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ORGANIZATION AND MANAGEMENT OF AGRICULTURAL RESEARCH IN SUB-SAHARAN AFRICA

RECENT EXPERIENCE AND FUTURE DIRECTION

by
H. K. Jain

isnar

International Service for National Agricultural Research

The International Service for National Agricultural Research (ISNAR) began operating at its headquarters in The Hague, Netherlands, on September 1, 1980. It was established by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force, for the purpose of assisting governments of developing countries to strengthen their agricultural research. It is a non-profit autonomous agency, international in character, and non-political in management, staffing, and operations.

Of the thirteen centers in the CGIAR network, ISNAR is the only one that focuses primarily on national agricultural research issues. It provides advice to governments, upon request, on research policy, organization, and management issues, thus complementing the activities of other assistance agencies.

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H. K. JAIN

INTRODUCTION

Agriculture in sub-Saharan Africa, as in other regions of the developing world, came to acquire a new significance in the changing social, economic, and political context of the 1960s and 1970s. The traditional systems of production the African farmers have practiced for hundreds of years could no longer meet the food needs of the rapidly rising populations of their countries. Faced with a similar situation, many developing countries in Asia and Latin America have responded by evolving a new agricultural policy, creating in the process, greatly strengthened research and extension services. The sub-Saharan African countries have made an important beginning with the setting up of a new and reorganized infrastructure of experiment stations forming part of national agricultural research systems, and with the training of a large number of agricultural scientists. The challenge in the future will be to enhance the capacity of these new institutions through improvement in their research policy, organization, and management so that they begin to harness science and technology for the modernization of the country's agriculture, making it more productive and profitable to farmers on a sustainable basis.

The present paper is based on ISNAR's experience of working with more than 20 national agricultural research systems and a number of regional research organizations in sub-Saharan Africa. The paper begins with a brief review of the production potential of agriculture in the sub-Saharan African countries and proceeds to the new technologies that would be most needed. In the sections which follow it describes the progress that has been made in the last 20 years in creating new research institutions with a major commitment of resources by the governments and the donor community.

The paper considers the policy and management issues which will have to receive greater attention in the coming years in order to make more effective use of the resources already created. It concludes with a brief consideration of the sustainability of national agricultural research systems in sub-Saharan Africa and argues that national agricultural research systems (NARS) perform an essential function that cannot be provided by regional and international organizations and must, therefore, receive continued support in the years to come. They must, however, define the scope of their work and develop complementary relationships with the regional and international agricultural research centers.

WEAK AGRICULTURAL GROWTH

The slow rate of growth of food production in sub-Saharan Africa has continued to receive wide attention. The international concern becomes greater in years of serious food shortages, as in 1984 and 1985, following widespread drought. According to the FAO

reports (1984), 21 countries of sub-Saharan Africa needed cereal imports of 12.2 million tons during this period, of which food aid requirements were estimated to be 7.0 million tons. Earlier, in the 1970s, the Sahelian countries faced a prolonged spell of drought lasting for 10 years, and African agriculture was then in the news also.

The situation in some of the sub-Saharan African countries again deteriorated during 1986-87, and famine conditions were reported. The reality behind these reports is that in contrast to other regions of the developing world, food production in many of the sub-Saharan countries saw a significant decline in the 1970s. This can be seen from Table 1, which shows that the value of agricultural output per capita fell in as many as 22 countries of sub-Saharan Africa during 1970-81. It improved in six other countries. The availability of food nutrients on a per capita basis changed for the worse in 21 countries, improved in five, and remained unchanged in one.

Consistent with this decline in food production is the fact that imports of cereals saw a rapid rise in many sub-Saharan African countries during the same period. Thus, cereal imports by the sub-Saharan African countries tripled during 1960-1979, as reported by FAO (1985). Food imports, whose costs were rather small in the 1960s and early 1970s, rose sharply in the late 1970s. The cost of sub-Saharan African cereal imports in 1978 was estimated to be six times that of 1970. Commenting on the projected food imports of 40 million tons by the year 2000, Delgado et al. (1987) draw attention to the anomaly that, in this vast land-abundant continent, with three-quarters of the population engaged in small-holder food production, over one-fifth of food staples consumed are imported and that the percentage is rising.

The many studies made on sub-Saharan African agriculture, arising from this concern, have undoubtedly served a useful purpose. Some of the authors were perhaps unduly influenced by the depressing record of the 1970s. Already, there is evidence that the declining trend has been checked, and food production in sub-Saharan Africa has seen a rise following the drought years of 1984 and 1985. A more recent FAO report (October 1989) points out that the aggregate output of cereals of the 45 countries of sub-Saharan Africa is expected to be above average for the second year in succession.

A World Bank and UNDP study (1989) supports this conclusion. According to the analysis carried out by the World Bank and the UNDP, the annual rate of agricultural output over the four years 1985-88 was triple that of the average over the previous fifteen — and exceeded population growth for the first extended period since 1970. The 1988 food production index rose just enough since 1984 to maintain per capita output. The World Bank report points out that this recent improvement diverges from a widely held perception that per capita agricultural production is declining in sub-Saharan Africa.

DEVELOPMENT OF SCIENTIFIC AGRICULTURE

The food situation in sub-Saharan Africa needs to be considered in the wider context of scientific upgrading of agriculture in the world as a whole and the potential which exists in this regard in this region. Agricultural production depends on so many factors. First and foremost, there should be the potential in terms of agroecological factors, soils, water, and other natural resources. But even if the potential is there, farmers should have the will to produce more, and this calls for a whole series of policy measures to motivate them. These

include marketing support, incentive prices, and the organization of an institutional infrastructure for the supply of credit, modern farm inputs, and services, combined with an improved production technology. While stressing the role of this wider policy framework, it is important to recognize that good research not only helps to generate improved production technologies; it can also move governments to take the needed decisions for the creation of an institutional infrastructure for the development of a more modern agriculture. Nothing makes a greater impression on the policymakers and planners than the evolution of new technologies with a much higher production potential that can be demonstrated on farmers' fields. This is a lesson that we should be learning from the recent history of agricultural development in many Asian countries. Contrary to popular belief, much new policy in Asia was put in place when the potential offered by the new technology was widely demonstrated by the scientists.

Table 1: Average Performance of Agricultural Sector in Countries of sub-Saharan Africa, 1970-81

Country	Value of agricultural output per capita change 1970-81 (%)	Total value of agricultural output: change 1970-81 (%)	Food nutrients per capita: change 1970-81 (%)
Countries with rising agricultural productivity			
Ivory Coast	+10	+71	+13
Rwanda	+ 7	+48	+ 5
Benin	+ 7	+47	+ 8
Zimbabwe	+ 6	+34	+11
Burundi	+ 1	+26	0
Cameroon	+ 1	+28	+ 2
Countries with falling agricultural productivity			
Ethiopia	– 2	+ 7	–16
Burkina Faso	– 2	– 2	– 3
Zambia	– 5	+16	– 4
Kenya	– 6	+43	–14
Mali	– 7	+23	–10
Madagascar	– 7	+23	– 8
Nigeria	– 9	+28	– 9
Chad	– 9	+14	– 5
Guinea	–10	+18	–10
Sudan	–12	+18	+ 4
Togo	–12	+19	–11
Tanzania	–14	+20	–11
Zaire	–14	+29	–13
Niger	–14	+17	–14
Liberia	–15	+24	–12
Ghana	–15	0	–28
Congo	–16	+10	–17
Lesotho	–16	+ 9	–10
Mauritania	–22	+ 6	–22
Sierra Leone	–23	+ 2	–23
Uganda	–30	– 2	–15
Somalia	–39	+ 7	–39

Source: D. G. R. Belshaw (1984).

Also, the role of research in transforming traditional systems of agricultural production must be seen in a historical perspective. The whole history of modern agriculture is so recent that it is too early to pass judgment. Considering how important agriculture is for meeting basic human needs, it is often not realized that while his evolutionary beginnings go back more than a million years, man took to agriculture only about 10,000 years ago. More important, what we now call "modern" agriculture is only about 50 years old, even in the developed countries. Indeed, the high-yield agriculture that has received so much attention recently has been possible only during the past 25 to 30 years. Most of it has been made possible through the synergistic interaction of Mendel's discovery, which makes it possible for us to manipulate genes in various combinations, and Liebig's work on mineral nutrition of plants, which has resulted in the development and use of inorganic fertilizers.

Many developing countries could not take advantage of scientific developments for increasing the productivity of their agriculture, for they were largely bypassed by the industrial revolution, which provided the inputs and purchasing power. Also, of course, many of them (but not all) did not have the trained scientific manpower to harness these resources of science for developing technologies adapted to their agroclimatic and socio-economic conditions, including the tenure and size of their land holdings. These countries over hundreds of years had learned to maintain some balance between low crop yields and the size of their human populations, kept in check by disease epidemics. This balance was seriously upset in the 1960s, when the population growth in many of them began to accelerate, and traditional agriculture could not feed their rapidly growing populations. The large Asian countries were the first to experience serious food shortages and were called upon to take important policy decisions. The sub-Saharan African countries are now faced with a similar situation and should find the Asian experience useful even if the countries in the two regions are very different in some ways.

PRODUCTION POTENTIAL OF SUB-SAHARAN AFRICA

An impression seems to persist in the minds of many people that Africa is mostly dry and its soils largely unproductive. Years of uncontrolled grazing, we are told, have taken their toll in terms of loss of soil fertility. While the agroecological conditions are certainly more difficult in Africa, none of them is unique to that continent. China, India, and Pakistan have their growing deserts, arid lands, and failing monsoons; and floods that devastate millions of hectares of crops every year. Many of the authors, in the wake of the 1984 drought, were obviously looking for factors that would explain the declining food production trends in the 1970s rather than attempting a careful analysis of the production potential of the subcontinent. Fortunately, we do have a scientific analysis of this kind, and while it does bring out clearly that Africa is a relatively dry continent and only 19% of its soils have no fertility limitations, the analysis also points to an enormous potential for increasing crop and animal production.

The Food and Agriculture Organization (FAO) of the United Nations has organized two major projects in order to determine the limits of food production as set out by soil and climatic conditions and by the use and management of the land (Higgins et al. 1981; Kassam et al. 1984). The basic approach of these studies has been the determination of rainfed production potential of African lands by matching the soil and climatic inventories with the soil and climatic requirements of individual crops. These requirements are determined in the first place by temperatures that would permit photosynthesis for crop growth, and

second, by the period when water is available for growth and development during the optimum length of the growth cycle of the crop. For this reason, the FAO scientists have used the concept of the growing period as a basis for assessment of the agroclimatic resources of Africa. The growing period has been defined as that period during which water availability and the prevailing temperatures would permit crop growth.

The FAO analysis leads to a number of important conclusions. Thus, it is seen that Africa offers a highly variable situation in terms of production potential, as we consider the lengths of crop growing periods of the different agroclimatic zones, their soil resources, and constraints of the various kinds. The analysis shows that 29.4% of the African region has dry desert conditions, while another 17% provides growing periods that are too short to be of much use, and 0.3% is cold, with severe photosynthetic constraints. The other 53.3% is climatically suitable for rainfed cereal production, with 19% having shorter periods (75-179 days), 33.6% long periods (180-365 days), and 0.7% year-round growing periods. It is the heterogeneity of this vast agroclimatically suitable area that is of great interest. Within this variability there are large areas that provide highly favorable conditions for cereal production approaching the yields of irrigated lands and others where the productivity potential is rather limited.

The more recent study — perhaps the most comprehensive of its kind — carried out in the wake of the 1984 and 1985 drought years, arrived at conclusions that express a similar guarded optimism (FAO, 1986). The study concludes that Africa has the potential to produce more, and if this potential were properly mobilized, many African countries could become more self-reliant and their economic situation more manageable. The most important single factor, the study concludes, is the conservation of Africa's physical resources of land and water. While stressing that Asia's green revolution technology cannot be transferred to Africa, the report draws attention to the fact that there is sufficient water to irrigate in the long term more than 20 million hectares of land, with another 20 million hectares already receiving ample rainfall. It follows that while new technology cannot be readily transferred to sub-Saharan Africa from other parts of the world, there is potential to generate a similar high-yield technology through locally organized agricultural research.

The regional variation in production potential

A long-term and highly theoretical view of the production potential of sub-Saharan agriculture has been advanced by Bunting (1989), who took into consideration the study carried out by FAO, the UN Fund for Population Activities, and the International Institute for Applied Systems Analysis. The study is based on eco-physiological growth and yield models applied to hundreds of different agroecological cells as defined by combinations of soil and climate in the different sub-Saharan African countries. The study indicates that the sub-Saharan African region, taken as a whole, could support about 1.1 billion people at the levels of production technique already available, about 4 billion with relatively straightforward inputs and improvements, and about 12 billion with the application of a more modern and highly advanced production technology. The study emphasizes, however, that the favorable environment resources are not evenly distributed and that sub-Saharan Africa contains countries that will always be potentially deficit, unless they manage to mobilize some of the more advanced technology of crop and animal production based on intensive use of costly industrial inputs.

Differences in the production potential of different regions of sub-Saharan Africa have received attention in the course of a number of other studies and need to be emphasized. The specific situations, the problems, and the potential vary greatly. Thus, the low agricultural production potential of the Sahel has been commented upon by other authors. Peter Matlon (1987) points out that the zone is characterized by shortness of growing season, low and variable rainfall (250-750 mm), and low soil fertility, all of which are major constraints to production. Michael Collinson (1987), reviewing the problems in food production technology development in eastern and southern Africa, where the potential is much greater, points out that cash for purchasing inputs and power for preparing the land and for planting are overwhelmingly the scarcest resources for most small farmers.

The food production potential of the vast savanna areas in West Africa has been analyzed in depth by Kassam et al. (1975). These authors concluded that the Guinea savanna areas, in particular, were characterized by very high-yield potential of maize, and with improvements in technology they could become the corn-belt of West Africa.

At the country level, the FAO analysis shows that countries mainly located in zones with long growing periods generally have the highest potential, while those in the drier areas have the least and reflect the restrictive nature of the climate on rainfed production. The analysis helps to identify countries where the land resources are insufficient to meet the food needs of the people living or projected to be living toward the closing years of the century. Table 2 shows that with improved production technology and high levels of input use, only three countries of sub-Saharan Africa should find themselves in a critical situation to feed their population at the end of the century. However, if the technology is not improved and input use continues to be low, as many as 28 countries will not be able to feed their populations in the year 2000.

Table 2: Number of Critical Countries Where Potential Population-Supporting Capacity Is Less Than the Population in Year 1975 and Year 2000

Level of Input	1975 Population	2000 Population
High	2	3
Intermediate	9	12
Low	22	28

Source: G. M. Higgins et al. (1981).

In summary, the situation in the vast areas of the warm tropics which account for 2020.8 million hectares of land is not generally considered critical. The FAO scientists conclude that this enormous climatic area could support more than three times the present population, even with low levels of inputs. With the application of an improved agricultural technology, combined with higher levels of input use, the production could be greatly increased. The analysis further shows that livestock production will always be a major enterprise and activity in large areas of sub-Saharan Africa.

Combined with this potential is the fact that domestic food production in sub-Saharan Africa is the dominant activity for a majority of its people, and it must have a central place in a development strategy virtually everywhere in sub-Saharan Africa (Mellor et al. 1987).

Delgado and colleagues have argued that for most of the people in sub-Saharan Africa it is unreasonable to expect a major shift in the foreseeable future to other occupations and that massive numbers of people must remain in the food sector for generations. Research on export commodities has been under way far longer than on food commodities, but it is the food sector that continues to command much of the economic resources and will require greater research effort.

DIVERSE TECHNOLOGY NEEDS

As far as the favorable lands with long growing seasons are concerned, and sub-Saharan Africa does have significant area of such lands, as the FAO analysis shows, the high-yield technology of the kind developed in recent years remains highly relevant. The central dogma of modern plant breeding is genotype-agronomic management interaction. This means that plant breeders are able to assemble genes in cultivars that take full advantage of modern farm inputs like chemical fertilizers to give high crop yields. The great advantage of new varieties based on such genotypes is that while they thrive on heavy doses of fertilizers and irrigation, they also, in general, give higher yields than the traditional varieties, even with moderate and small doses of chemical fertilizers. This means that the resource-poor farmers, who start by using only small doses of chemical fertilizers, are also able to achieve significantly higher yields with these varieties than with the traditional types. The implication is that plant breeders do not have to develop a different group of varieties for intermediate levels of agronomic management. The strategy which they have successfully followed in recent years is to create high yield potentials and make it possible for farmers to harvest higher yields virtually at all levels of investment in chemical fertilizers and other modern farm inputs. The highest yields, of course, are obtained by those farmers who use large doses of chemical fertilizers and other inputs. However, the resource-poor farmers who use limited doses of chemical fertilizers are generally able to capture the better part of the response curve of the varieties, even if they do not harvest very high yields. A different breeding strategy would, of course, be needed for situations characterized by stress environments of various kinds.

It should be recognized that hardly any improved technology would result in higher crop yields if agronomic management continues to be very traditional and no modern farm inputs are used at all. It would be a great mistake to suggest that the small and marginal farmers in sub-Saharan Africa should stay with a technology that discounts the use of modern farm inputs, even if they have to start with small doses.

Some countries of sub-Saharan Africa are beginning to adopt this strategy of using modern farm inputs and already have a surplus of foodgrains. The more recent FAO Report (1989) on food supply situation and crop prospects in sub-Saharan Africa shows that 13 countries had a total exportable surplus of 2.1 million tons of cereals in their 1988-89 (or 1989-90) marketing year. These supplies could be increased considerably with greater application of the high-yield technology. The surpluses could be used to meet food deficits in neighboring countries. During 1989, for example, donors have already provided financial support for the export of some 382,000 tons of surplus cereals through triangular transactions and barter arrangements, while the surplus countries themselves have exported 347,000 tons commercially.

Does this mean that the green revolution technology which has made such an important contribution to increased food production in Asia and Latin America is also relevant to sub-Saharan Africa? The answer to this question is a qualified yes. The qualification arises from the fact that the agroecological situation in sub-Saharan Africa is not comparable and that the problems of moisture deficit areas and of problem soils will have to receive much greater attention in the very early stages of research planning, simply because of the predominance of these lands, especially in the west African semi-arid tropics and the humid tropics. While the concept of a production advance in the short term from the more favorable lands remains valid, the decisions taken by the Asian policymakers in the 1960s to concentrate mostly on such lands in order to buy time for addressing the problems of the more difficult lands later, could not be an acceptable policy option in the case of sub-Saharan Africa. In sub-Saharan Africa it must be recognized from the very outset that the development of an improved production technology for the drylands so that stable and reasonably good yields can be obtained from the vast areas where the moisture conditions are not so favorable, must be a major priority of agricultural research. This has been stressed among others by the noted Kenyan scientist Odhiambo (1984). Odhiambo has argued that considering the agroecological framework of Africa, with its unpredictable physical environment, the requirement is development of locale-specific agricultural production methods which assure a stable and continuous productivity under the existing resource-poor farmer knowledge base, but rationalized and upgraded to yield predictable results in a more technologically ordered manner.

The second qualification arises from the fact that constraints to the development of a high-yield agriculture in the more favorable regions of sub-Saharan Africa are institutional as well as technological. Both technology generation and organization of effective support services for the farmers will require much greater attention than those currently available. The support services which need to be created include marketing and offering of incentive prices, storage, institutional credit and the distribution of modern farm inputs such as seeds, fertilizers, pesticides and improved farm implements, where necessary, with elements of subsidy built into them. The Asian experience shows that much of the new technology was scale-neutral but that the small farmers responded to it only when they had access to services and modern farm inputs for which a new institutional infrastructure had to be created by the governments.

Technology for the drylands

The task of evolving an improved production technology for the drylands which suffer from moisture stress during some point of the growing season is more challenging and much more difficult. Relatively little progress has been made in developing technologies of this kind, even in other parts of the developing world, and the Asian countries do not have a better record in this regard. Both national and international agricultural research systems in the last 20 years have concentrated heavily on exploiting favorable genotype-environment interactions in lands characterized by high fertility and good conditions for crop growth and have only recently started paying significant attention to the drylands. Much of the leadership in this kind of scientific transformation of traditional agriculture has rested with the geneticists. They were called upon to develop new plant types that would respond to the improved levels of agronomic management.

In sub-Saharan Africa in the longer term the need would be for scientific leadership of a different kind. It must be provided by the agronomists and soil scientists working in close collaboration with the breeders and crop-protection scientists. The FAO report (1986) provides successful examples of improved technologies for the conservation of Africa's physical resources of land and water, which hold the promise of arresting the downward trends in agricultural production on a more sustained basis. They include technologies that would halt the degradation of cropland, reverse soil fertility decline, prevent degradation of grazing land, enable water harvesting, arrest forest liquidation, and build soil fertility through the introduction of legumes into the cropping systems, with integrated use of chemical fertilizers.

The challenge, of course, is not only for the scientists in sub-Saharan Africa but also for the international agricultural research system that supports them. The Consultative Group on International Agricultural Research (CGIAR) has already recognized the need for new technologies in the context of Africa. The last TAC Review (1985) of CGIAR priorities and future strategies clearly states that in Africa the absence of large-scale irrigation potential and the prevalence of dryland farming suggest that a distinct research strategy will be required for generating improved technologies. The review argues that what is needed is a wide range of technologies more specifically targeted for both the diverse and the more difficult conditions of rainfed agriculture in complex, small-scale production systems. Also, increased emphasis will need to be placed on the goal of long-term sustainability of production in these environments. The more recent TAC paper (1989) on development of a sustainable agriculture highlights some of these technological issues.

Consistent with these priorities, the TAC paper points out that Africa already accounts for the largest share of the CG funds. Thus, in 1983, 42% of the funds of CGIAR were used in Africa, 25% in Asia, 19% in Latin America, and 14% in North Africa and the Near East. Also, four of the CG centers are located in Africa, and nearly 40% of the 700 scientists of the CG system have their main research focus, or a significant part of it, on problems of African agriculture. The important question now is one of using these resources more effectively for the kind of technical solutions that will make greater impact. It may well be that a greater decentralization of their work will be necessary, with many of the center scientists working closely with their counterparts in the national systems, providing critical support in their research programs and helping to build institutional capacity.

As regards the national agricultural research systems of sub-Saharan Africa, their current research infrastructure — which is considerable — should be mobilized for a massive program of adaptive and applied research. Especially important in this context is large-scale introduction of breeding material of different crops in advanced generations so that final selections can be made under local conditions. The wealth of improved genetic material available at the international agricultural research centers and with the cooperating national agricultural research systems in different parts of the world is very large. In the short term, this material offers the largest potential for accelerated programs of crop improvement for the more favorable lands in sub-Saharan countries, especially for crops like maize, sorghum, millet, rice, wheat, cassava, and potato. What has not always worked in the past is a direct introduction of these materials. What is needed is the use of this material as valuable germplasm in the organization of local crop improvement programs. Some outstanding examples of such programs can already be formed. Plucknett et al. (1986) have drawn attention to the new technologies which are beginning to be available from the joint

work of scientists of the international agricultural research centers and the national systems in several sub-Saharan African countries.

REORGANIZATION OF AGRICULTURAL RESEARCH IN SUB-SAHARAN AFRICA

If the sub-Saharan African countries have all this potential to increase their food production, and improved technology holds the key to the transformation of their traditional agriculture, what are they doing to create a capacity to organize strong programs of research? The Asian and Latin American countries, faced with the kind of problems which sub-Saharan Africa now faces, responded by taking bold policy decisions to reorganize their agricultural research services. The fundamental change in these countries has been in the organization and management of research and the institutional framework within which their agricultural scientists function. Many countries have created new research councils and national institutes with a great deal of functional autonomy so that the bureaucratic procedures characteristic of government departments do not apply in the management of agricultural research (Jain, 1989). There has also been much greater political commitment to research since the 1960s in the form of increased funding support, resulting in considerable expansion of their research programs. What about the African countries? Their progress in some ways has been even more significant when viewed against the background of their past history. At the same time agricultural research institutions in sub-Saharan Africa remain in early stages of their development and must be further strengthened.

The historical background

Agricultural research in most countries of anglophone sub-Saharan Africa was developed during the colonial period within the ministerial departments of agriculture, supported later by a number of specialist regional or other research organizations like EAAFRO — the East African Agricultural and Forestry Research Organization, and ECG — the Empire Cotton Growing Organization. Research services were dominated by expatriates, with few national scientists. The result was that these institutions were politically vulnerable and, when the expatriates left following independence, there was a great deal of disruption, and in many countries a vacuum was created.

In francophone Africa, an extension of the national agricultural research system of France to the colonies was the main instrument for providing technological support to the agriculture of many of the West African countries. In this highly centralized system ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer), with its headquarters in Paris, carried out basic research, while eight other specialist French institutions with a common board of management, had their units for applied and adaptive research in the colonies.

The dominant organizational form for agricultural research adopted in much of anglophone and francophone West Africa during the late colonial period was the regional export crop research institute. Following independence, the process of nationalization was relatively rapidly achieved in the anglophone countries, thanks to the earlier development of post-secondary colleges and universities; but, research experience necessarily took time to develop. In francophone West Africa, on the other hand, the nationalization process has been considerably more complex and protracted, with few exceptions. The colonial pattern

of organization remained relatively unchanged throughout the 1960s, and it was not until the early 1970s that serious attempts to nationalize and integrate the French institutes into national research organizations were initiated (Rocheteau et al. 1988).

The recent developments

An important feature of the agricultural research scene in sub-Saharan Africa today is the significant progress that has been made in the last 20 years in organizing a new physical infrastructure. New institutions have been created in many of the countries, their research station networks expanded, and a large number of African scientists trained. These newly organized services have increasingly taken over responsibility for agricultural research, replacing the colonial institutions in many countries.

Some of the national research services created in the last 20 years are small compared to their counterparts in the Asian and Latin American countries. It is important, however, to recognize that while there were few agricultural research institutions based on indigenous capacity in the sub-Saharan African countries in the 1960s, today most of them have a research service of their own, with both research policy and the management of the new institutions resting with the African scientists, managers, and policymakers. A large number of expatriate scientists still continue to work in the NARS of sub-Saharan Africa, particularly in the francophone countries, but they complement the work of the African scientists rather than substitute for them — a role they performed during the colonial period. St. George Cooper, an FAO Regional Adviser for Africa on Research and Development, wrote in his book on agricultural research in tropical Africa in 1970: "if there is to be a fundamental alteration in the structure and scope of research activities in Africa, then all the organizations engaged in research such as Specialized Commodity Institutes, Universities, Government Research Institutes — all should become part of an integrated set up, and should become instilled with a sense of common purpose, merging into an effective scientific body, which can provide the leadership necessary for stimulating major research breakthroughs." Looking at the situation today, it would be fair to say that considerable progress has been made in this direction, but much remains to be done to make the newly created institutions more effective. And, unless this is done, the criticism will be made that the new institutes remain largely unused. Those who recognize that institution building is a long process and that sub-Saharan Africa will have a lag period — considering that many of the earlier institutions were transplants that did not take root — will have litte reason to be impatient with the progress already made.

The new institutions combine some of the features of the research councils of Asia and the national research institutes of Latin America, but in many other ways they tend to be different. First, many of them have rather limited resources, and more importantly, quite a few of them tend to be located in the ministry of science rather than the ministry of agriculture. The affiliation with the ministry of science is more common in sub-Saharan Africa than in Asia or Latin America, where research institutions are more closely linked with the ministry of agriculture. In view of their close association with the ministry of scientific research, some of the agricultural research systems in sub-Saharan Africa have evolved a value system and a research policy that does not bind them closely to the process of economic development in the rural sector. Some of the new institutions continue to be integrated in the bureaucratic structure of the ministry of agriculture.

Table 3: National Agricultural Research Institutions in French-Speaking Countries of West and Central Africa, 1987

Country	Year	Institution	Mandate	Affiliation
Mali	1960	Institut d'Economie Rurale (IER)	Crop production	Department of Agriculture*
Mali	1960	Institut National de la Recherche Zootechnique, Forestière et Hydrobiologique (INRZFH)	Animal production	Department of Forestry and Environment
Senegal	1961	Institut de Technologie Alimentaire (ITA)	Food technology	Department of Agriculture
Burundi	1962	Institut des Sciences Agronomiques du Burundi (ISABU)	Agricultural Production, Forestry	Department of Agriculture
Rwanda	1962	Institut des Sciences Agronomiques du Rwanda (ISAR)	Agricultural Production, Forestry	Department of Agriculture
Togo	1965	Institut National de la Recherche Scientifique (INRS)	Botany, social sciences	Department of Science
Togo	1968	Direction Nationale de Technologie Alimentaire (DNTA)	Food technology	Department of Agriculture
Zaire	1970	Institut National pour l'Etude et la Recherche Agronomiques (INERA)	Agricultural Production	Department of Science
Côte d'Ivoire	1971	Centre Ivoirien de Recherches Economiques et Sociales (CIRES)	Social sciences and Ag. Econ.	University of Abidjan
Mauritania	1973	Centre National d'Etudes et de Recherches Vétérinaires (CNERV)	Animal production	Department of Agriculture
Niger	1974	Institut National de la Recherche Agronomique (INRAN)	Agricultural production	Department of Agriculture
Cameroon	1974	Institut de Recherche Agronomique (IRA)	Crop production	Department of Science
Cameroon	1974	Institut de Recherches Zootechniques (IRZ)	Animal production	Department of Science
Cameroon	1974	Institut des Services Humains (ISH)	Social sciences	Department of Science
Senegal	1975	Institut Sénégalais de Recherches Agricoles (ISRA)	Agricultural production	Department of Agriculture
Togo	1976	Direction de la Recherche Agronomique (DRA)	Crop production	Department of Agriculture
Mauritania	1977	Laboratoire d'Entomologie Agricole (LEA)	Agr. entomology	Department of Agriculture
Burkina Faso	1981	Institut d'Etudes et de Recherches Agricoles (INERA)	Agricultural production	Department of Science
Burkina Faso	1982	Institut de Recherche en Biologie et Ecologie Tropicale (IRBET)	Tropical ecology	Department of Science
Ivory Coast	1982	Institut de Développement des Savannes (IDESSA)	Agricultural production	Department of Science
Benin	1984	Direction de la Recherche Agronomique (DRA)	Agricultural production	Department of Agriculture

Source: Based on ISNAR Working Paper no. 21.
* Department of Agriculture also stands as a proxy for other government departments having main responsibility for development of agriculture.

Table 3 lists the semiautonomous national agricultural research institutions in the francophone West African countries. In the anglophone countries the trend has been for closer association with the ministry of agriculture. Table 4 shows some of these newly created/consolidated institutions in the anglophone countries.

Table 4: Different Types of Agricultural Research Institutions in Anglophone Africa

Semiautonomous research councils	Council for Scientific and Industrial Research (CSIR), Ghana Agricultural Research Corporation (ARC), Sudan
Semiautonomous research institutes/ organizations	Kenya Agricultural Research Institute, (KARI) *The Tanzanian Agricultural Research Organization (TARO) *The Tanzania Livestock Research Organization (TALIRO) Cameroon Institute of Agricultural Research (ISAR) Agricultural Research Institute, Ethiopia
Autonomous advisory and coordinating councils	National Council for Science and Technology (NCST), Nigeria and Kenya National Research Council (NRC), Uganda National Council for Scientific and Industrial Research (NCSIR), Zimbabwe National Council for Scientific Research (NCSR), Zambia Agricultural Research Council (ARC), Zimbabwe
Departments of agricultural research in the ministries of agriculture	Department of Research and Specialist Services (DR&SS), Zimbabwe Agricultural Research Division, Lesotho Department of Agricultural Research, Botswana Department of Agricultural Research, Uganda Department of Agricultural Research, Zambia Department of Agricultural Research, Malawi Agricultural Research Institute, Somalia Department of Agricultural Research, Gambia
University faculties/institutes of agriculture	Ahmadu Bello University Institute of Agricultural Research (IAR), Nigeria Sokoine University of Agriculture (SUA), Tanzania University of Swaziland, Swaziland Obafemi Awolowo University, Ife Institute of Agricultural Research & Training (IAR&T), Nigeria

Source: Taylor (1988).
* Integrated into the Research and Training Division of the Ministry of Agriculture and Livestock Development in 1989.

SUB-SAHARAN AFRICA'S NEW RESEARCH INFRASTRUCTURE

ISNAR's reviews of National Agricultural Research Systems (NARS) in 20 countries of sub-Saharan Africa and collaboration with them and with others in system-building activities show the type of new institutions that have been set up since independence. Appendix 1 lists the reviews and Appendix 2 describes the organization and structure of

eight of the national institutions and the research station network which they manage in different regions of sub-Saharan Africa. In addition, ISNAR's data base on national agricultural research systems in different regions of the world provides indicators of progress made by 43 countries of sub-Saharan Africa. Table 5 shows the resources of scientific manpower these countries have developed in their newly organized research systems following independence, and Table 6 summarizes their average research budget during 1980-1985, in absolute terms and as percentage of their agricultural gross domestic product (AgGDP). The table also shows the expenditure per researcher derived by dividing the total research budget by the number of researchers, including the expatriate scientists.

Number of researchers and rising investments in research

It is possible to draw a number of important conclusions from these and other data. First, it is clear that the sub-Saharan African countries have made major investments (often with donor support) in creating a significant agricultural research capacity during the past 20 years. ISNAR's data base shows that sub-Saharan Africa had a world share of only 2.3% of research personnel during 1960-64. This share more than doubled, so that in 1980-85 sub-Saharan Africa had a share of 4.9% out of a total of 99,671 researchers in the global agricultural research system. In absolute terms, the increase in the number of researchers is found to be even more significant. The 43 sub-Saharan African countries had a total of 1,159 researchers during the period 1960-1964. This number increased to 4,870 (excluding the scientists in the universities) during 1980-85, showing a fourfold rise. In this respect sub-Saharan Africa's record is comparable with that of other regions of the developing world. However, as we shall see, even with all this buildup, scientific manpower continues to be a major weakness of NARS in sub-Saharan Africa, particularly in respect of scientists with postgraduate qualifications.

In terms of expenditure, too, there is evidence of increased investments in the research services of the sub-Saharan African countries during this 20-year period. In global terms, sub-Saharan Africa's agricultural research expenditure increased from 4.5% to 5.3% during this period. This share of the world investment in agricultural research was achieved by a threefold rise in agricultural research expenditures in constant dollars. Thus, during 1960-64, sub-Saharan Africa had a research budget of US$ 120,879,000 in 1980 US dollars. In 1980-85 this amount increased to US$ 381,940,000, again in terms of the 1980 value of the dollar.

The significant increase in investments supporting agricultural research in the sub-Saharan African countries can also be seen when research expenditures are expressed as a percentage of the Agricultural Gross Domestic Product (AgGDP). This has been done in Table 7 for the different regions of sub-Saharan Africa, and for the purpose of comparison, with other regions of the world. It will be seen that in percentage terms the investments in sub-Saharan Africa compare well with those of Asia, where the investments generally are lower, and with those of Latin America, West Asia, and North Africa. These investments, of course, are still far short of the value of 2.01% for the developed countries, and they have a large component of donor support.

The sub-Saharan African countries, like developing countries in other regions of the world, will take many years before they reach the level of investment of 2% of the Agricultural Gross Domestic Product, which a World Bank Sector Policy paper (1981) has argued would be an appropriate target for all the countries in which agriculture is the key economic sector.

Table 5: Resources of Scientific Manpower for Agricultural Research in sub-Saharan Africa

	National Agricultural Research Services research staff (BS and higher), 1980-86 (number and percentage/average)				Scientists with postgraduate MSc & PhD or equivalent degrees at institutes of higher agricultural education, 1980-86
			Postgraduates		
ESTERN AFRICA	Total researchers	% Expatriates	% of Total researchers	% Nationals	
BENIN	45	7	73	71	26
BURKINA FASO	114	48			42
CAMEROON	187	33			
CAPE VERDE	16	19	57	45	0
CHAD	28	29			28
GAMBIA	62	27			0
GHANA	138	6	74	69	142
GUINEA	177				
GUINEA-BISSAU	8	13	75	71	0
IVORY COAST	201	73			59
LIBERIA	33	27	69	57	31
MALI	275	11	29	20	66
MAURITANIA	12		92		0
NIGER	57	56			18
NIGERIA	1005				637
SENEGAL	174	29			56
SIERRA LEONE	46				65
TOGO	49	24			21
Subtotal	2626	31	50	29	1191
CENTRAL AFRICA					
BURUNDI	53	43	85	73	17
CENTRAL AFRICAN REPUBLIC	NA				11
CONGO	68	46			51
GABON	24	58	71	30	10
RWANDA	34	28			8
SAO TOME & PRINCIPE	3				0
ZAIRE	43		23		124
Subtotal	225	43	60	59	221
SOUTHERN AFRICA					
ANGOLA	28	46	46	0	
BOTSWANA	50	56	73	38	0
LESOTHO	18	50	67	33	0
MADAGASCAR	83	12	48	40	36
MALAWI	80	6	30	26	41
MAURITIUS	99		36		17
MOZAMBIQUE	77	83	83	0	33
SWAZILAND	11	36	44	17	27
ZAMBIA	111	49	61	24	21
ZIMBABWE	153		45		32
Subtotal	710	41	52	24	207
EASTERN AFRICA					
COMOROS	14	50	50	0	0
ETHIOPIA	142	6	43	40	68
KENYA	483	16	45		242
SEYCHELLES	7	38	38	0	0
SOMALIA	31	13	9		57
SUDAN	206		81		164
TANZANIA	276	22	61	49	168
UGANDA	168				56
Subtotal	1326	17	54	44	755
TOTAL	4888	29	53	38	2374

Source: Calculation based on data summarized in Pardey and Roseboom (1989a). Gaps in columns indicate information not available.

Table 6: Expenditure on Agricultural Research in sub-Saharan African Countries (Average, 1980-85)

COUNTRY	EXPENDITURES (millions of 1980 US Dollars)	EXPENDITURES PER RESEARCHER	EXPENDITURES (as % of AgGDP)
ANGOLA	4.335	154,816	0.24
BENIN	2.383	54,993	0.32
BOTSWANA	5.849	113,634	4.24
BURKINA FASO	15.568	134,029	1.74
BURUNDI	4.381	74,251	0.52
CAMEROON	15.069	92,163	0.74
CAPE VERDE	0.320	22,860	1.23
CENTRAL AFRICAN REP.			
CHAD	1.481		0.33
COMOROS			
CONGO	2.494	33,703	1.34
ETHIOPIA	11.323	94.053	0.21
GABON	2.494	103,925	
GAMBIA			
GHANA	3.344	25,821	0.11
GUINEA	5.605	31,667	0.66
GUINEA-BISSAU	0.907	113,345	0.68
IVORY COAST	28.330	141,625	1.09
KENYA	28.397	67,927	0.87
LESOTHO	6.043	335,726	3.38
LIBERIA	5.247	166,672	2.81
MADAGASCAR	7.318	107,016	0.38
MALAWI	4.902	59,778	0.52
MALI	12.552	45,645	1.18
MAURITANIA	0.501		0.18
MAURITIUS	5.546	53,616	2.79
MOZAMBIQUE			
NIGER	1.994	33,771	0.19
NIGERIA	92.393	91,958	0.59
RWANDA	2.004	65,668	0.23
SAO TOME & PRINCIPE	0.164	81,846	0.74
SENEGAL	13.206	93,275	1.54
SEYCHELLES			
SIERRA LEONE	0.946	15,405	0.22
SOMALIA	0.322	9,476	0.03
SUDAN	13.683	74,863	0.31
SWAZILAND	2.472	348,740	1.87
TANZANIA	20.417	54,133	0.64
TOGO	6.174	138,808	1.46
UGANDA			
ZAIRE	3.820	93,259	0.19
ZAMBIA	3.576	37,942	0.69
ZIMBABWE	17.448	115,941	1.91
Sub-Saharan Africa total	381.940	78,430	0.54

Source: Calculation based on data summarized in Pardey and Roseboom (1989a).

The World Bank paper, however, makes a clear distinction between the desirable or the optimum target and what is feasible. Considering the present scientific and other resources of many developing countries, the paper suggests that a 2% target must be viewed as a

Table 7: Comparative Expenditures on Agricultural Research — Sub-Saharan Africa and Other Regions

Region	Agricultural Research Expenditures (Millions of 1980 US Dollars) With expenditure as a % of AgGDP in brackets										Ratio
	1960-64	%	1965-69	%	1970-74	%	1975-79	%	1980-85	%	1980-85:1960-64
Sub-Saharan Africa	120.879	(0.25)	202.817	(0.41)	267.161	(0.44)	347.858	(0.55)	381.940	(0.54)	3.2
Asia & Pacific	238.337	(0.12)	395.226	(0.17)	598.826	(0.22)	810.699	(0.27)	1105.523	(0.34)	4.6
Latin America & Caribbean	179.386	(0.24)	251.788	(0.31)	447.231	(0.41)	656.884	(0.53)	714.349	(0.54)	4.0
West Asia & North Africa	110.652	(0.25)	163.024	(0.31)	304.837	(0.47)	362.832	(0.53)	344.048	(0.43)	3.1
Developed Countries	2020.762	(0.89)	2955.308	(1.26)	3656.655	(1.42)	4090.231	(1.58)	4717.398	(2.01)	2.3

Source: Calculation based on data summarized in Pardey and Roseboom (1989a).
Note: In this table as in others on expenditure, the purchasing power parity indices have been used to convert to US dollars.

long-term objective and that its achievement would require a large effort over an extended period. Even if investments for agricultural research were to be expanded by 10% annually, it would take 10 years for many of the sub-Saharan African countries to arrive at this norm.

So the suggestion is not that the sub-Saharan African countries should continue to make new investments in agricultural research to expand their existing research infrastructure. Whatever additional investment can be mobilized in the present climate of tight fiscal policies, it is clear that they should be used primarily to increase the effectiveness of the existing infrastructure. Upgrading the quality of the scientific manpower and expanding it would obviously be an important area of future investment. Improving the balance between the salary costs of scientists and operating funds for research-related expenditure would be another. The third potential area for investment would be the one which helps to improve the laboratory and field facilities for scientists to do their job more effectively.

Decline in operating costs

Much has been written about the relative decline in expenditure per researcher in sub-Saharan Africa over this 20-year period. With a fourfold increase in the number of scientists and a threefold increase in the amount of research budget, the expenditure per scientist in sub-Saharan Africa has tended to decline relative to some of the other regions of the developing world, as can be seen from Table 8. Based on this kind of analysis, it has been concluded by some that the growth of scientific manpower in sub-Saharan Africa has been at the expense of operating costs for research. ISNAR's data base (Pardey and Roseboom, 1989b) provides a fuller understanding of this complex issue. It highlights the fact that the expenditure per researcher (expressed as total research budget divided by the number of researchers) in sub-Saharan Africa has been traditionally much higher than that in other parts of the world, including the developed countries. Thus, in the early 1970s sub-Saharan Africa had the highest research expenditure per researcher, totalling nearly US$ 119,161 in 1980 US dollars — much higher than that in any other part of the world. In 1980-1985 this amount came down to 78,430 in 1980 US dollars, which was still close to the amount for the developed countries and was vastly higher than the corresponding amount of 48,864 for Asia and the Pacific region.

The expenditure per scientist in sub-Saharan Africa has to be understood in its proper context. In the 1960s the research services in sub-Saharan Africa were dominated by

Table 8: Comparative Expenditures on Agricultural Research (per Scientist) in sub-Saharan Africa and other Regions

	Expenditure per Scientist (1980 US Dollars)					
Region	1960-64	1965-69	1970-74	1975-79	1980-85	Ratio 1980-85:1960-64
Sub-Saharan Africa	104257	120592	119161	104757	78430	0.75
Asia & Pacific	46526	49756	56289	46649	48864	1.05
Latin America & Caribbean	85645	89011	94438	99494	81917	0.96
West Asia & North Africa	52687	52021	67659	55704	38366	0.73
Developed Countries	51685	67677	77266	80997	86576	1.68

Source: Calculation based on data summarized in Pardey and Roseboom (1989a).

expatriate scientists, whose salary costs were relatively high. As the sub-Saharan African countries have trained and employed more local scientists, the salary costs have come down, and correspondingly, the costs per scientist. Even with this scaling down, however, the fact remains that research costs per scientist in sub-Saharan Africa continue to be high compared to those in many other parts of the developing world.

So what is the problem? The problem is that expenditure per researcher, as defined above, tells only part of the story. It is a composite figure that includes all kinds of costs — salaries of scientific and supporting staff, wages, capital costs of diverse kinds, maintenance costs of the physical infrastructure, including field and laboratory facilities, travel and transport costs, and the operating funds available to scientists for their field and laboratory work. It is the imbalance between these different kinds of costs, and especially the operating funds, equipment and salaries, which is often a problem. This can be seen from the analysis ISNAR carried out in the course of the recent review of the research system in Ghana. The analysis focuses on (1) operating funds per scientist, which exclude salary costs, and (2) total recurrent cost per scientist, which includes salary costs. Table 9 gives these two sets of figures for a number of research institutes in Ghana for the year 1987. It will be seen that in many institutes, operating funds in 1987 were less than 10,000 US$ per scientist.

The exceptions were the Ghana Grain Development Project supported by the Canadian International Development Agency, the Oil Palm Research Institute and the Nyankpala Research Station supported by the Federal Republic of Germany. The analysis further showed that both the operating funds and the recurrent cost per scientist in 1987 were close to half of those available, in constant dollar terms, in the year 1974. Thus, over the years, there has been a great deal of decline in the operating funds for the use of scientists. The salary costs as relative share of the recurrent costs have tended to increase over the years because of increases in the number of staff. It was noted that, on an average, a researcher was being supported by as many as 12 other staff consisting of technicians, administrative personnel, and other support staff.

Table 9: 1987 Funding of Agricultural Research: Operating Funds and Total Recurrent Costs per Scientist (in US Dollars)

	Number of scientists	Operating funds per scientist	Total recurrent costs per scientist
CSIR			
ARI	15	2,900	19,600
SRI	10	7,300	48,600
OPRI	8	16,200	74,700
FRI	26	2,000	8,100
IAB	11	4,200	11,700
CRI			
Nyankpala	13	32,300	56,000
GGDP	22	16,200	36,000
Others	14	10,900	52,400
FPRI	18	6,200	32,100
Average per Scientist	137	10,100	33,140

Source: Review of the Ghana Agricultural Research System, Volume 1, 1989, CSIR and ISNAR.

ISNAR's review of the research system in Cameroon also noted that the relative share of the salary costs had increased over the years. An analysis of the operating expenditure in the country's two major institutes — IRA, the Institute of Agricultural Research, and IRZ, the Institute of Animal Research — showed that the personnel costs for IRA had increased from 59% in 1981/82 to 79% in 1986/87, and for IRZ they had increased over the same period from 49% to 74%. The costs directly related to research programs came down during this period from 25% to 12% in the case of IRA, and from 25% to 16% in IRZ. The ratio of researchers to other personnel for the two institutes taken together was 1:11 in 1987.

Limited scientific manpower

A more serious problem is that of the number of qualified scientists. Many of the national agricultural research systems in sub-Saharan Africa, even with all the efforts they have made in the last 20 years, continue to have a limited number of highly trained scientists. This can be seen from Table 5 and also from Figure 1, which shows the frequency distribution of 42 countries of sub-Saharan Africa in terms of the number of researchers in their agricultural research services, during the 1980-86 period. The figures give the total number of researchers, including the expatriate scientists, who constituted for the region as a whole 29% of the total researchers.

It will be seen from Figure 1 that more than half of the countries of sub-Saharan Africa during this period had, on an average, fewer than 100 researchers, and 18 had fewer than 50. Only six countries had more than 200 scientists in their research system, of which the largest were Nigeria (1005) and Kenya (483).

The small number of scientists in many of the research systems creates the problem of critical mass in organizing significant programs of research. The problem becomes compounded by the fact that a large proportion of scientists do not hold postgraduate qualifications, so that they do not have basic training as researchers. This can be seen again from Table 5, which gives the percentage of scientists holding the MSc and PhD degree qualifications in the different regions of sub-Saharan Africa. If we exclude the expatriate scientists, who generally hold postgraduate qualifications, it will be seen that only 29% of the researchers held such qualifications in Western Africa, 59% in Central Africa, 24% in southern Africa, 44% in eastern Africa — a total of 38% for sub-Saharan Africa as a whole. If we now consider Bangladesh for comparison purposes, we find that as many as 70% of the total number of 1,040 scientists in that country were holding postgraduate qualifications during the corresponding period. There were very few expatriates in the system.

It is true that the low level of scientific training is not unique to sub-Saharan Africa. In several other parts of the developing world, including Southeast Asia and Latin America, the percentage of scientists holding only the first degree qualifications is often quite high. However, NARS in these countries generally have a much larger number of scientists, and for this reason, the absolute number of scientists with postgraduate qualifications can be quite high.

It should be stressed that sub-Saharan Africa, as will be seen from Table 5, does have a large number of highly qualified scientists in its faculties of agriculture. In most of these countries, however, scientists in the faculties of agriculture have their main responsibility as teachers and, with some exceptions, few institutional mechanisms exist to involve them in development-oriented agricultural research.

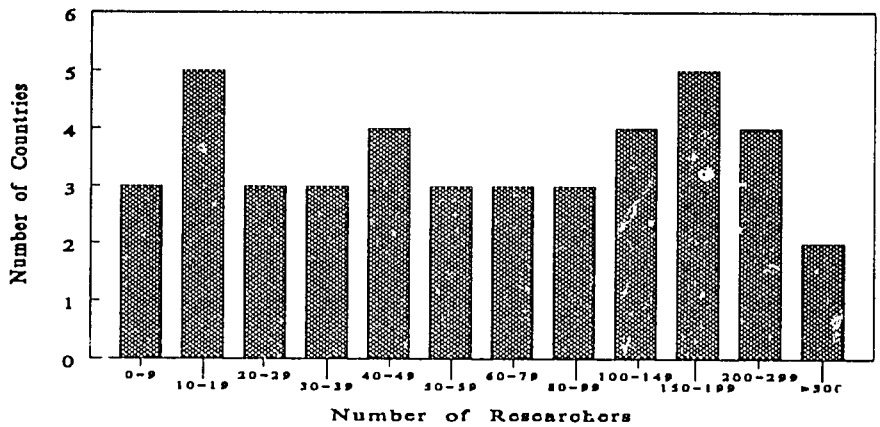

Figure 1. Size distribution by number of researchers of forty-two sub-Saharan NARS (1980–1986)
(Source: ISNAR data base)

STRENGTHENING OF NARS IN SUB-SAHARAN AFRICA — POLICIES AND PRINCIPLES FOR THE NEXT PHASE

While it is important to review the experience of the past 20 years and learn lessons from it, the paramount need is to keep up the momentum, and build on the foundations established. The swift pursuit would require continuing funding support, combined with a long-term commitment to institution building. If the last 20 years have been dominated by major investments in reorganizing and creating a new research infrastructure following the colonial period, attention should now be focussed on harnessing these newly created resources for a significant impact on production through the development of new technologies. A more effective and efficient use of these resources through a well-defined research policy and improved organization, management and planning should become a key concern of national policymakers and the donor community. Some of the principles that should guide this new drive in search of greater effectiveness are considered here.

LINKING RESEARCH TO DEVELOPMENT: A NEW POLICY

The 1960s became a decade of decision for the policymakers and planners in many developing countries. The basic decision was to make their agricultural research services a centerpiece of the development process. This integration of research and development, conceived as part of a strategy for the modernization of their agriculture, has marked a new

chapter in the agricultural growth of many of these countries. In others, and especially in sub-Saharan Africa, this kind of integration is yet to be achieved fully.

The highly populated Asian countries faced with mounting food deficits were the first to evolve a new science policy of this kind, and as a result, they have undertaken a radical reorganization of their agricultural research services in the past 20 years. Their reorganized agricultural research systems, in close interaction with agricultural planners and administrators, have been asked to place major emphasis on developing improved technologies for the farmers, working closely with them and with the extension services. At the same time, the reorganized research services have been given a great deal of operational autonomy, recognizing that research needed a different kind of management culture.

Combining these two needs presented a difficult challenge. The Indian Government in the 1960s was so concerned with this aspect of the organization of their agricultural research that they made sure that the reorganized Indian Council of Agricultural Research, while not forming a part of the bureaucracy of the Ministry of Agriculture, would work closely with it. The mechanism they established for this purpose was to appoint the Minister of Agriculture as the President of the Council so that the government could have an important role in the determination of the research policy. At the same time, the Director General of the Council, a nongovernment organization, was given the status of a permanent secretary in the Ministry of Agriculture, so that the Council will be represented at the policy-making level in the government and will be held accountable to Parliament.

In a different part of the world, in Argentina, the newly created autonomous research organization in the form of INTA — the Institución Nacional de Tecnología Agropecuaria — was made responsible to its Council, which lays down its research and management policy. The Council has its membership drawn mostly from representatives of the powerful producer organizations in the country and from the nominees of the Secretary of State for agriculture. The purpose in both cases was to foster a contractor/customer relationship between the agricultural research service and the ministry of agriculture (representing the farmers), a relationship first suggested by Lord Rothschild (1971), a scientific advisor to the British Prime Minister in the 1970s.

The validity of this new science policy is now widely recognized, and there is little doubt that the agricultural research services in most countries of sub-Saharan Africa and in other developing countries will be increasingly aligned with the ministry of agriculture in the coming decades. At the present time, however, agricultural research in many countries of sub-Saharan Africa, especially in the francophone countries, either continues to be located in the ministry of science or has relatively weak links with programs of agricultural development and those who organize and manage these programs in support of the farmers. It may be unrealistic to believe that the process of change would be accelerated and that a radical reorganization of the structure of research in many sub-Saharan African countries would take place in the near future. However, it is an issue that cannot be brushed aside, even if many countries choose to go for softer options for the present.

Short of radical reorganization, many sub-Saharan countries must give serious thought to creating institutional mechanisms, which will bring the research service and the development departments of the government and the farmers into a closer working relationship. The essence of these institutional mechanisms is the creation of new structures that perform

the linkage function. The suggestion is that while the ministry of science should be seen as the facilitating ministry, policy for agricultural research should be laid down by a body with strong representation from the ministry of agriculture and the economic development and planning departments of the government. An example of this kind of structural change now being contemplated is provided by Ghana and Nigeria.

Agricultural research in Ghana before independence was organized in the Ministry of Agriculture. Following independence in 1962, the Ghanaian Academy of Science was set up, and responsibility for agricultural research was transferred to it. In 1968, the Council for Scientific and Industrial Research was created as an autonomous organization, currently under the Ministry of Industry, Science and Technology, and this Council has responsibility for the organization and management of agricultural as well as industrial research. The system in Ghana has been reviewed recently by a joint Ghanaian/ISNAR team in the context of a proposed World Bank-funded project for strengthening the agricultural sector. The Review Panel has proposed, among other options, the creation of an interministerial National Agricultural Research Policy Committee as subcommittee to the powerful Agricultural Policy Coordinating Committee of the Ministry of Finance and Economic Planning. The new body will have strong representation from the Ministry of Agriculture and other user departments of the government.

In the case of Nigeria, following independence in 1960, the responsibility for agricultural research was assigned to the federal Ministry of Agriculture and Natural Resources — the client ministry. In 1970, however, this close relationship between the research service and its client government departments was changed. First, agricultural research became the responsibility of the Nigerian Council of Science and Technology, and in more recent years, the research station network consisting of 18 federal institutes and over 80 substations is managed by the federal Ministry of Science and Technology. The Government of Nigeria, in consultation with the World Bank and FAO, has initiated a review process, and new options are being considered. The suggestion has been made that a national agricultural research board, with appropriate representation from farmers and senior officials of the development departments of the government, including the Department of Agriculture, should be created to lay down the research policy.

It should be stressed that the organization of public-funded agricultural research based on a value system which recognizes that the scientists will work to find solutions to farmers' problems has continued to be debated since the first adoption of the Land Grant Act of 1862 by the US Congress. Even in the United States, where this concept has gained most ground and has been found to be so highly successful, questions have continued to be asked about how far it is being implemented at present (Hood and Schutjer, 1990). In the United Kingdom, a recent review, organized in the wake of the Rothschild report, had led to the closure of some of the government-funded institutions because the government had a perception that their work was not in line with their service role. Many of the developing countries have yet to make a commitment of this kind, and nowhere is this value system needed more than in the research systems of sub-Saharan Africa.

Determination of research priorities

As NARS in sub-Saharan Africa focus their research agenda on the development needs of the country, working closely with the policymakers, agricultural administrators, extension workers and farmers, they will be using a more defined set of criteria for setting their

priorities. Some of these, based on various scoring methods, are already in use in a number of countries. All of them start with a good congruence analysis, which helps to define the economic and social setting in the country that should guide the research system in evolving its research focus. It takes into consideration the importance of the different development areas and of the relevant crops and livestock that may be grown in them and their significance to the national economy, both in terms of domestic consumption and the export potential, the current and future demand for increased production of the particular item, the urgency of the need for additional research on a particular problem, the public distribution of benefits of research, and the chances of a successful outcome for the research itself. Political consideration may come into play in determining these priorities — some countries may heavily emphasize food self-sufficiency, while others may attach greater importance to food security, exploiting more fully their comparative advantage for export of certain other commodities.

A good example of priority-setting is provided by the recent analysis carried out by the researchers in Gambia, which is leading to some significant changes in resource allocation. Groundnut is the most important crop of this small West African country, accounting for nearly 50% of the total cultivated area, 20% to 30% of the gross domestic product, and 70% of the country's export earnings. With all this, groundnut has received relatively little attention from the scientists in Gambia. The research service, following the weighted criteria method, has evolved a new set of priorities that has placed the different commodities at high, medium and low level in terms of resource allocation. Groundnut in the high-priority group has been placed on top of all the other commodities. Groundnut research in Gambia now receives significantly greater attention, with the possibility that it will be further increased, based on the analysis that is now before the newly created National Agricultural Research Board, the highest policy-making body in the country.

Another good example of consolidation and priority-setting is provided by the recent experience of the research system in Madagascar. FOFIFA, the national research organization in Madagascar has reduced the number of its major research programs from 26 in 1983 to 17 in 1989. This has permitted considerable reallocation of resources. Thus, the rice crop, which had a resource allocation of nine person-years in 1983, receives much greater attention now, with 30 scientists working on it. For some of the other programs the resource allocation increased from 2.4 person years in 1983 to 3.8 in 1989. The result of this consolidation is that, in addition to rice, there has been increased concentration of resources to 11 other programs — 3 in agricultural production, 3 in animal production, and 5 in forestry and pisciculture.

The NARS in Kenya, which has been recently reorganized with the resurrection of the Kenya Agricultural Research Institute, has given high priority to selected commodities and natural resources by building nationally coordinated research programs around them. These include maize, roots and tubers, rice, food legumes, oilseeds, horticultural crops, animal production, pasture and fodder improvement, soil/water management, farming systems, and veterinary research. Of these, soil/water management and farming systems find a particularly important place in terms of resource allocation.

Consolidation of research infrastructure and program focus

One of the more important needs of NARS in sub-Saharan Africa today is consolidation of their scientific and other resources so that these limited resources can be focussed on

selected, priority programs of research. The progress made in the last 20 years must be recognized, but the impression that one forms from ISNAR's reviews is that of thin dispersal of resources, with too many programs, projects, and experiment stations. Consolidation of the physical infrastructure for research becomes all the more important in a policy environment where funding support is unlikely to see a major increase in the short term.

The 43 countries of sub-Saharan Africa included in ISNAR's data base have hundreds of experiment stations — some quite large, others with no more than two to three scientists. ISNAR's reviews suggest that quite a few of the countries suffer from a proliferation of experiment stations. The problem is by no means unique to sub-Saharan Africa, but it takes a much heavier toll in this region than in other parts of the world. It adversely affects the productivity of the research system in two ways. First, the research responsibility of the different stations is seldom clearly defined, with the result that the priority programs of research fail to receive a sharp focus because of overlapping mandates. Second, and more important, the limited resources of scientific manpower are dispersed over a large number of locations so that it becomes difficult to establish a critical mass of scientific effort around the priority programs. Many of the younger scientists, inexperienced and untrained in research methodology, find themselves isolated on remote stations, with little hope of guidance from their senior colleagues.

Rationalization of research station network

The factors that should determine the number of experiment stations and their location in a country are well recognized. An important consideration is the size of the country, the diversity of its agricultural sector, and its agroecological differentiation. More important, the number should be determined by the availability of scientific and other resources. In general, there appears to be considerable merit in having two types of stations — a limited number of national research stations working in close collaboration with a network of regional research centers. The national stations, whose mandate transcends regions, do the more advanced work of technology generation, while the regional research centers, placed strategically in the different agro-ecological or production zones, do adaptive and on-farm research in close association with the extension service and the farmers. The advantage of this kind of division of responsibility is that it results in considerable economy, because not all the stations will be working to generate new technologies — many of them will be doing adaptive research, working closely with the extension services and the farmers. Table 10 indicates how the size of the research system could be controlled using this general principle. It is assumed that all the countries have large agricultural populations and that there is a great deal of agro-ecological diversity, especially in the larger countries.

In sub-Saharan Africa, some of the countries with their present resources of scientific manpower may not be able to afford more than a few stations located in the different regions, with a mandate to do technology testing and adaptive research. They must borrow technology from the international agricultural research centers (IARCs) and from the more-advanced national agricultural research systems in the region or outside the region. It is not generally recognized that introducing technology from other countries is a very healthy practice and, indeed, some of the world's more successful research systems, particularly those in the developed countries, make special efforts to introduce new techniques and genetic materials in a highly systematic manner from other parts of the

Table 10: Organization of Research Station Network

Country size	Resource base	Type of station	Type of research
Large	Excellent	National stations Regional stations	Strategic and applied Applied and adaptive
Large	Fair amount of resources	National stations (several) Regional stations	Strategic and applied Adaptive and applied
Medium	Limited resources	National stations (few) Regional station	Applied Adaptive
Small	Limited resources	National stations (one) Regional stations	Applied Adaptive
Small	Very limited resources	Regional stations: some with lead functions	Adaptive and applied
Very small	Limited resources	National station (one) Testing sites	Adaptive and technology testing

Source: Based on Jain (1989).

world and evaluate them for meeting their own needs. Some countries have built a significant part of their agriculture based on introductions made from other parts of the world, combined with purposeful testing and adaptive research. A particularly good example is the successful tea industry of Kenya, which has been developed almost entirely on sensible borrowing, with local research modifying only a few components of the introduced production technology.

Some countries of sub-Saharan Africa are already beginning to address the problem of their overextended experiment station infrastructure. Thus, the Kenya Agricultural Research Institute is now in the process of rationalizing its network in the form of 22 experiment stations, reducing from the earlier number of more than 35. Malawi provides an extreme example of such consolidation. Malawi used to have 11 major research stations, 9 substations, and 220 trial sites under the Department of Agriculture. This network has now been consolidated into 3 main stations, 3 substations, and 9 trial sites.

The emphasis on consolidation at the present juncture should not be taken to imply that sub-Saharan African countries can do with a limited experiment station network on a long-term basis. There may, indeed, be a great need to expand these networks as demand for improved technology grows, and as they are called upon to move beyond adaptive research; this should be done in a phased manner as scientific and other resources become available. It would be counterproductive, however, to have large numbers of experiment stations and research programs, with very limited scientific and other resources.

Program planning

Consolidation of the research station network needs to be accompanied by similar consolidation at the program level. Probably the greatest wastage in research in most developing countries occurs when scientists try to cope with too many programs, projects, and experiments, including those which are more of academic than practical interest. The very first step in this process of consolidation is a clear determination of national research priorities, as discussed above. Once these have been defined there is still the problem of translating them into the most relevant research projects and experiments that would result in improved production technologies. There are three basic considerations here that should be receiving increasing attention from the NARS managers in sub-Saharan Africa.

First, there are the general principles of program formulation. These include consideration of program structure so that there are built-in mechanisms for multidisciplinary team work, for monitoring and evaluation, for making the projects time bound and, above all, for allocation of required resources of scientific manpower and materials. In all this a number of internal committees of scientists and senior research managers play an important role. Their main effort is to make sure that the proposed research work would help to exploit opportunities and overcome the important constraints affecting agricultural production. The constraints, of course, may be in the policy area, but the availability of a good production technology often persuades governments to take the needed policy decisions.

Second, there are mechanisms of coordination which some of the developing countries, especially India, have very successfully employed in generating a great deal of interinstitutional collaboration in the planning and implementation of their research programs (Jain, 1985). They have done this by organizing research on some of their high-priority commodities in the form of a series of nationally coordinated programs. This concept of national research coordination has particular significance for the larger countries of sub-Saharan Africa. Typically, a coordinated research program consists of a national coordination center at one of the experiment stations and a number of cooperating centers located at the other stations in different regions of the country. The coordination center is headed by a project coordinator, who is a senior scientist capable of providing technical leadership for the national program.

Project coordinators have the main responsibility for guiding and monitoring the implementation of the research program. They help to define the responsibilities and research projects of the different cooperating centers. These responsibilities are identified on the basis of discussions at the annual workshop of scientists from the different cooperating stations. The results of research carried out at each of the participating stations is presented by the respective group of scientists and by the coordinator, and this helps to formulate the next year's program. It is in the course of these workshops that strong interdisciplinary and interinstitutional links are forged. The discussions at the workshop also lead to recommendations about the release of new technologies to farmers. The main functions of the project coordinator may be defined as follows:

- help define the objectives and technical content of the nationally coordinated program;
- recommend allocation of resources to the different cooperating stations for the implementation of their part of the program;
- monitor the progress of work at each center;
- organize multilocational trials of improved varieties and other technologies emerging from the program and consolidate the findings from these trials for presentation, review, and recommendations;
- organize annual workshop of all the participating scientists to review the past year's results and plan the next year's work at each of the centers; the workshop should provide an opportunity for interaction with the staff of the extension service for identification of technologies to be recommended to farmers;

- prepare and present annual progress report of the program to the national director;
- liaise with the international agricultural research centers for introduction of new genetic materials and technologies for induction into the national program;
- organize training of young scientists from the different cooperating centers.

On-farm research

The third consideration in program formulation is to keep in view the factors that affect the adoption of results of research by the farmers. And this stresses the importance of establishing close links with the extension service and the farmers through on-farm research. Much of on-farm research, as far as the more favorable lands are concerned, should be concerned not so much with diagnosis as with the verification and testing of new technologies, whose adoption should be facilitated by a new institutional infrastructure of credit, marketing support, and input delivery systems. Research can make little contribution to development in sub-Saharan Africa in the absence of such a framework of support services. In the developed countries this kind of support to farmers is provided by the agribusiness sector. In developing countries, too, the growth of the agribusiness sector should be promoted, to take up this responsibility more fully in the longer term. In the short term, however, the governments must supplement the efforts of the agribusiness sector if the farmers are to be motivated to adopt the new technology. The success of the Asian countries in improving their agriculture in recent years underlines the crucial role of such support services.

While on-farm research has this important role in the process of the transfer of technology and in receiving feedback from farmers about its limitations, farming systems research can provide an important input in formulating research programs, especially for lands characterized by agroecological stresses of various kinds. In the case of sub-Saharan Africa, the vast humid forest zone is subject to intense rainfall, with the result that widespread cultivation not only removes many of the nutrients directly, but also exposes the soil to the effects of rain, heat, and sunlight. This can lead to rapid loss of soil productivity through leaching, acidification, erosion, and structural deterioration. The farmers in these forest zones have managed to maintain the productivity of their land with the adoption of a wide range of strategies, including various shifting cultivation and bush fallows, complex cropping patterns and sequences, mixtures of tree crops and animals, and intensive compound gardening techniques (IITA, 1988). While it is important to increase the productivity of these lands and make it possible for farmers to move away from mainly subsistence farming, the new technology must make sure that their long-term sustainability is not lost in the process. In these complex ecological situations, on-farm experimentation may provide useful insights into planning of on-station research. The alternatives would be to locate the experiment stations in such lands.

Simmonds (1986) has discussed at some length the role of on-farm research with a farming systems perspective (OFR/FPS), as he describes it. The purpose, however, is not to become preoccupied with current practices, farmers' circumstances and resources, and their traditional methods, as these have basically evolved around low-yield, traditional agriculture. The starting point for organizing on-farm research in most developing countries should be the realization of their compelling need to modernize agriculture in order to make it a major instrument of their economic and social advancement. Most developing countries have no

comparative advantage in industry, and in the short term they must concentrate on fully developing their agricultural potential. Agriculture in this role has many clients and not just the farmers. The farmers, however, are the most important group, for nothing will work until they are motivated to adopt the new technology. And they will not be motivated to increase production unless they receive some benefit from it. The scientists should be able to demonstrate such benefits through on-farm research.

The organization of on-farm research presents its own institutional challenge. Recognizing this challenge and in response to requests from research managers in many developing countries, ISNAR has completed a 3-year study to analyze the organization, management, and institutionalization of on-farm research in national agricultural research systems (Merrill-Sands and McAllister, 1988). The objective of this study was to provide a body of practical experience that research managers can draw upon as they strive to make on-farm research an integral part of their NARS. The study involved a series of case studies, including three in sub-Saharan Africa — Senegal, Zambia, and Zimbabwe. These countries were chosen because they have made a major commitment to on-farm research. The experience from this collaborative work, which is now being applied in a number of countries, has shown that the success of on-farm research depends on the effectiveness of four sets of critical linkages. These are linkages of on-farm research with on-station research, with farmers, especially the resource-poor farmers, with technology transfer agencies, such as the extension services and, finally, between researchers working in different disciplines or commodities.

Institution building: A new kind of support

Development of highly relevant research programs, creation and management of motivated teams of scientists, and providing a productive work environment for them comes from an understanding of the research process acquired through years of experience and traditions built over time. Many of the NARS in Asia received powerful support in this process by their close association with the research systems of the developed countries, especially the land-grant institutions in the United States. In contrast, many of the managers of research in sub-Saharan Africa, often young scientists without a great deal of management experience, have received much less support of this kind. Most of the assistance from external sources that has been available to them is built around specific technical assistance projects. While this support has been valuable scientifically and in the creation of the research infrastructure, it has not done much for institutional development and creation of a management capacity for research, for which a different approach and greater continuity are needed.

A change in donor strategy in favor of a major shift of resources for institution building has been suggested, among others, by Uma Lele and Arthur Goldsmith (1989), of the World Bank. They question the desirability of donors focussing on final growth or equity objectives in the short term rather than contributing to the creation of national capacity to achieve these objectives in the long run through the establishment of institutions, trained manpower, procedures, policy analysis, and information capacity. In this context, Lele and Goldsmith point out that in the early 1980s there were around 80,000 external technical assistance personnel residing in 40 countries of sub-Saharan Africa. If they did not make the expected impact, the explanation is to be found partly in the fact that few of them had their major focus on institution building and on management. In sharp contrast to this, the

authors describe the experience of the Rockefeller Foundation in the 1950s and 1960s in helping to develop the national research capacity of India (Lele and Goldsmith 1989).

There are, however, exceptions. One example of this kind of donor support is provided by the strategy the United States Agency for International Development (USAID) and the Ford Foundation followed in the 1970s in helping to build new agricultural universities and faculties of agriculture in many developing countries of Asia, in particular (Read, 1974). A key feature of this strategy was to enlist the support of land-grant institutions in the USA as the primary source of technical assistance. Thus, the different land grant universities acted as contractors of USAID and sent out large teams of their senior managers and scientists to work with their less-experienced counterparts in the developing countries on a long-term basis. A number of faculties of agriculture in sub-Saharan Africa were also identified for a collaboration of this kind with land-grant institutions in the United States and there are important lessons to be learned from this experience.

Perhaps the best example of collaboration with the faculties of agriculture in sub-Saharan Africa is provided by those USAID projects, which during the 1960s and 1970s extended support to three newly established Nigerian universities by linking them in a cooperative framework with three U.S. land-grant colleges: Ahmadu Bello University and Kansas State University, the University of Ife and the University of Wisconsin, and the University of Nigeria at Nsukka and Michigan State University. The longer collaborations, with Kansas State University continued for 16 years, from 1962 to 1978, and with the University of Wisconsin for 15 years, from 1962 to 1975.

A recent evaluation of this collaborative institution-building program by Gamble and colleagues (1988) shows that while all three Nigerian universities saw enormous growth in their educational programs, efforts to transfer the tripartite land-grant model (teaching, research, and extension) to the three Nigerian universities had mixed success. Ahmadu Bello university gained the most in adapting this model, and the reasons for this are now obvious. Ahmadu Bello started with a definite advantage because it had already incorporated in it at the time of its founding an established Nigerian research institute of the Department of Agriculture, with a well-defined mandate to provide technological support for the region's agriculture. The other two universities had no such institutional base on which to graft the new culture.

Gamble and colleagues concluded that research and extension are functions that mean power (power to administer and offer employment), and few ministries are prepared to transfer such powers to autonomous institutions like the universities. The second factor accounting for the mixed success related to the incentive system of the universities for staff, which took little notice of development-oriented research and outreach activities.

The Ghana grain development project involving collaboration between CIMMYT and IITA, on the one hand, and the Crops Research Institute of Ghana, on the other, provides another example of institutional collaboration of a different kind. The project, funded by a major donor, in this case the Canadian International Development Agency, has continued since 1978. Its major objective has been the development of superior maize production technology and the upgrading of the Ghanaian research and production staff of the Crops Research Institute, the Grains and Legumes Development Board, and the Ministry of Agriculture. An important feature of this project which distinguishes it from many others

is the location of a team of high-caliber scientists from CIMMYT and IITA at the Crop Research Institute, so that they would work jointly with their local counterparts. The project, over a period of over 10 years, has made a significant impact, both in improved production technology and development of human resources. Many new varieties of maize have been released, and important recommendations with regard to production technology of maize and maize in intercropping systems have been widely disseminated. A more lasting impact of the project should be seen in the training of a large number of scientists through formal degree programs and, above all, in-country training of participating local scientists.

In the case of the sub-Saharan African countries, the national agricultural research system as a whole (and not just the faculty of agriculture) needs to be supported by twinning arrangements of this kind. The donor organizations should be able to identify suitable institutions in their own countries or outside for this purpose. The senior staff of these institutions would bring with them not only technical expertise in specific fields but also the experience in the organization and management of successful research programs, in the mechanisms of transfer of technology through close links with the extension service and the farmers, and in the promotion of a value system that motivates the scientists to do problem-solving research. The land-grant institutions have been the pioneers in the development of this approach, but most other developed countries also have a network of experiment stations where a research culture of this kind prevails and where senior staff members have the relevant management experience. A particularly good example is that of the agricultural research system of the Netherlands, built around the university and the research institutes at Wageningen.

While twinning arrangements of the kind discussed above have already demonstrated their effectiveness in strengthening the organization and management of research in developing countries, the management needs of the newly created NARS in sub-Saharan Africa would also require organization of training programs especially designed for this purpose. ISNAR's research management training program developed in the last nine years provides support of this kind and so do the training programs organized by SACCAR — the Southern African Center for Cooperation in Agricultural Research. These training workshops assist NARS professionals to develop leadership and management skills that are particularly relevant to the needs of agricultural research. The program has emphasized three types of activities: management courses, workshops, and seminars; development of training materials; and in-house training of NARS managers. Most of the training courses and workshops have been implemented in a developing-country setting in collaboration with the national research systems or regional organizations. The ISNAR training program differs from management training, in general, for its heavy concentration on factors that are considered to be critical in building effective national systems. ISNAR recognizes 12 such critical factors in the broad areas of research policy, organization, and management, as follows:

The policy context of agricultural research

- Interactions between national development policy and agricultural research

- Formulation of agricultural research policy: priority setting, resource allocation, and long-term planning

Structure and organization of agricultural research

- Structure and organization of research systems
- Linkages between NARS and policymakers
- Linkages between NARS, the technology transfer system, and users
- Linkages between NARS and external sources of knowledge

Management of agricultural research

- Program formulation and program budgeting
- Monitoring and evaluation
- Information management
- Development and management of human resources
- Development and management of physical resources
- Acquisition and management of financial resources.

DEVELOPMENT OF SCIENTIFIC MANPOWER

Development of scientific manpower, in terms of research management and technical skills, should become in the next 10 years a particularly important factor contributing to institutional strengthening of NARS in sub-Saharan Africa. Despite the impressive progress made during the last 20 years, many of the national agricultural research systems in the region continue to have in relative terms few trained scientists. As we saw in Table 5, as many as 18 of the NARS in sub-Saharan Africa had, on an average, less than 50 scientists, including the expatriates, in their research services during 1980-1986. The 43 countries, during this period, had a total of 4,888 scientists, including the expatriates, in the government-sponsored national agricultural research services. In addition, there were 2,374 scientists working in the faculties of agriculture of the universities; only a small proportion of them, however, were directly involved in applied and adaptive research in response to the needs of agricultural development.

The problem, however, is not merely one of quantity. Of the scientists working in government-sponsored agricultural research services, a little over one-third had post-graduate qualifications at the PhD or MSc levels. The problem of rapid turnover exacerbated the problem. It has been estimated that NARS in sub-Saharan Africa lose 7% of their qualified staff per year. It becomes difficult under these conditions to build strong teams of researchers on a sustained basis around national research programs of high priority.

The quantitative dimension

The progress which the sub-Saharan African countries have made in creating scientific manpower during the last 20 years is not discouraging when one considers the fact that

there were few national scientists doing agricultural research during the colonial period. The need now is to accelerate this process. The magnitude of the problem has been analyzed in the World Bank-sponsored West Africa agricultural research review during 1985-86. Swanson and Reeves, who carried out part of this review, used the norm of national agricultural domestic product as a measure of the scientific strength of the research service. The World Bank research-sector policy paper of 1981 calculated that the average number of research scientists per million dollars of agricultural domestic production for all the developing countries was 0.16, but this number for the 24 countries of west Africa included in the World Bank study was only 0.06. It is obvious that the West African countries were employing, during this period, less than half the average number of researchers compared to developing countries taken as a whole.

The gap appears to be even greater if one takes into consideration the kind of investments in agricultural research that can be expected to be made in the closing years of the century. Swanson and Reeves, in the course of the World Bank review, estimated that if the West African countries were prepared to invest one percent of their domestic agricultural product in research, they would need to train collectively 14,000 researchers during 1985-2000, taking into consideration the expected losses from attrition. More realistically, the investment level may be expected to increase to 0.67% of agricultural domestic product, and if this were to happen, the 24 countries must train 10,000 scientists. On the basis of a more constrained demand scenario, Swanson and Reeves considered an average investment of 0.33% of agricultural domestic product, which leads to a training requirement of some 5,000 scientists. The current number of research personnel employed by the 24 countries according to the World Bank review was 1,966, of which 495 were expatriates. ISNAR's data base shows that, on an average, only 29% of the national scientists held postgraduate degree qualifications in Western Africa during 1980-86 period.

Swanson and Reeves emphasized, citing the discussions at the World Bank-sponsored Cotonou workshop, which was attended among others by senior scientists from NARS in Africa, that a BSc degree is an insufficient qualification for independent research responsibility; the more modest estimate of 5,000 scientists proposed a minimum of MSc degree, with the suggestion that an increasing number will have PhD degrees. Much the same kind of estimate can be expected to be made in terms of training scientific manpower in other parts of sub-Saharan Africa, as suggested by the World Bank-sponsored Eastern and Southern Africa Agricultural Research Review.

Another criterion that should help to determine the scientific manpower needs of research systems in sub-Saharan Africa is based on the extent of its arable lands. Table 11 gives the number of researchers per million hectares of arable land in different regions of the world. It is obvious that on this criterion the sub-Saharan African countries would need five times as many researchers as they have at present to catch up with other parts of the developing world.

The projection of the scientific manpower needs of NARS in sub-Saharan Africa should serve another important purpose. It should help to impart a sense of realism with regard to building of research institutions in this part of the world, relative to others. Far too often the expectations have been unjustifiably high, and there has been a great deal of talk of comparison with national research systems in Asia/Latin America. If the NARS in Asia have done better, it is no big deal, for many of them started with a tremendous advantage

— with a well-established and mature university system, which could respond readily to the growing manpower needs of the scientific manpower in these countries. To take one example, the Government of India in 1958 asked the Indian Agricultural Research Institute (IARI) to organize a Graduate School, building on its past teaching programs, to produce potential professional staff for the proposed network of State Agricultural Universities. The IARI Graduate School alone, during the last 25 years, has produced more than 3,500 scientists, more than half of them with the PhD degree. There are 27 State Agricultural Universities, many of them with graduate schools of their own.

The development planners and policymakers in sub-Saharan Africa have had few resources of this kind, and the national governments and the donor community have done well in training a large number of scientists. The paramount need at this stage is to recognize that the development of human resources in sub-Saharan Africa will continue to require a long-term commitment on their part.

Personnel policies

Finally, it should be stressed that staffing of agricultural research services in sub-Saharan Africa is not merely a question of training more scientists although this must remain an important objective. Ideally, a whole set of new personnel policies will be needed in the long term to develop a highly motivated cadre of research scientists to provide leadership for sub-Saharan Africa's research programs. One, however, has to be realistic in this regard. Many governments find it difficult to offer new service conditions to scientists as long as they remain an integral part of the country's civil service. Some countries have responded to this stituation by taking the research service out of the purview of the civil service structure so that the scientists could be governed by a different kind of personnel policy. For many others, the problem will continue to exist giving rise to a high turnover of scientists. The solution lies in trainig more scientists specially at the post-graduate level. The rapid turnover in the short term should be accepted for the scientists do make a contribution in other development areas even if they are no longer carrying out research. Improved personnel policies are important but it is not possible to insist that they should be a precondition for the preparation of human resource development plans.

Thus, it will be increasingly necessary for each country to prepare a long-term plan for the development and more efficient utilization of its scientific resources. ISNAR's collaborative work with a number of research systems provides examples of this kind. These plans address not only the projected manpower needs but also the issues of salary structures, in-service training, career paths, manpower information systems and performance planning and evaluation.

Partnership with the faculties of agriculture

The significant progress which many sub-Saharan African countries have made since independence in creating new agricultural research institutions and training a large number of scientists, should receive powerful support from the university system in sub-Saharan Africa as it becomes stronger. With more and more universities adding agriculture to their postgraduate programs, these institutions of higher learning will be making an important contribution to the human resource development plans of the national research systems. They will be producing graduates with MSc and PhD degrees who will be much better informed and exposed to the conditions of African agriculture, based on their own field

Table 11: Number of Researchers per Million Hectares of Agricultural Land — Sub-Saharan Africa and Other Regions

	Expenditures as a % of AgGDP					Number of researchers per million hectares agricultural land				
Region	1960-64	1965-69	1970-74	1975-79	1980-85	1960-64	1965-69	1970-74	1975-79	1980-85
Sub-Saharan Africa	0.25	0.41	0.44	0.55	0.54	1.7	2.4	3.1	4.6	6.7
Asia & Pacific, excluding China	0.12	0.17	0.22	0.27	0.34	15.5	23.3	29.6	47.2	62.1
Latin America & Caribbean	0.24	0.31	0.41	0.53	0.54	3.4	4.3	7.7	9.3	12.0
West Asia & North Africa	0.25	0.31	0.47	0.53	0.43	6.7	9.9	14.0	20.4	27.8
Developed Countries	0.89	1.26	1.42	1.58	2.01	33.5	37.3	40.5	43.4	46.8

Source: Calculations based on data summarized in Pardey and Roseboom (1989a).

research. Nigeria alone has developed 16 universities with large faculties of agriculture or schools of agriculture; indeed, two have been planned as agricultural universities. In addition, faculties of agriculture (or equivalent divisions) exist in 33 other universities across the sub-continent, and two of the smaller countries — Lesotho and Botswana — are currently in the process of developing such faculties. The Sokoine University of Agriculture in Tanzania is more than a faculty — it is potentially an agricultural university based on the concept developed so successfully in recent years in countries like India, and there are proposals to create similar institutions in some of the other African countries.

A paramount need is for the national systems to develop partnership with the faculties of agriculture and mobilize their resources of scientific manpower in support of their research programs. It will be unrealistic to believe that the faculties of agriculture as they are organized at present can be integrated into the national systems in the technology generation process. They will need a great deal of support and investment to acquire a research capacity of this kind. What is needed is a more modest approach in the short term and a more imaginative plan of development in the long term.

The more modest plan would be to seek collaboration with the 2,374 (more now) national scientists with postgraduate qualifications who were working in the faculties of agriculture in sub-Saharan Africa during 1980-86 (see Table 5). Many of them have had little direct involvement in development-oriented agricultural research. Most of them would be interested in taking up such research if they have the resources and if their potential role in this field was more fully recognized. The national agricultural research systems need to create institutional mechanisms that will attract these scientists.

One of these mechanisms can be provided by a system of contract research. The NARS should be able to allocate a small part of its budget for organizing such research with the participation of university scientists. The university scientists should be invited to submit research projects they would like to take up and for which they would like to seek funding support. It is important, however, that the NARS managers first define the priority program areas in which they would like the university scientists to develop their projects. The identified research priorities and programs should be widely circulated for implementing the system of contract research. In the absence of this exercise, the research system could find itself disbursing funds in support of a research agenda which is not its own but is driven by the academic interests of the university scientists.

Another important point of interaction should be created by encouraging graduate students in the faculties of agriculture to do their thesis work at one of the experiment stations of the Ministry of Agriculture. Some of the staff members of these stations should be recognized as supervisors for this purpose.

In a paper on linking agricultural research and higher agricultural education, Contant (1988) has discussed the different ways in which the institutions of higher agricultural education in sub-Saharan Africa can collaborate effectively with the agricultural research institutes sponsored by the ministry of agriculture. They include contributions to technology generation to meet farmers' and sector needs, providing information to guide government policy for agricultural development, making their course content more responsive to the needs of development, and creating and maintaining a pool of highly qualified scientists in active research positions. Conversely, the paper discusses how the government-spon-

sored agricultural research services can help the institutions of higher agricultural education to increase their capacity for a more productive partnership.

In the longer term, reforms and improvements of a far-reaching nature will be necessary if the universities in sub-Saharan Africa are to become a full partner in the process of technology generation for the development of agriculture. This applies to sub-Saharan Africa as well as to most other parts of the developing world. The difference is that the needs are so much greater in the case of sub-Saharan Africa. Again, it should be stressed that what is being proposed is not a blueprint for immediate action. The intention is to initiate a process of thinking, which over a long period of time could give sub-Saharan Africa a new kind of university institution, which would be making a highly significant and effective contribution to the development of agriculture. The policymakers should at least be conscious of these possibilities, even if nothing much can be done in the short term because of limitations of resources and other constraints.

ISNAR's collaborative work with more than 40 countries, including 24 countries of sub-Saharan Africa, in the past 10 years, has helped to understand the factors responsible for weak links between national agricultural research services sponsored by the government departments and the faculties of agriculture. The main conclusion is that full partnership between the two groups of scientists in adaptive and applied research will not be achieved until the serious constraints that limit the work of scientists in the faculties of agriculture are recognized. Some of these constraints are as follows:

- Few faculties of agriculture have an organizational culture and a value system that encourages and rewards active involvement of their staff in technology-generating, applied, and adaptive research. Academic work is considered to be their main responsibility.

- Faculties of agriculture, as part of the university system, have their links with the ministry of education rather than the ministry of agriculture.

- The faculties of agriculture have very little financial and other resources for taking up responsibility in organizing programs of basic, applied, or adaptive research.

- The infrastructure available to the faculties of agriculture provides little or no facilities in the form of experiment stations and laboratories for conducting research in support of agriculture. Most of them have laboratories and some greenhouses, more for teaching than for research.

- The postgraduate teaching programs, including their research component, provide little exposure to problems of agriculture in the field.

All this is in sharp contrast to the concept of land-grant institutions in the United States, which have been organized on the concept of integration of research, teaching, and extension. Unfortunately, the term *land grant* creates confusion in the minds of many policymakers and research managers in the developing countries, with the result that many of its positive features, which could be incorporated in the existing system without major organizational changes, have failed to receive attention. No one has suggested that the developing countries, much less the countries of sub-Saharan Africa, need to enact

legislation like the Morrill and Hatch Acts, which were responsible for the creation of land-grant colleges of agriculture and state experiment stations in the United States during the last century. On the other hand, the basic philosophy of the land-grant institutions and allocation of resources that goes with it in creating the required facilities remains highly relevant and should be incorporated in many of the faculties of agriculture in other parts of the world.

The chief merit of the land-grant concept is that it has a strong public service orientation, as against an elitist attitude commonly found in other universities. Basically, the faculties of agriculture must integrate into them the three functions of teaching, research, and extension if they are to become a part of the country's mainstream of national agricultural research. Countries like Pakistan, Bangladesh, the Philippines and above all, India, have attempted in recent years to borrow this useful concept, and the success they have already achieved should send a positive message to other developing countries.

The United States Agency for International Development, through its African Bureau, prepared in 1985 a tactical plan for university-building in sub-Saharan Africa. The objective of the plan was to overcome the lack of technology generation in the region by improving quality and increasing the number of trained agricultural human resources to resolve food problems by:

- strengthening and reorienting the grade and professional level, higher agricultural education programs in five or six selected African universities;
- providing resources to attract and/or develop the quality of research and teaching facilities to develop both national and regional constituencies through vigorous and stimulating learning environments which have a production and problem-solving orientation;
- developing linkages between higher agricultural education and research and the farmer.

The African Bureau estimated that the cost of developing this type of professional and institutional capacity would be 32 million US Dollars per institution for the first five years, with substantially decreased support for the next 15 years. It is this kind of funding requirement which continues to be a major constraint in the development of the faculties of agriculture in sub-Saharan Africa for the partnership role which they must eventually play in the development of the countries' agriculture.

Finally, it should be stressed that sub-Saharan Africa does provide some outstanding examples of faculties of agriculture that are fully integrated in the mainstream national agricultural research and are making important contributions to the generation of improved technology, but their number is limited. The concept needs to be extended, especially now when postgraduate programs are being introduced into many of the faculties of agriculture.

Perhaps the best example is provided by the Institute for Agricultural Research of the Faculty of Agriculture of the Ahmadu Bello University of Nigeria. This institute, which earlier belonged to the Research and Specialist Services Division of the Ministry of Agriculture of the Northern Region of Nigeria, was transferred to the jurisdiction of the new Ahmadu Bello University as a semiautonomous department of its Faculty of Agricul-

ture. The Ministry of Agriculture was initially very unsure whether the institute would relate closely to the needs of extension and development, and decided for this reason to set up an extension and research liaison service. The service was located at the institute, charged with the responsibility of ensuring efficient linkage between state extension and university research.

These institutional arrangements worked so well that within a few years the institute for agricultural research within the jurisdiction of the university was recognized as the Northern Region's main source for improved agricultural technology. Looking back, it is clear that a large part of the success of the institute has depended on its policy framework. While the vice-chancellor continues to be chairman of its board of governors, a strong input into the research policy of the institutes is provided by the ministries of agriculture of the concerned states, the federal ministry of agriculture, and the federal department of science and technology.

Ahmadu Bello University found itself in a fortunate position to inherit a well-established institute of the ministry of agriculture. Obviously, this is not an example that can be widely followed. What would be needed in most cases would be the creation of an experiment station facility, a new value system, and provision of financial resources for the university scientists to carry out this kind of research. The transformation will obviously have to be an evolutionary process.

The faculties of agriculture in sub-Saharan Africa must be transformed to achieve an integration of this kind. Africa needs to produce agriculture graduates who will have a deep understanding of the problems of its agriculture; this can come about only when the students are exposed to a great deal of field work, especially in the course of their postgraduate research studies. The transformed faculties of agriculture should be making an equally important contribution to the future manpower needs of sub-Saharan Africa in the field of agricultural research.

THE SUSTAINABILITY ISSUE

The NARS in sub-Saharan Africa have come a long way since policy decisions were taken by the newly independent countries to create a research capacity of their own. The investments and the efforts made in the past 20 years have provided a basic framework for the national research services, and today a great deal of potential exists for many of them to become more effective and to provide greater technological support for the development of their country's agriculture. The important requirement now is to build on the foundations already established. A pessimistic view would be that, considering the small number of scientists in many of the sub-Saharan NARS and their dependence on donor support, the answer to the technology needs of some of these countries should be sought in institutions of a different kind.

ISNAR's own analysis of organizational, financial, and human resource issues facing West African agricultural research systems brings out their heavy reliance on external donor assistance (Rocheteau et al. 1988). It further shows that this kind of dependence and the problems like the donor funding cycles, internal bureaucratic demands, political objectives, sometimes neocolonial attitudes, and a sense of territoriality, all give rise to an independent

series of projects contributing to a mosaic rather than a fully integrated national research system. This approach obviously does not contribute much to the sustainability of the research systems or their institutional development.

Carl Eicher (1989), who has studied the sustainability problem of institutions for African agricultural development, points to the creativity of numerous national research services, and proposes that the African governments and donors should progressively strengthen the capacity of NARS to enable them to play the lead role in generating technology in Africa in the future. At the same time Eicher has proposed that, taking into consideration the potential spillover benefits of research and the immediate needs, there is a compelling need for African research managers and donors to adopt a subregional geographical area as the operational unit for developing research strategies. This, in his view, should replace the present manner of preparing feasibility studies for NARS on a country-by-country basis. Eicher fears that by following this strategy the donors will overinvest in NARS, contributing to their inflation and endangering their long-term sustainability.

Need for continued focus on NARS

While the note of caution about overinvestment in NARS may be necessary, it is important to recognize, as the ISNAR analysis points out, that without donor support some of these countries would have conducted little or no research in the years since independence. Also, many people have been educated and much new physical infrastructure has been built, some of it perhaps on an overambitious scale. The need now is to shift these resources from the project-assistance mode to program assistance. This should be increasingly possible if the NARS were to come out with well-defined and realistic research plans. ISNAR's own collaboration, which in earlier years mostly involved reviews of the research systems, is increasingly moving in the direction of research planning with an increasing number of NARS in sub-Saharan Africa. A major objective of this collaboration is, as discussed above, to ensure that the offers of donor support are much better integrated into national research priorities and lead to the creation of greater institutional capacity.

The problem of inadequate scientific manpower and continued dependence on donor support for research in sub-Saharan Africa needs to be viewed with a positive perspective. Carl Eicher's recommendation that much greater emphasis needs to be placed on institution building, like that of Uma Lele and Goldsmith earlier, deserves serious consideration. The sustainability issue is important and should be discussed, but it would be unfortunate if it results in diversion of donor resources from national research systems.

Past experience shows quite clearly that only countries with some research capacity of their own can benefit from collaboration with international and regional research institutions. Basically, the international institutes and regional organizations help to buy time for the national systems to assume greater responsibility. In no other region of the world do the international centers and regional organizations have a greater contribution to make at the present time than in sub-Saharan Africa. In the long term, however, the international centers and regional organizations cannot provide the research support that a country needs on a continued basis, as agriculture encounters new problems and science offers new opportunities. They do not help to build an institutional memory in terms of research capacity that every country needs. For another, the regional and international institutions, by virtue of their organization and mandate, are not equipped to take up adaptive and on-farm research in each of the different countries of the region or to work at the grass-roots level

in close collaboration with the farmers and the extension service. This function obviously belongs to the scientists of the national agricultural research services. The sub-Saharan African countries need this kind of research more than any other at the present time, and a national capacity must be created for this purpose. Finally, only national research services can develop close links with the development policy of their governments.

The recent World Bank review of agricultural research services in 24 countries of West Africa, whose findings were analyzed by ISNAR to formulate the main recommendations, takes a balanced view of the sustainability problem. The review recognizes that many of the small countries of West Africa have limited resources to finance their own national research on a scale needed to meet their total requirements. Environmental variations subdivide these countries into several zones of crop and animal adaptations, which tend to increase the cost of research per unit of land area. The review, however, concluded that each country, however small, needs to have a core group of scientists and supporting infrastructure for adaptive and maintenance research. At the same time, each of these countries must develop mechanisms for drawing as heavily as possible upon international and regional research efforts for back-up support from basic, strategic, and applied research programs. The World Bank review thus places heavy emphasis on linking the small research systems of sub-Saharan Africa with international and regional research centers through networking mechanisms. Mechanisms of this kind in recent years have been promoted by one of the technical working groups of the Special Program on African Agricultural Research (SPAAR). Regional organizations like SACCAR play a key role in forging links of this kind and should be strengthened.

The debate on the relative importance of NARS and regional institutions serves little useful purpose when it is organized on the basis of an either/or proposition. Clearly, that is not the issue and both are needed. The NARS are needed because in their absence international and regional institutions have no way to link with the farmers and extension services in a country. Equally clearly, many of the NARS in sub-Saharan Africa at the present stage of their development have such limited resources of their own for applied research that they must borrow technology from other sources. This kind of complementary relationship is already well established as far as the national and international research systems are concerned. The role of the regional institutions in sub-Saharan Africa needs to be reviewed and strengthened in this context.

Institutional sustainability and scope of research systems

An important issue in relation to sustainability of national agricultural research systems in sub-Saharan Africa is the scope of their work and their phased evolution. The scope question seldom receives the attention it deserves in most developing countries. Many kinds of studies constitute the continuum of research effort, including basic, strategic, applied, adaptive, and testing/verification demonstrations. While a national agricultural research system must consider, as Dagg and Haworth (1988) point out, all of these different kinds of research and their appropriate contributions in the national system, it does not follow that every country should attempt all of them for each or any commodity.

In making judgments about the scope of NARS, one must recognize the basic principle that increased production comes from farmers, and the final essential phase of research must, therefore, be verification or testing of technology for profitability under farmers' conditions. In the developed countries this is mostly done by the agribusiness sector or the

farmers themselves, but in the developing countries the NARS have a major responsibility in this regard. This, as Dagg and Haworth stress, is the irreducible minimum field research which even the smallest of the national research systems must do.

For this purpose, the minimum starting point for public-sector research services is creation of a capacity that would keep them informed of the world knowledge on commodity possibilities and identification of the best opportunities. At the next stage, introductions must be made, and the opportunities the new technologies and materials offer must be tested. If the tests are promising, the research service can proceed to verification on farmers' fields. Only if the introduced technology is not satisfactory is there need for the research service to move to the next stage of modifying components of the technology through the process of adaptive research, using available alternative components. This may mean modifying the fertilizer schedule, the sowing date, the pest control regime, or any of the other agronomic practices. Only if such modifications are not successful is it necessary to move to applied research to generate new components using existing scientific techniques and knowledge. This would obviously call for a much higher level of scientific expertise.

The next stage of strategic or basic research to generate new knowledge and scientific techniques becomes necessary when programs of applied research encounter major obstacles. For example, to control a particular insect pest, scientists might first need to fully understand its biology, devise techniques of mass rearing, and determine its more vulnerable growth and development stages.

Some of the developing countries of sub-Saharan Africa with very limited scientific resources must obviously develop an adaptive research capacity, including testing and verification of introduced technology. Many others, like Kenya and Zimbabwe, already have the resources and are successfully organizing major programs of applied research. What can be sustained in one country cannot be sustained in others, but all of them must organize the minimum component and build on it to generate greater capacity as their resources improve.

An important question is what sort of research capacity the NARS in sub-Saharan Africa should be developing in the longer term — in the next 10 to 15 years. Should they be staying with adaptive research, as some of them are doing at present, or should they have more ambitious programs to do applied and strategic research in the years to come? It is clear that while adaptive research could help to meet some of their more urgent and pressing technology needs, most sub-Saharan countries, in the longer term, would need the capacity for more advanced work, including applied and strategic research for a fuller exploitation of their agricultural potential. Adaptive research basically helps to manipulate the package of agronomic practices, so that the borrowed genetic materials can be adapted to local conditions. It obviously has its limitations, and increasingly NARS scientists in the years to come will be generating their own breeding material and making selections of improved varieties from these and from the introduced material. Similarly, livestock production would derive greater support from applied and strategic research.

For a modest program of adaptive and applied research, Guy Vallaeys and colleagues (1987) have proposed that the minimum size of the national agricultural research effort is built around 100 research workers and that this number is compatible with the economies

of most sub-Saharan African countries. This is the kind of target many of the smaller countries of sub-Saharan Africa should be striving for in the next 10 to 15 years.

In the ultimate analysis, the sustainability of NARS in sub-Saharan Africa will be determined largely by improvement in their policy, organization, and management, resulting in better technological support for the development of the country's agriculture. There is little evidence to suggest that the political commitment to research by the new governments in the 1960s and 1970s has declined. A good example of this continued commitment is provided by the recent experience of Cameroon. Agricultural research in Cameroon is conducted mainly by the Institute of Agricultural Research (IRA) and the Institute of Animal Research (IRZ), both attached to the Ministry of Higher Education, Computer Services and Scientific Research. Both institutes saw considerable growth in their size in the 1970s and early 1980s, with growing support from the national budget and from the donor community.

Cameroon, however, has encountered serious economic problems in the last five years in the wake of a sharp drop in oil prices and in its traditional export commodities, like cocoa, coffee, rubber, palm oil, and cotton. With a sharply increased debt burden since the 1980s, the government of Cameroon had to resort to some drastic measures to reduce expenditure, and 75 of the public-sector enterprises were ordered to be reviewed by external consultants for possible closure or major restructuring.

The government has made an exception in the case of IRA and IRZ, however, and a different review procedure has been followed. ISNAR, which started its collaboration with the research system in Cameroon in 1983-1984, was asked to assist the senior staff of the two institutes to prepare their own action plans for restructuring and rehabilitating their experiment stations and to review the orientation of their research programs. This exercise, which has now been completed, has led to preparation by the institutes of performance contracts, which while limiting further growth, should make them more effective. The contracts have been approved by the government.

It is true that the development of national agricultural research systems in sub-Saharan Africa, especially in the francophone countries, continues to receive strong donor support. This support, however, must be seen in the context of the fact that the establishment of national agricultural research systems in sub-Saharan Africa had to start from a very limited resource base. There were few national African scientists during the colonial period, and the regional and other institutions that did exist paid much greater attention to the needs of the export commodities than the food crops.

The situation, following independence, called for major investments in creating a new research infrastructure in the form of laboratory and field facilities and in the training of hundreds of scientists. Significant progress has been made in this direction with a great deal of support coming from the donor community. Now, perhaps, is the time to recognize the need for a better balance between national and donor investments in support of agricultural research.

With the construction phase mostly over in some countries, and having made significant progress in others, the national governments will be called upon to take greater responsibility for the operations of the newly created research services. The sustainability of the

research systems will require that the national governments in the coming years make an increasing commitment to providing staff salaries and also much of the recurrent costs. Donor support, however, will continue to be needed for the upgrading of the research station infrastructure, including field and laboratory facilities and for the development of human resources.

The question is whether the sub-Saharan African countries, with all of their present economic problems, can afford to make these investments in agricultural research. The World Bank Sector Policy Paper of 1981 on agricultural research, to which reference has been made earlier, suggests that they cannot afford not to make a commitment of this kind. The paper argues that benefit-cost analysis indicates that the optimal level of expenditure on research should be as much as 2% of the value of agricultural production in large agriculture-oriented countries. A target of this magnitude, the paper argues, seems particularly appropriate for small countries with poorly developed research infrastructure and relatively large agricultural sectors. Many of the sub-Saharan African countries, as we saw earlier, currently invest less than 0.5% of their AgGDP in agricultural research. While it will take them many years to reach the proposed higher levels of investment, they should at least try to maintain the investment levels which have already been reached, with an increasing part of the funds coming from their own resources.

The first reason why the African governments may not be inclined to invest more in agricultural research is probably to be found in their perception that they have not had the kinds of returns which the World Bank paper promises. These returns need to be studied and documented, and it may turn out that they are much greater than many of us have thought. Countries like Kenya and Zimbabwe, and more recently even some of the Sahel countries, have accumulated surpluses of food grains, and apart from good rains, improved technology had something to do with it. Second, as we saw earlier, research systems in sub-Saharan Africa had to be reorganized following independence, and one should expect a lag period before they become more effective. Therefore, the need is to improve their policy, organization, and management, and this is beginning to take place.

ISNAR'S INTERACTION AND THE CONTINUING PROCESS OF INSTITUTIONAL DEVELOPMENT

We see in Appendix 2 the organization and structure of some of the newly created institutions and the research station network they manage in the different regions of sub-Saharan Africa. Many of these research systems continue to be in a state of evolution, adding to their institutional capacity. The reforms that have been taking place cover a wide range of issues, including research policy, organization and structure, and management of the system. Some of the NARS have been giving serious thought to the creation of institutional mechanisms to link more effectively with the policymakers and the development departments of the government, and with the extension services and the farmers. Another structural issue receiving a great deal of attention has been the rationalization and consolidation of the research station network. Better definition of research priorities and resource allocation, and following this, the translation of these priorities into sound research programs, has been important for many systems. Another management theme that has received considerable attention is the monitoring and evaluation of research programs and their coordination at the national level. Human resource development through improved planning and new personnel policies has been a major concern of a number of NARS.

Some of the NARS in more recent years have been giving thought to the preparation of strategic research plans, which should help to guide the development of the system in the next 10 to 15 years. A major objective in preparing these plans is to improve the capacity of NARS managers to negotiate more purposefully with their own governments and with the donor community, with a view to increasing the effectiveness of future investments in research. Many of the NARS managers have been anxious to develop a long-term perspective for the growth of the system, replacing the project-dominated approach of the past. Some of this work is leading to coordination of donor activities in support of the research systems. ISNAR's collaboration with NARS in sub-Saharan Africa covers these and other system-building activities.

SUMMARY

1. Agricultural production in sub-Saharan Africa saw a decline in the 1970s and early 1980s, resulting in growing food deficits and a serious concern among the national leaders and the international community, reminiscent of the situation in South and Southeast Asia in the 1960s. A question that has been widely debated in this context is whether agricultural research can make the same kind of contribution to overcoming the food problem in the sub-Saharan African countries as it has made during the past 20 years in many of the Asian countries.

2. While recognizing that the African situation is different, and in some ways more difficult, this paper argues that improved production technologies have a key contribution to make in sub-Saharan Africa, and that agricultural research must have a central place in the development policies of the governments and the donor community. There are no alternatives to generation of new technologies or to the creation of an institutional infrastructure of support services, which would enable the farmers to adopt these technologies.

3. A critical analysis of the production potential of the vast lands of sub-Saharan Africa shows that there are significant regional differences and that some countries are characterized by difficult agro-ecological conditions, but the sub-continent as a whole offers many opportunities for increasing agricultural production.

4. A detailed analysis carried out by FAO shows that while the green revolution technology of Asia may not hold a similar potential for sub-Saharan Africa and can not be transferred to it, there is sufficient water to irrigate, in the long-term, more than 20 million hectares of land in Africa as a whole if resources can be found. There are another 20 million hectares of land that already receive ample rainfall.

5. In the short term, agricultural scientists in sub-Saharan Africa would be called upon to help exploit the production potential of these more favorable lands, recognizing at the same time that the need for the development of a different kind of technology for the more difficult lands through improved soil and water management is far more urgent in this region than in other parts of the developing world. This is dictated both by the equity and sustainability considerations and the fact that the development of appropriate technologies for the vast dry lands alone can help to unfold the full production potential of sub-Saharan Africa.

6. Many of the sub-Saharan African countries have taken important policy decisions in the past 20 years, like the Asian and Latin American countries earlier, to strengthen their agricultural research services, but they started with a great disadvantage. Unlike Asia and Latin America, agricultural research in the countries of sub-Saharan Africa during the colonial period was carried out mostly by expatriate scientists. An important organizational form was the Regional Export Crop Research Institute with less attention being paid to food and other crops. The sub-Saharan African countries have responded to this challenge by creating and organizing a new research infrastructure and by training a large number of their scientists.

7. The substantial progress made by the sub-Saharan African countries during the past 15 years can be clearly seen from the investments they have made (often with donor support) in agricultural research. Thus, ISNAR's data base shows that sub-Saharan Africa, which had a world share of only 2.3% of research personnel in agriculture during 1969-64, had more than doubled this share in 1980-85, with 4.9% out of a total of 99,671 researchers in the global agricultural research system during this period. In absolute terms, the 43 sub-Saharan African countries had a total of 1,159 researchers during 1960-64; this number rose to 4,870 during 1980-85, registering a fourfold increase.

8. In terms of investments, sub-Saharan Africa's agricultural research expenditure in global terms increased from 4.5% to 5.3% during the 20-year period. This share of world investment in agricultural research was achieved by a threefold rise in agricultural research expenditure in constant dollar terms. When seen as a percentage of the agricultural gross domestic product (AgGDP), ISNAR's data base shows that the investment in agricultural research in sub-Saharan Africa (0.54%) compares well with that of Asia, Latin America, and West Asia and North Africa. These investments, however, continue to be far short of the value of nearly 2% for the developed countries, and they are quite small in absolute terms because of the small size of the AgGDP in many of the sub-Saharan countries. Also, many of the countries continue to depend heavily on donor support.

9. Following a fourfold increase in the number of scientists and only a threefold increase in the amount of research budgets, there has been a decline in the recurrent costs (total research budget divided by the number of scientists). Even so, the average amount of US$ 78,430 in 1980 dollars is close to the amount for the developed countries and much greater than the corresponding amount for Asia. The real problem is one of imbalance between the different components of the recurrent cost. ISNAR's reviews of NARS in the sub-Saharan African countries show that the personnel costs, which include a large component of support staff, have tended to rise, while there has been a decline in the operating funds for research-related expenditure.

10. Even as we recognize the significant progress many countries of sub-Saharan Africa have made in the last 20 years in creating new institutional and scientific resources for agricultural research, major gaps remain and a great deal remains to be done.

11. One of the more important of these gaps relates to the limited scientific manpower of NARS in many of the sub-Saharan African countries. ISNAR's data base shows that, including the expatriate scientists who during 1980-86 constituted 29% of the

total researchers, as many as 18 countries had, on an average, less than 50 researchers in their research service during this period. Besides, a large proportion of scientists did not have postgraduate qualifications, so that they lacked basic training for carrying out research work.

12. An important need at this stage is to make a long-term commmitment for the development of human resources. In addition to trained scientific manpower, a whole set of new personnel policies would be needed if a highly motivated community of scientists is to provide leadership and continuity to sub-Saharan African agricultural research programs. It will be unrealistic, however, to insist that these policies should be a precondition for the training of more scientists. Just as improved technologies can be a catalyst for the formulation of new pricing and other support policies for the farmers, they could also induce the governments to offer better service conditions to their scientists. The present policy of some of the countries to induct into their research services all the new graduates from the university faculties of agriculture does little to provide the kind of scientific manpower needed for research. It also creates a serious imbalance between the personnel and the operating costs.

13. The long-term solution to the scientific manpower needs of the agricultural research systems in sub-Saharan Africa will be found in their faculties of agriculture. These institutions, with their reservoir of highly qualified scientists, need to be strengthened to produce students with a more relevant training and to make a greater contribution, direct and indirect, to the process of technology generation. They need to be linked with the research services of the ministry of agriculture. The university scientists and the students of the faculties of agriculture, with few exceptions, remain largely isolated from the mainstream of development-oriented research.

14. Another paramount need is more effective use of the resources already created through a better definition of the research policy and through improvement in the organization and management of the research systems. This will call for reforms in several different areas, some of which have been discussed in this paper.

15. The major objective of the research policy and the value system for the scientists should be to make research a handmaiden of development. Pursuing this policy the NARS in sub-Saharan Africa, like their counterparts in other parts of the developing world, should increasingly develop a contractor-client orientation — the clients being the farmers, the extension services, and the development departments of the government. This policy does not suggest that the sub-Saharan African countries should not be developing a capacity for basic research. Advancement of science for most developing countries remains, however, a longer-term objective, and the universities, rather than the government-sponsored research services should have major involvement in this type of research.

16. Consistent with this role in development, the NARS are best located in the ministry of agriculture, giving them at the same time considerable functional autonomy. In many sub-Saharan African countries, the agricultural research services form a part of the structure of the ministry of science. If a major reorganization is not possible for political reasons, it is important that the policy for agricultural research in these countries be determined by statutory bodies with strong representation from the

ministry of agriculture and other economic development and planning departments of the government, and from organizations representing the farmers.

17. Equally important is the need for the consolidation of the research station infrastructure and the research work, which would help to focus them on selected priority programs. The impression that one forms today is one of thin dispersal of limited resources on too many experiment stations, programs, and projects. The rationalization of the country's research station network with a clear definition of national and regional mandates would be an important component of the new policy. Consolidation would also be needed at the program level, with some of the work of the national and regional stations on the more important commodities organized in the form of nationally coordinated projects. The consolidation should also help to answer the criticism that is sometimes made that the donors in some cases have contributed to the creation of an unduly large and overextended physical infrastructure. The problem is not one of overinvestment but one of more efficient use of resources.

18. Closely related to the new policy which should help to link research with development is the organization of on-farm research for the demonstration and verification of new technologies and for receiving feedback from the farmers. On-farm research offers its greatest opportunity in the area of transfer of technology and is best organized in association with strong programs of on-station research. At the same time, the governments should recognize that research can make little contribution in most developing countries, unless the adoption of new technologies is facilitated by the creation of a new institutional infrastructure of marketing, credit and input delivery systems for the farmers.

19. The donor funds during the past 20 years have been used mainly for the creation of the new research infrastructure and for specific research projects. This support should be increasingly directed from now on toward improving the institutional capacity of NARS. The NARS in sub-Saharan Africa should benefit enormously from the kind of help that was provided to the research systems in the Asian countries in the 1970s through their close association with research institutions of the developed countries.

20. With all the progress they have made, the long-term sustainability of some of the NARS in sub-Saharan Africa remains a matter of concern, considering their inadequate scientific manpower and continued heavy dependence on donor support. A more rational division of responsibility should emerge in the coming years, with the national governments taking increasing responsibility for the salary costs and research-related expenditure, and the donors providing support for the rehabilitation of the experiment stations, including field and laboratory equipment, and above all, for the development of human resources.

21. The real issue is not whether all countries of sub-Saharan Africa can sustain a NARS of their own. Few countries can afford not to have one, for past experience shows quite clearly that it is only countries having a research capacity of their own which benefit most from collaboration with regional and international institutions. Also, NARS alone are equipped to take up adaptive and on-farm research and work at the grass roots level with the farmers and the extension services. While the regional and international institutions can and must make an important contribution in the short

term, their role must be seen as complementary to that of the national systems. The real issue is one of the scope of NARS. The smaller countries, with their limited scientific and other resources, must start with testing/verification of introduced technologies and adaptive research, moving at a subsequent stage to the creation of capacity for applied research. The larger countries, in the longer term, will be called upon to do a great deal of strategic research, in addition to their current programs of applied and adaptive research.

22. NARS in sub-Saharan Africa continue to be in a state of rapid evolution. ISNAR's collaborative work with more than 20 national agricultural research systems shows that the reforms now taking place cover a wide range of organizational and management issues including those discussed in this paper. Some of the NARS have been preparing strategic research plans which should help to guide their growth in the next five to 10 years. A major objective of these plans is more purposeful negotiations with their own governments and with the donor community, with a view to increasing the returns from future investments.

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Appendix 1
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R48e. Review of Lesotho's Agricultural Research System, 1989.

Appendix 2
Evolving organization and structure of NARS in some of the sub-Saharan African countries

COUNTRY	ORGANIZATION AND STRUCTURE	RESEARCH STATION NETWORK
Burkina Faso	Agricultural research has been organized under the National Committee for Scientific and Technological Research (CNRST) within the Ministry of Higher Education and Scientific Research. The two major national agricultural research institutes under CNRST are: INERA: Institut National d'Etudes et de Recherches Agricoles (all agronomic and livestock research). IRBET: Institut de Recherche Biologique et d'Ecologie Tropicale (for forestry + agroforestry research). INERA and IRBET have evolved out of the activities of the former French (CIRAD) research institutes. Other research activities are with the University of Ouagadougou and with the research units of various regional development projects.	In addition to three stations — **Kar bolnre** and **Saria** for the North Sudanian/Central Zone (Mossi Plateau) and **Farako-Ba** for high-rainfall–high-potential South and southwest zones, *three* more regional stations are being developed: **Kouaré** (Eastern region), **Katchari** (Sahelian region), and **Di** (Western region-irrigated agriculture).
Cameroon	Most agricultural research has been organized under the Ministry of Higher Education and Scientific Research (MESRES) in two institutes, IRA for crops and forestry, IRZ for livestock and fisheries. Agricultural and related research also takes place at the Dschang University Centre (CUDS) and the University of Yaoundé, both under MESRES. CUDS is potentially the main collaborator of IRA and IRZ in Cameroon.	In the **Far North** and **Northeast**, IRA and IRZ have one station each, with a second being developed; IRA has seven substations. On the Adamaoua Plateau, IRA has one substation, whereas IRZ has a major station. In the **Northwest/West**, IRA and IRZ have adjoining stations at Bambui. Both institutes have two other stations in that zone, each with several substations and trial sites. In the **Southwest/Littoral** zone, IRA has five stations of widely varying size; IRZ has a marine fisheries research station at Limbé but is planning a livestock station at Kumba, independent from nearby IRA facilities. In the **Central/Southern** zone, both institutes have their headquarters as well as research facilities at or near Nkolbisson, and IRA also has one other station and an antenna. In the **Eastern** zone, neither institute has a station, but both are planning to upgrade their (separate) substations at Bertoua to stations, and IRA has two other substations in the zone.
The Gambia	Agricultural research has been organized into two ministries: Agriculture, and Water Resources and Environment. The research units are divisions or sections within line departments that are concerned mainly with development. Research activity is spread over three departments in MOA: Dept. of Agriculture (Research Division), Dept. of Animal Health and Production; Dept. of Crop Protection Services; three departments in MWRE: Dept. of Water Resources, Dept. of Fisheries, Dept. of Forestry; and in one joint unit, the Project Planning and Monitoring Unit. Coordination of research is provided by the newly created Agricultural Research Advisory Board, when heads of departments meet to consider the research program of the Research Services Division of the Department of Agriculture, which has almost half of the manpower assigned to research in the country.	There are two main stations for crops research, one at Yundum near the coast, and one at Sapu, some 200 km inland. The Department of Animal Health and Production had its headquarters at Abuko, near Yundum. There are two substations for rice research, and a significant amount of off-station research.

COUNTRY	ORGANIZATION AND STRUCTURE	RESEARCH STATION NETWORK
Kenya	Following major policy decisions in the 1970s the Kenya Agricultural Research Institute (KARI) was created as a semiautonomous organization which controlled the research station Muguga and facilities inherited from the East African Agricultural and Forestry Research Organization (EAAFRO) and EAVRO (veterinary). In addition, the government organized a large Scientific Research Division (SRD) in the Ministry of Agriculture, which managed most of the national and regional research stations. Some veterinary research and diagnostic services had formed part of the Ministry of Livestock and Development. Coffee and tea research have been organized in two semiautonomous research foundations funded principally by cesses from these commodities. Faculties of Agriculture and Veterinary Medicine, University of Nairobi, undertook some research in agriculture and veterinary science, and a separate national trypanosomiasis research institute was being initiated. In mid 1980s KARI was reorganized to become the main research organization, embodying in it the SRD and livestock research.	Consisted of 40 national and regional research stations and substations, including those for coffee and tea. Following recent nationalization, the network now consists of 22 national and regional research stations.
Madagascar	National Agricultural Research Institute (FOFIFA) has been created as the main research organization, under the Ministry of Scientific and Technological Research for Development.	Consisted in the early 1980s of four regional centers and 18 experiment stations and substations.
Rwanda	The Rwandan Institute of Agricultural Science (ISAR) has been organized as the main parastatal research organization for crops, livestock, and forestry research under the Ministry of Agriculture, governed by a board chaired by the Secretary General of the Ministry of Higher Education and Scientific Research. ISAR has four scientific departments (crops, livestock, forestry, and environment/farming systems), but the research programs, each with a coordinator, play a central role. A substantial amount of research is also carried out in the Faculty of Agriculture of the National University of Rwanda, and in a number of donor-aided development projects. ISAR maintains relations with some of these.	One main station (Rubona/Songa), four regional stations (three are in the north), and one station for forestry research. There are three important gaps in geographic coverage (southeast, Zaire-Nile Divide, and Cyangugu in the southwestern corner); tentative plans exist to fill the first two of these.
Zimbabwe	(1984) — NARS has been organized mainly in the form of institutes and stations of the Department of Research and Specialist Services (DR & SS) of the Ministry of Agriculture and Lands and Rural Resettlement. In addition, some national agricultural research is undertaken by semi-autonomous institutions such as the Pig Research Board, Tobacco Research Board, Agricultural Research Trust, the University of Zimbabwe, the Institute of Agricultural Engineering and the Department of Veterinary Services of the Agricultural and Technical Services Department (AGRITEX) of the Ministry of Agriculture, Lands and Rural Resettlement. DR & SS is organized into three divisions: Crops Research, Livestock and Pastures, and Research Services.	Organized in the form of six research institutes, nine research stations and experiment stations, and six service units.

COUNTRY	ORGANIZATION AND STRUCTURE	RESEARCH STATION NETWORK
Zaire	NARS has been organized in the form of: INERA (the national institution), under the umbrella of the Ministry of Higher Education and Scientific Research; "national programs" (food crops), under the umbrella of the Ministry of Agriculture; university research (animal production and veterinary sciences, soil sciences, etc.) and research units in development projects.	Zaire inherited 39 stations at the time of independence in 1960 and maintained 22 of these until recently. The reorganization that followed has consolidated the network into 10 experiment stations.