Sub-Saharan African agricultural research

Recent investment trends

Nienke M. Beintema and Gert-Jan Stads

***Abstract**: Following two decades of increasing investments, growth in public agricultural research spending in Sub-Saharan Africa stagnated during the 1980s and 1990s at an average rate of about 1% per year. Nonetheless, this continent-wide trend masks significant variation among countries. During 1991–2000, about half the countries in the authors' 27-country sample experienced negative annual growth in total agricultural research and development (R&D) spending. Declines often resulted from political unrest or the completion of large donor-funded projects. The majority of African agricultural research is still conducted by the government sector, with the private for-profit sector accounting for only a small, but seemingly increasing, share of total research expenditures.*

***Keywords**: agricultural researchers; agricultural research investments; R&D; Sub-Saharan Africa*

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As a region, Sub-Saharan Africa (Africa hereafter) relies heavily on agriculture. The sector accounts, on average, for close to 20% of total gross domestic product and about 60% of the region's total labour force – although many countries in the region depend on agriculture to a much greater extent than these regional averages indicate (FAO, 2003; World Bank, 2003). Small-scale farmers predominate in a climate of increasing population pressure, food insecurity, very low (and declining) levels of agricultural productivity and rapid natural resource degradation. Building agricultural productivity and food security will require new and improved technologies – more specifically, broad dissemination of newly developed and existing technologies – and agricultural research and development (R&D) institutions are the channel through which this will occur. Further, considerable empirical evidence indicates high rates of return from agricultural R&D investments, making agricultural research a cost-effective way for governments to accelerate agricultural development. But despite all this, growth in agricultural research investments in Africa has stagnated over the past two decades.

This article reviews the major investment and institutional trends in African public agricultural research since the early 1970s,[1] drawing directly on a new set of data for the 1990s developed through a comprehensive survey conducted in 27 countries by the International Food Policy Research Institute (IFPRI), the International Service for National Agricultural Research (ISNAR) and many African partners during the period 2000–03.[2]

Institutional developments in public agricultural R&D[3]

With political independence in the late 1950s and early 1960s, many African countries inherited the agricultural research infrastructure established by former colonial powers. Some countries inherited very specialized institutes that did not necessarily address their production needs, while other (often smaller) countries were unable to sustain their systems when financial resources and expatriate research staff were withdrawn. Research at that time focused mainly on export crops and little attention was given to the production problems of small-scale subsistence farmers. Hence, many countries were left with minimal physical, human resource or organizational research capacity.

In the early years after independence, most countries focused on building capacity, specifically in terms of replacing expatriate staff with national researchers and

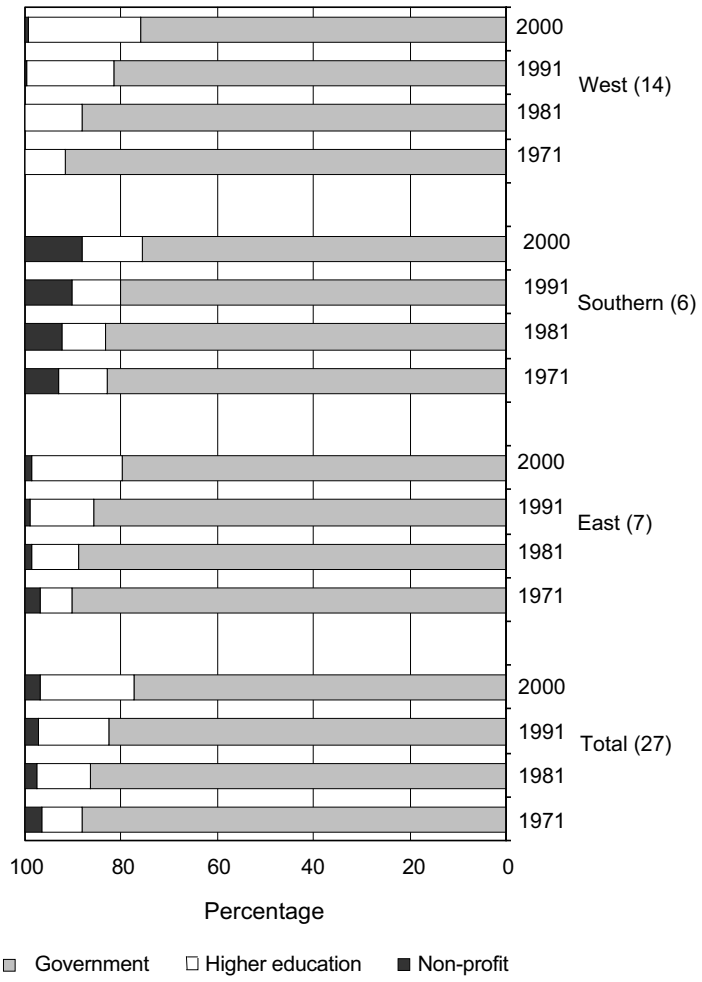

Figure 1. Total public agricultural research staff by insititutional category, 1971–2000.
Notes: Figures in parentheses indicate the number of countries. The seven East African countries are Burundi, Eritrea, Ethiopia, Kenya, Sudan, Tanzania and Uganda; the six Southern African countries are Botswana, Madagascar, Malawi, Mauritius, South Africa and Zambia; the 14 West African countries are Benin, Burkina Faso, Republic of Congo, Côte d'Ivoire, Gabon, the Gambia, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal and Togo. For six (mainly small) countries, data were not available prior to 1991 and were estimated using the trends for the other countries in the respective subregions.
Source: Beintema and Stads (forthcoming).

enhancing research infrastructure, a process that was often hindered by political unrest and institutional instability (Roseboom, Pardey and Beintema, 1998). By the early 1980s, the focus of reform had turned towards improving the effectiveness of national agricultural R&D, which involved amalgamating disparate research activities within a single agency, coordinating and developing national agricultural research plans, and improving management practices such as planning, monitoring and evaluation. In more recent years, reforms in Africa have moved towards issues such as redefining the government's role in agricultural research, decentralizing decision-making processes, increasing farmer/stakeholder participation, identifying new funding sources and mechanisms, and strengthening system linkages (Chema, Gilbert and Roseboom, 2003).

Nonetheless, despite significant capacity expansion in the 1970s and 1980s, public African agricultural research remains heavily fragmented, with more than half the region's countries employing fewer than 100 full-time equivalent (fte) researchers.

The government sector still conducts the majority of agricultural research – over three-quarters of total agricultural R&D capacity in 2000 (Figure 1). Moreover, while the number of agriculture-related universities, colleges and schools significantly expanded over this time (agricultural R&D capacity in the higher-education sector grew from 8% in 1971 to 19% in 2000), the individual capacity of many remained very small; more than 40% of the 86 agricultural higher-education units in Nigeria and Sudan employed fewer than five fte researchers in 2000, for example.

While non-profit institutions, by definition, are not directly controlled by national governments, they are often linked to producer organizations and hence receive most of their funding through taxes levied on production or exports; examples include agencies conducting research on tea (Kenya, Malawi, Tanzania), coffee (Kenya, Tanzania, Uganda), cotton (Zambia) and sugar (Mauritius, South Africa). Other types of non-profit institutions (independent of producer organizations) have been established in a number of countries such as Madagascar and Togo, but non-profit institutions still play a limited role in agricultural research in the region. In 2000 they accounted for only 3% of Africa's total public agricultural research capacity.

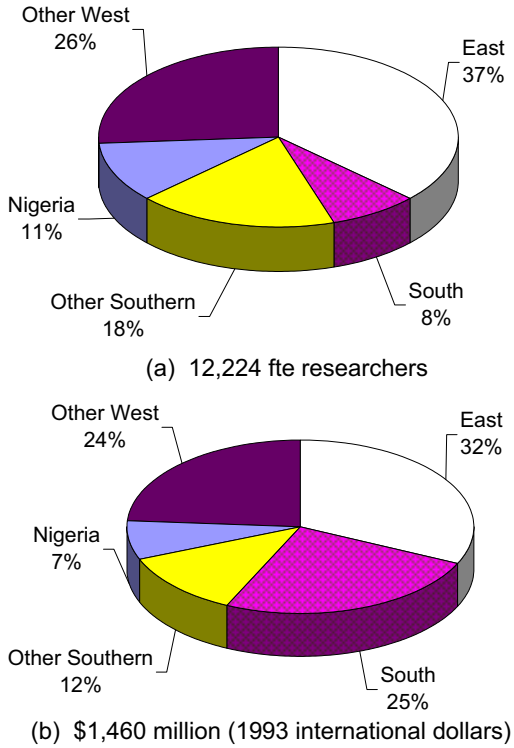

Figure 2. Total public agricultural research staff and spending in Sub-Saharan Africa.
Notes: The total includes all 48 Sub-Saharan African countries. The research capacity of 21 countries has been estimated in line with their share of total agricultural output.
Source: Beintema and Stads (forthcoming).

Human resources in public agricultural R&D

In 2000, the total number of fte researchers working in public agricultural research agencies in Africa was well over 12,000 (Figure 2a), with equal shares active in East and West Africa (37%) and the remainder in Southern Africa (26%). About 40% of this total capacity was located in five of the 48 countries: Nigeria and South Africa had the largest capacities (1,352 and 1,029 fte researchers respectively), followed by Kenya, Sudan and Ethiopia – all three located in East Africa.

Over the past three decades, total agricultural research staff numbers in the 27 countries for which we have time series data increased threefold (at an average of 4% per year) between 1971 and 2000, but the majority of this growth occurred in the 1970s and 1980s (Table 1).[4] These regional averages mask considerable differences among the subregions and sample countries. The Southern Africa subregion showed much slower growth than its East and West African counterparts, which was mainly due to a stagnation in the growth of agricultural research staff employed in South Africa. Burundi and Côte d'Ivoire, for example, experienced strong declines in total fte researcher numbers in the 1990s (due to civil war in Burundi and the departure of expatriate staff in Côte d'Ivoire with the nationalization of its agricultural R&D system). In contrast, total researcher numbers increased by more than two-thirds in Botswana and Ethiopia over the same period because of intensified government investment in agricultural R&D in combination with large World Bank-funded projects.

Degree status

In 2000, 75% of the total fte researchers in our 27-country sample had postgraduate-level training, with about one quarter holding doctorate degrees (Figure 3). Practically identical postgraduate shares were found in the three subregions, though relatively more researchers held doctorate degrees in West Africa. In addition, a higher proportion of university staff held PhD degrees compared with staff at other agencies, a pattern that was prevalent among most of the countries in the region. This is consistent over time and with other regions such as Latin America (Beintema and Pardey, 2001). Detailed time series data on the degree status of agricultural researchers point to a significant increase in the quality of staff. In 1971, only 45% of the fte researchers had received post-graduate-level training; by 1991 that share had reached 65% (Pardey, Roseboom, and Beintema, 1997), and it continued to increase to the aforementioned share of 75% in 2000. Many donor projects, particularly those financed through World Bank loans, had important training components, allowing research staff to receive post-graduate-level training at universities at home or abroad.

Once again, the share of researchers with postgraduate-level training – that is, researchers with PhD and MSc degrees – varied markedly among countries. In 2000, this share was 80% or higher for 11 of the 27 countries in our sample, and 95% or even higher in Senegal, Togo and Burkina Faso (all three in the West African subregion). At the other end of the spectrum, the share of PhD and MSc holders in Eritrea, Ethiopia, Guinea and Mauritius was much lower than the respective continent-wide averages of 31 and 53%, due to the limited number of holders of doctorate degrees in these countries.

Financial resources in public agricultural R&D

In 2000, agricultural R&D spending in 48 Sub-Saharan countries in Africa (including all 48 countries) totalled close to $1.5 billion in 1993 international dollars (Figure 2b).[5] The spread of total spending over the three subregions differed from the allocation of total research staff. About 37% of financial resources were spent in Southern Africa (including South Africa, which alone accounted for a quarter of the continent's total spending), and although Nigeria employed the highest total number of fte researchers in Africa (11% of the region's total), its share of spending was only 7%, highlighting the more limited resources available to Nigerian researchers compared with their counterparts in South Africa, for example.

Most of the growth in public agricultural research spending in Africa took place in the 1960s when real (inflation-adjusted) spending increased by an annual average of 6.8% (Pardey *et al*, 1997). The 27 countries for which we had time series data spent more than $1.1 billion in 1993 international dollars in 2000, close to one-third more than the average of $0.8 billion in the 1970s (Table 2). Although expenditure growth appears to have been more evenly distributed over time than growth in researcher numbers, the annual growth rate in spending declined from 2% in the 1970s to 1.3% in the 1980s, and to only 0.8% in the 1990s.[6] Excluding Nigeria and South Africa, total public agricultural R&D spending in Africa actually declined by 0.3% per year in the 1990s.

Again, these regional averages mask considerable differences among the various subregions and countries. During the 1990s, about half the sample countries experienced negative annual growth in total agricultural R&D spending. Rates in Burundi, the Republic of Congo and Sudan fell below the negative 10% mark, for example. Declines resulted from political unrest (Burundi, Republic of Congo and Sudan) or the completion of large donor-funded projects (Burkina Faso, Guinea, Madagascar, Niger, Togo and Zambia). In contrast, total spending in Nigeria – which had one of the lowest spending-per-scientist levels in Africa – grew by an annual average of 6.3% in the 1990s. This was a combined result of increased agricultural research staff numbers (mainly in the higher-education sector) and a substantial rise in civil service salaries in 2000. Spending in South Africa also grew during 1991–2000, but this increase occurred in the first half of the decade, after which it contracted considerably following reductions in federal and provincial government funding for agricultural research.

Spending per scientist

Spending per scientist has declined considerably within African agricultural R&D agencies over the past three decades. In 2000, the average cost per researcher in our 27-country sample was about $130,000 in 1993 international dollars, which was about half the corresponding 1971 figure. This trend reflects the rapid growth in

Table 1. Trends in public agricultural researchers, 1971–2000.

	Total researchers[a]			Annual growth rates[b]			
	1971–80	*1981–90*	*1991–2000[c]*	*1971–81*	*1981–91*	*1991–2000*	*1971–2000[c]*
	(full-time equivalents per year)			*(percentage)*			
East (7)	998.0	1,903.8	2,960.3	5.83	6.25	1.62	5.48
Southern (6)	1,143.1	1,618.7	1,864.0	2.18	2.19	0.79	2.39
West (14)	1,621.0	2,678.4	3,368.4	8.76	2.85	1.38	3.80
Total (27)	*3,762.1*	*6,200.9*	*8,164.7*	*5.89*	*3.74*	*1.31*	*3.97*
Nigeria	655.4	998.2	1,175.2	10.67	1.39	1.95	3.32
South Africa	732.5	965.7	1,087.1	1.31	1.66	0.18	1.88
Total minus Nigeria and South Africa (25)	*2,374.3*	*4,237.1*	*5,902.3*	*6.13*	*4.78*	*1.42*	*4.65*

Source: Beintema and Stads, forthcoming.
Note: See Figure 1.
[a]Data are presented as 10-year averages.
[b]Annual growth rates are calculated using the least-squares regression method, which takes into account all observations in a period.
[c]Total researchers and growth rates for the 14 West African countries are for 1991–2001.

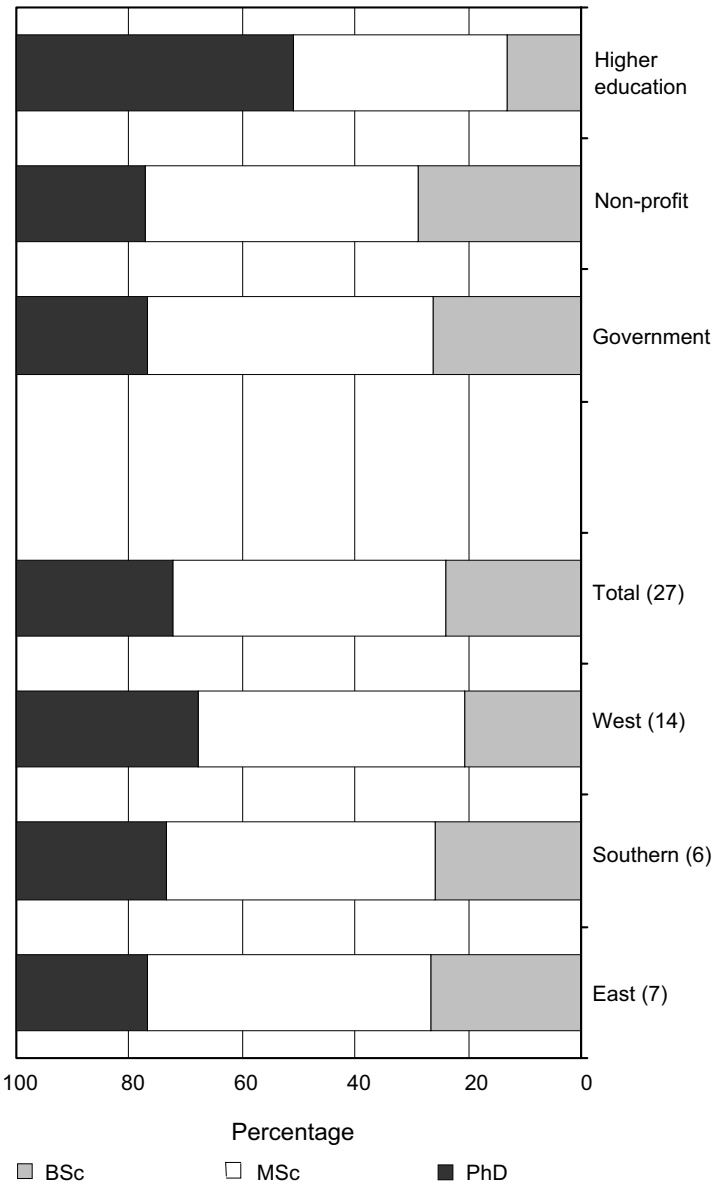

Figure 3. Degree status of public agricultural researchers.
Note: See Figure 1.
Source: Beintema and Stads (forthcoming).

numbers of research staff, especially during the 1970s and 1980s, combined with very slow growth in the funds that support these researchers.

There is, however, a significant variation in spending per scientist, not only among the various countries, but also among the various agencies within these countries. Generally agricultural scientists employed by the non-profit organizations had almost double the financial resources to hand compared with their colleagues working at government or higher education agencies. This is reflected in the relatively higher salary packages offered by the non-profit institutions. Also, many private companies do offer higher salaries than the public service sector, which has been the reason for many government researchers leaving the public sector.

Intensity ratios

Total public spending as a percentage of agricultural output (agricultural GDP) is a common research investment indicator that helps place a country's agricultural R&D spending in an internationally comparable context. In 2000, Africa invested $0.70 for every $100 of agricultural output; lower than the $0.84 in 1981 (Table 3). Excluding the two large systems, South Africa and Nigeria, the ratio was substantially lower, at 0.53, which is the result of the high research intensity in South Africa (3.04). At the country level, ratios ranged from 0.20% or lower in the Gambia, Niger and Sudan, to over 3% in Botswana, Mauritius and South Africa – all three located in Southern Africa, explaining the high average intensity ratios for this region compared with the other two regions. The research-intensity ratios for these three Southern African countries were also high compared with the intensity ratios in many developed countries. In 1995, the latest year for which global data are available, Africa's average agricultural research-intensity ratio (0.76%) was greater than the average ratio for the developing world (0.62%), but lower than the global average (1.04%) (Figure 4).

Table 2. Trends in public agricultural R&D spending, 1971–2000.

	Total spending[a]			Annual growth rates[b]			
	1971–80	*1981–90*	*1991–2000[c]*	*1971–81*	*1981–91*	*1991–2000*	*1971–2000[c]*
	(million 1993 international dollars per year)			*(percentage)*			
East (7)	160.3	208.4	304.0	2.21	5.07	0.88	3.17
Southern (6)	331.9	388.6	437.1	–0.19	0.30	1.20	1.25
West (14)	302.6	338.9	317.0	4.62	0.14	0.06	0.39
Total (27)	*794.8*	*936.0*	*1,058.4*	*2.02*	*1.32*	*0.77*	*1.43*
Nigeria	105.8	81.0	63.3	5.64	–6.71	6.27	–1.84
South Africa	255.0	308.7	365.0	0.11	0.14	1.85	1.65
Total minus Nigeria and South Africa (25)	*434.0*	*546.3*	*630.0*	*2.46*	*3.31*	*–0.30*	*1.89*

Source: Beintema and Stads (forthcoming).
Note: See Figure 1.
[a]Data are presented as 10-year averages.
[b]Annual growth rates are calculated using the least-squares regression method, which takes into account all observations in a period.
[c]Total researchers and growth rates for the 14 West African countries are for 1991–2001.

Table 3. African agricultural research-intensity ratios, 1981, 1991 and 2000.

	1981	1991	2000
		(percentage)	
East (7)	0.47	0.61	0.52
Southern (6)	1.45	1.92	2.28
West (14)	0.80	0.59	0.44
Total (27)	*0.84*	*0.81*	*0.70*
Nigeria	0.80	0.29	0.38
South Africa	1.48	2.15	3.04
Total minus Nigeria and South Africa (25)	*0.67*	*0.74*	*0.53*

Source: Beintema and Stads (forthcoming).
Note: See Figure 1.

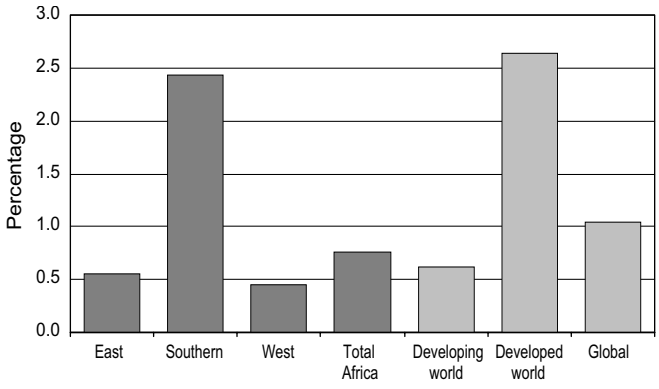

Figure 4. African agricultural research-intensity ratios compared globally, 1995.
Note: See Figure 1.
Source: Beintema and Stads (forthcoming).

There is no universally recognized standard for the desirable level of agricultural research intensity in Africa. In the early 1980s the World Bank set a 2% target, which has been widely quoted ever since. Others, however, have found an intensity ratio of 1% to be a more realistic objective, but few countries in Africa have achieved even this lower target. A recent report of the InterAcademy Council (IAC) recommends doubling Africa's agricultural research-intensity ratio from the current 0.7% to 1.5% by 2015 (IAC, 2004). Assuming that African agricultural output continues to increase, on average, at the same pace as it has throughout the past few decades, agricultural R&D spending will need to grow by an average of 10% per year for the next decade in order to achieve this target. This growth rate is seven times higher than the regional average growth rate the region experienced in the 1990s.

Funding public agricultural R&D

Agricultural research in Africa became increasingly dependent on donor funding towards 2000; yet the share of donor contributions in total funding declined in the latter half of the 1990s – at least for the 23 countries in our funding sample. Such declines resulted in part from the termination of a large number of World Bank projects in support of agricultural R&D or the agricultural sector at large. Donor contributions (including World Bank loans) accounted for an average of 35% of funding to principal agricultural research agencies in 2000. Five years earlier, close to half the funding of the 20 countries for which time series data were available was derived from donor contributions (Figure 5).

Once again, this sample average masks great variety across countries. In 2000, donor funding accounted for more than half of the agricultural R&D funding in seven of the 23 countries. Eritrea, in particular, was highly dependent on donor contributions. Its principal agricultural research agency received more than three-quarters of its funding from donors. In contrast, donor

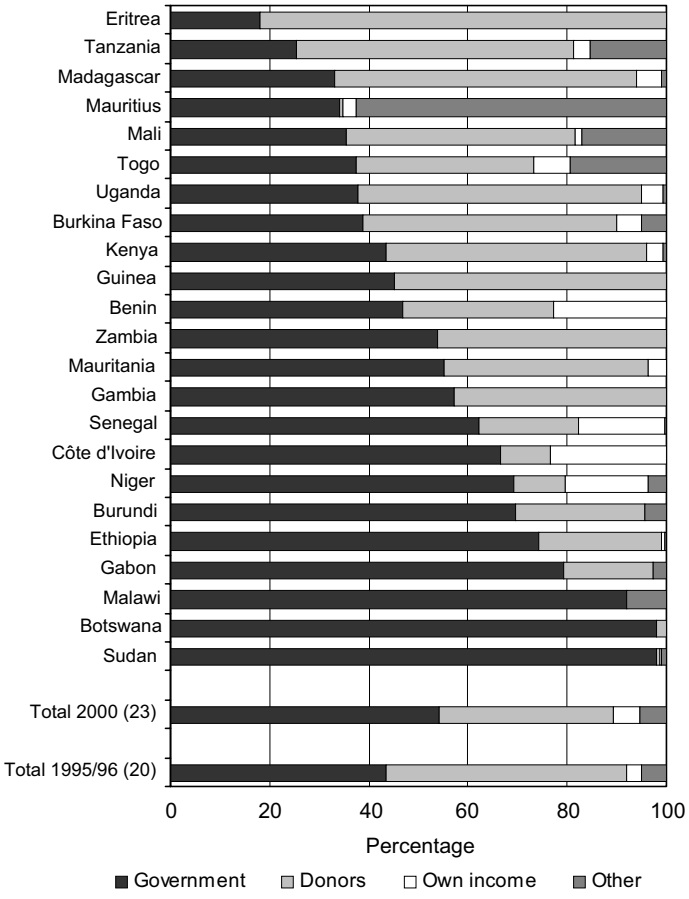

Figure 5. Sources of funding by country, 1995/96 and 2000.
Notes: Funding sources are for the main agricultural research agencies only. When combined, these agencies accounted for 76% of total spending for the 23-country sample in 2000. The total for 1995/96 excludes Benin, Côte d'Ivoire and Gabon. Data for West Africa, with the exception of Nigeria, are for 2001.
Source: Beintema and Stads (forthcoming).

funding was virtually insignificant in Botswana, Malawi, Mauritius and Sudan (under 5%). From the mid-1990s to 2000, one-third of the 20 countries for which time series data were available experienced declines in the share of donor funding by 10 percentage points or more, while for four sample countries donor dependency increased by at least 10 percentage points. Significantly, donor funding fell from over 50% of total funding to 10% or less for Malawi, Niger and Sudan, as a result of the completion of major projects funded by World Bank loans or contributions from the Food and Agriculture Organization of the United Nations (FAO).

Funding other than through government or donor sources such as internally generated revenues was relatively small, representing 11% of total funding in 2000. The principal agricultural research agencies of Benin and Côte d'Ivoire, for example, generated significant shares of total funding from research contracts, commercialization of agricultural products, and dissemination of research results. In the case of Côte d'Ivoire, the World Bank's second National Agricultural Services Support Project (PNASA II) had an important commercialization component, stipulating that 35% of the annual budget of the National Agricultural Research Center (CNRA) was to be self-generated through mechanisms such as commodity sales. The nine agencies working under the Council for Scientific and Industrial Research (CSIR) in neighbouring Ghana were also mandated to derive 30% of their budget from private sources. In practice, however, only the more commercially oriented agencies focusing on export crops are in a position to achieve this somewhat ambitious goal.

Only limited funding information was available for the largest agricultural research systems – Nigeria and South Africa – hence these were excluded from Figure 5. The majority of agricultural research in Nigeria is currently funded by the government, but in the 1990s considerable funding was provided through a World Bank loan as part of the National Agricultural Research Project (NARP). Funding for agricultural research in South Africa comes primarily from the government, commodity trusts, levies from producer organizations, and private-sector enterprises; unlike most other countries in Africa it receives very limited donor funding.

In certain African countries, we have seen an increasing share of total research financed through competitive funds. These funds typically aim to optimize the performance of agricultural research through increased collaboration between the various actors involved in agricultural research in a particular country. Such competitive funding mechanisms were installed in, for example, Kenya, Mali, Senegal and Tanzania as part of broader World Bank-financed projects. Research proposals are typically submitted by a research team consisting of members from various agencies. A committee then reviews the proposal and makes a final selection based on a range of criteria. Research agencies in countries where competitive funding mechanisms have been introduced are increasingly forced to respond to farmer demands in order to secure sufficient funding for their research projects.

The private sector

Agricultural research conducted by the private sector has grown in recent years, especially in the developed world. Nevertheless, the role of the private sector in the developing world is still small and is likely to remain so, given the weak funding incentives for private research. In addition, many of the private-sector activities in developing countries focus solely on the provision of input technologies or technological services for agricultural production, but most of those technologies are produced in the developed world.

In 2000, private firms in our 27-country sample invested $26 million in agricultural R&D, in 1993 international dollars, representing only 2% of total (public and private) research investments that year (Table 4). South Africa, with $16 million, accounted for close to two-thirds of agricultural research conducted by the private sector. The private sector does, however, play a stronger role in funding agricultural research, as opposed to performing research itself. Many private companies contract government and higher-education agencies to perform research on their behalf.

Table 4. Public and private agricultural R&D investments, 2000.

	Total spending			Shares	
	Public	*Private*	*Total*	*Public*	*Private*
	(million 1993 international dollars)			*(percentage)*	
East (7)	341.4	5.4	346.8	98.4	1.6
South Africa[a]	365.6	15.6	381.2	95.9	4.1
Other Southern (5)	62.4	2.8	65.2	95.7	4.3
Nigeria[b]	106.0	—	106.0	100.0	—
Other West (13)[c]	209.3	1.8	211.1	99.1	0.9
Total (27)	*1,084.7*	*25.6*	*1,110.3*	*97.7*	*2.3*

Source: Beintema and Stads (forthcoming).
Notes: Figures in parentheses indicate the number of countries. A number of private companies in some countries were excluded because they chose not to share their financial and human resource data.
[a]The share of omitted companies was estimated at about one-third of South Africa's private-sector agricultural R&D spending.
[b]Private-sector involvement in Nigerian agricultural research (as well as for a few other African countries) was negligible, and often *ad hoc* in nature.
[c]Data for other West African countries are for 2001.

For reasons of confidentiality, many private companies are reluctant to provide information on their resources and investments in agricultural research. In addition, private research activities in Africa are often small-scale and *ad hoc*, making it difficult to capture accurate information. Were data for all the private agencies in Africa included, the private-sector share in overall agricultural research investments would be slightly higher, but seemingly not substantially so.

Conclusion

Public agricultural research spending in Africa increased rapidly during the 1960s. Since then, growth has stalled for the region as a whole. Many individual countries, however, actually experienced a decline in agricultural R&D expenditures during the 1990s when funding became increasingly scarce, irregular and donor-dependent. In addition, the national science and technology (S&T) policies of many African countries are often poorly formulated. Given the continued withdrawal of donor funding, other sources will need to be consolidated and further developed in order to prevent a rapid erosion of agricultural R&D capacity. This should be accompanied by institutional reforms and sound S&T policies, both of which are prerequisites for improving the efficiency and effectiveness of the region's agricultural research.

So far, private sector research has not stepped in to fill the gap. Reliable estimates on private research spending are hard to come by, but the best (and most recent) evidence suggests that in 2000 an estimated $26 million of the $1.1 billion of agricultural R&D spending in 1993 international dollars in a 27-country sample was spent by private firms, representing only 2% of total (public and private) research investments that year. Most of the private technologies used throughout the region are supposedly based on research conducted elsewhere.

Technical change is a major factor in assuring food security and economic stability in Africa. New and better-targeted technologies are essential to reach technical change, and a well developed and well supported agricultural research system is a prerequisite not only for the design of these technologies, but also for their dissemination and adoption. Evidently agricultural R&D has become a priority for many African governments and donor agencies. The recent IAC (2004) report recommends a substantial funding increase for African agricultural research by 2015 at an average rate of 10% per year. In view of the low, and often declining, level of agricultural R&D investments in Africa, as evidenced in this article, attaining this goal will be extremely challenging.

Notes

[1] This article is an expanded version of Beintema, N. M., and Stads, G. J. (2004), *Investing in Sub-Saharan African Agricultural Research: Recent Trends, IFPRI 2020 Conference Brief No. 8*, a forthcoming synthesis report on Sub-Saharan African agricultural R&D investments, and a series of country briefs that are (or soon will be) available on the Agricultural Science and Technology Indicators (ASTI) Website at http://www.asti.cgiar.org. The ASTI initiative comprises a network of national, regional and international agricultural R&D agencies, and is managed under the International Service of National Agricultural Research (ISNAR) Division of the International Food Policy Research Institute (IFPRI). The initiative compiles, processes and makes available internationally comparable data on institutional developments and investments in public and private agricultural R&D worldwide, and analyses and reports on these trends in the form of occasional policy digests for research policy formulation and priority-setting purposes.

[2] These 27 countries accounted for about three-quarters of total Sub-Saharan African (ie 48 countries) agricultural GDP in 2001.

[3] The data reported here were compiled using internationally accepted statistical procedures and definitions developed by the OECD and UNESCO for compiling R&D statistics (OECD, 1994; UNESCO, 1984). Agricultural R&D investments are measured on a performer basis. We grouped our estimates into four major institutional categories: government agencies, higher-education agencies, non-profit institutions, and business enterprises. We defined public agricultural research to include government agencies, higher-education agencies and non-profit institutions (thereby excluding business enterprises). The dataset for our 27-country sample included information for more than 400 agencies. Agricultural research includes crops, livestock, forestry and fisheries research, as well as agriculturally related natural resources research.

[4] Annual growth rates are calculated using the least-squares regression method, which takes into account all observations in a period. This results in growth rates that reflect general trends that are not disproportionately influenced by exceptional values, especially at the end point of the period.

[5] Expenditures in current local currency units were first deflated to 1993 international dollars using a local implicit GDP deflator (base year 1993), and then converted into international dollars using a 1993 purchasing power parity (PPP) index, both taken from World Bank (2003). PPPs are synthetic exchange rates used to reflect the purchasing power of currencies, typically comparing prices among a broader basket of goods and services than do conventional exchange rates.

[6] The annual growth rates of the region's public agricultural R&D spending in the 1980s and 1990s differ from the 2.6 and 0.1% respectively, found in Pardey, Roseboom and Beintema (1997). The reason for this is the larger sample size in this study in combination with some modifications that were made – specifically for South Africa – in the earlier dataset.

[7] Pardey, Roseboom and Beintema (1997) found that in 1991, 43% of total agricultural research spending for a group of 22

countries (excluding South Africa) came from donors in the form of loans and grants, compared with 34% during the early 1980s.

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