven regional programmes, of which four are based in Africa:

- Eastern and Central Africa Regional Programme (based in Nairobi, Kenya)
- Southern Africa Regional Programme (based in Harare, Zimbabwe)
- Sahel Regional Programme (based in Bamako, Mali)
- African Humid Tropics Regional Programme (based in Cameroon)

(www.worldagroforestrycentre.org)

The program focuses its R&D activities on priority problem domains. Problem domains are broad problem categories within the regions, with spatial definition and both biophysical and socio-economic dimensions. Five principal domains have been identified for ICRAF–ECA R&D activities. The five domains and their key problems are as follows:

- High Potential Highlands. Low and declining land (soil and water) productivity, declining profitability of coffee-based systems, limited products and diversification of farm enterprises, and poor market access, and in some countries there is shortage of fuel wood, often resulting in the use of crop residues and livestock manure, exacerbating further the decline in soil fertility and productivity. (www.worldagroforestrycentre.org)
- Lake Victoria Basin and other major watersheds in the regions. Degradation of land and water resources, poverty and health problems particularly high incidence of HIV/AIDS and malaria.
- Major water towers and watersheds of national and regional significance. Deforestation and conversion to agriculture, conflicts between wildlife and agriculture, conflicts over water among up and downstream users, excessive extraction of wood and fuel wood, inadequate policies and incentives for market-led production and conservation of natural resources. (www.worldagroforestrycentre.org)
- Arid and semi-arid lands. Inadequate water and water harvesting techniques, extraction of wood and fuel wood enhancing degradation and desertification, and shortage of fodder.
- Urban and Peri-Urban agriculture. Lack of policy support, poor tree germplasm for nurseries and lack of mechanisms among tree nursery operators to take advantage of competitive market situations. (www.worldagroforestrycentre.org)

West and Central African Council for Agricultural Research and Development (CORAF/WECARD)

The West and Central African Council for Agricultural Research and Development (CORAF/WECARD) evolved as the Conference of Africa and French leaders of agricultural research institutes in 1987 but assumed its current name in July 1999. CORAF/WECARD comprise the national agricultural research systems (NARS) of twenty-one (21) French-speaking, English-speaking countries and Portuguese-speaking countries of West and Central African regions. (http://www.coraf.org/English/historique.php 23 May 2007). The land area is 11.5 millions km2 with a population of 318 million out of which 65% are engaged in agriculture (CORAF, 2007).

CORAF/WECARD has formulated its Operational Plan for 2007-2012, which anticipates an Integrated Agricultural Research for Development built on the principle of inter-sectoral and multilevel approach in priority setting, engaging the whole range of multiple stakeholders from policy-makers to development service providers. The Operational Plan is for the implementation of West African Agricultural Productivity Programme (WAAPP) and the Central African Agricultural Productivity Programme (CAAPP) under the framework of the Comprehensive African Agriculture Development Programme (CAADP, the NEPAD agricultural research programme) (Owusu-Bennoah and Sereme, 2007). In line with CORAF/WECARD new Strategic Plan, studies and consultations, the Operational Plan identifies eight core programme areas of research and development including:

1. Livestock, Fisheries and Aquaculture
2. Staples Crops
3. Non-staple crops
4. Natural Resource Management
5. Biotechnology and Bio-safety
6. Policy, markets trade

7. Knowledge management, and
8. Capacity strengthening and co-ordination (CORAF, 2007:10)

WARDA -Africa Rice Centre

The West African Rice Development Association (WARDA) was established in 1970 as an autonomous intergovernmental research association of African member states. In 2003 it was renamed by the WARDA Council of Members as the Africa Rice Centre in recognition of its growing and leading role in rice R&D in Sub-Saharan Africa (WARDA, 2004). WARDA is one of the 15 international agricultural research Centres supported by the Consultative Group on International Agricultural Research (CGIAR) following a process initiated in 1986. The Africa Rice Centre (WARDA) is the premier research Centre for rice development in sub-Saharan Africa. It also serves as a hub for rice-related R&D networks in the region (http://www.warda.org/warda/aboutus.asp).

The initial establishment of WARDA in 1970, which became operational in 1971, involved the efforts of 11 West African countries with the assistance from the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), and the Economic Commission for Africa (ECA). Today it comprises 17 member states: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo http://www.warda.org/warda/aboutus.asp

WARDA's mission is to contribute to poverty alleviation and food security in Africa, through research, development and partnership activities aimed at increasing the productivity and profitability of the rice sector in ways that ensure the sustainability of the farming environment (http://www.warda.org/warda/aboutus.asp

Since January 2005, the Centre has been working from Cotonou, Benin, having relocated from its headquarters in Bouaké, Côte d'Ivoire, because of the civil conflicts in the country (it first moved from Monrovia, Liberia because of political instability in 1987).

WARDA's research programmes are implemented through various task forces and networks. However, WARDA's regional Task Forces were merged with CORAF/WECARD's Rice Network to form ROCARIZ (*Réseau oust et centre africain du riz*) in 2000. ROCARIZ is seen as a well-established "primary mechanism for regional collaboration in rice research and development". Today, WARDA hosts and facilitates the co-ordination of three research programmes including the African Rice Initiative (ARI), Regional Research and Development Network for West and Central Africa (ROCARIZ) and Inland Valley Consortium (IVC). In 2004 it helped to create and supports the Co-ordination Unit of the East and Central Africa Rice Research Network (ECARRN). It has regional research stations near St Louis, Senegal and at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. WARDA's team of researchers participate in the international network to improve rice production in Africa.

One of the Major achievements of WARDA's research programmes is the development of the New Rice for Africa (NERICA) varieties for both upland and lowland cultivation. Dr Monty Jones a former WARDA researcher and current Executive Secretary of FARA was selected as a co-recipient of the *2004 World Food Prize* for his role in developing the NERICA varieties successfully. The African Rice Initiative (ARI), which was launched in March 2002, aims to increase the dissemination of NERICA throughout sub-Saharan Africa.

International Crop Research Institute for the Semi-Arid Tropics (ICRISAT)

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political, international organization for science-based agricultural development. ICRISAT conducts research on sorghum, pearl millet, chickpea, pigeon pea and groundnut - crops that support the livelihoods of the poorest of the poor in the semi-arid tropics encompassing 48 countries. ICRISAT also shares information and knowledge through capacity building, publications and information and communication technologies (ICTs). Established in 1972, it is one of 15 Centres supported by the Consultative Group on International Agricultural Research (CGIAR).

(http://www.icrisat.org/aboutus/ICRISAT_a_glimpse.pdf)

The Regional hub for West and Central Africa is located in Niamey, Niger and scientists are also located in the research centre in Bamako, Mali. Another research location is in Kano, Nigeria. ICRISAT's work covers approximately 20 countries in the Semi-Arid Tropics (SAT) of WCA. ICRISAT is currently endowed with core competencies in the areas of agronomy (2), soil science (2), pearl millet breeding (1), sorghum breeding (1), groundnut breeding (1), socio-economy (1) and GIS (1). (http://www.icrisat.org/index.htm)

The International Institute of Tropical Agriculture (IITA)

The International Institute of Tropical Agriculture (IITA) is an Africa-based international research-for-development organization, established in 1967, and governed by a board of trustees. There vision is to be one of Africa's leading research partners in finding solutions for hunger and poverty. They have more than 100 international scientists based in various IITA stations across Africa. This network of scientists is dedicated to the development of technologies that reduce producer and consumer risk, increase local production, and generate wealth. The IITA Research Stations are:

- Benin
- Cameroon
- DR Congo
- Ghana
- Kenya
- Malawi
- Mozambique
- Nigeria Ibadan
- Nigeria Kano
- Nigeria Onne
- Tanzania
- Uganda