Impact Assessment

of the

SAFGRAD Commodity Networks

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The SAFGRAD Impact Study

Introduction

In response to the agricultural crisis experienced in the 1970s, and in recognition of the urgent need for a concerted regional research effort, African heads of states created the Semi-Arid Food Grain And Development (SAFGRAD) Project in 1977. It became operational two years later as an OAU/STRC-JP-31 project mainly with USAID support to reinforce and coordinate agricultural research and develop suitable farming systems for the increased productivity of major staple food crops: sorghum, maize, millet, cowpea, and groundnuts.

The first phase of SAFGRAD resulted in the generation of technologies targeted to improve the productivity of the above-mentioned food crops. A follow-up phase, SAFGRAD II, linked regional research efforts such as those of IARCs (IITA, CIMMYT, ICRISAT, ILCA, CIRAD, ICRAF) to the national systems. The development of foodgrain research networks, therefore, became central to SAFGRAD II activities.

The final evaluation of SAFGRAD Phase II in July 1991 identified a number of indicators of project achievements. However, there were insufficient data available then to quantitatively evaluate the impact of the research networks. This final evaluation then recommended that USAID fund this impact study. This effort was begun in 1992 and the results are reported here.

Objectives

The purpose of this impact study has been (1) to determine the impact of agricultural research in improving farmer and consumer incomes resulting from the use of technology, (2) to evaluate the on-station and on-farm performances of selected NARS in the SAFGRAD network, and (3) to document the institutional evolution and the constraints to future development of selected NARS in the SAFGRAD network.

Strategy and Methodology of the Impact Assessment

The study involved the cooperative efforts of national scientists and institutions; the network entities, particularly the Steering Committees of the respective networks and the Oversight Committee; and the International Agricultural Research Centers, particularly IITA (through the Maize and Cowpea Network Coordinators) and ICRISAT (through the Coordinator of Sorghum network in West and Central Africa and Sorghum and Millet Network in Eastern Africa).

First, the format for the collection of technical data was developed in full consultation with more than 40 NARS scientists and the network coordinators. The initial effort of the SAFGRAD Coordination Office in sensitizing the networks' entities and national institutions facilitated cooperation in different countries.

With the arrival of the economist (third member of the assessment team) in July, an action plan for the collection and analysis of data was developed. This plan consisted of work programs elaborating main activities, outputs, responsible entities, and target dates for completing activities of the assessment study.

Initially, the Steering Committee of each network identified four countries for an in-depth study. Recognizing the shortage of funds and time constraints for the study, the Assessment Team used four basic sets of criteria with which it rated and ranked the 16 countries. This exercise led to selection of eight countries for the in-depth study.

The travel plan and program of specific activities specifying the countries to be visited and the the network programs were also developed. In consultation with network coordinators, the formats for the collection of technical data were dispatched in advance to the eight countries. Economic tables for formats intended to measure the impact of research results were administered in two ways:

1. The IARC economists (for example, those of the ICRISAT Sahelian Center in Niger and the West African Sorghum Improvement Program in Mali) assisted in gathering the data for Niger and Mali, respectively.

2. In the countries where IARCs economists were not available, national economists were contracted (as in Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, and Nigeria) to assist in gathering the economic data.

Data for the impact assessment were collected for the period 1982-92.

ACKNOWLEDGEMENTS

This report presents findings of the impact assessment of Semi-Arid Food Grain Research and Development (SAFGRAD) Networks that was carried out from May 1992 to April 1993. It involved several institutions, scientists, research policymakers, managers, and development ministries. Their cooperation in making available agricultural research and production data in eight case-study National Agricultural Research Systems (NARS) has been instrumental for the completion of the study.

Due to limitation of funds and time, representatives for only eight of the 26 SAFGRAD-member countries were selected for the in-depth research and impact-assessment study. These countries are: Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Mali, Niger, and Nigeria.

This impact-assessment study on SAFGRAD Networks would not have been possible without the financial support of the United States Agency for International Development (USAID) and guidance provided by its Africa Bureau, specifically the Office of Sahel West African Affairs (SWA); the office of Analysis, Research and Technical Support/Division of Food, Agriculture, and Resources Analysis (ARTS/FARA); and the USAID/Burkina Faso Mission.

The economic impact analysis was made by John H. Sanders, agricultural economist of the Department of Agricultural Economics, Purdue University.

The report of experiment-station and on-farm technology development was prepared by Alan Schroeder, a member of the assessment team and research analyst in USAID/AFR/ARTS/FARA.

The institutional analysis report was prepared by Taye Bezuneh, leader of the assessment team and Director of Research for the Organization of African Unity (OAU). His report deals with the evolution of human resources, infrastructure development, and funding of research.

The section on Conclusions and Policy Implications was written by Bezuneh and Sanders.

The collection of the macroeconomic data for the case study of NARS from 1982-91 has been a formidable task; it was monitored by Dr. Juan F. Scott, serving as consultant. In preparation for the study, he gathered data from the various countries and directed the team in the first phase of impact evaluation. The assessment team is also grateful to ICRISAT economists Drs. J. Baidu-Forson and S.K. Debrah at the ICRISAT Sahelian Center, Niger, and the West African Sorghum Improvement Program, Mali, respectively, and to a number of NARS agricultural economists and agronomists for the collection of macro-economic and production data, especially Drs. K. A. Marfo, Ghana; J. Olukosi and A.O. Ogungbile, Nigeria; Kimsey Savadogo, Burkina Faso; Mme. Loise N. Wambuguh, Kenya; and Mr. Tadesse Mulatu and Mr. Alelign Kefyale, Ethiopia.

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Very special thanks go to NARS directors in the case-study countries for their invaluable administrative and logistic support and keen interest in the impact-assessment study.

The impact-assessment team acknowledges the critical roles of the network coordinators — Drs. N. Muleba, M.D. Thomas, B. Badu-Apraku, and S.Z. Mukuru — for their full participation in the development of the technical format and for facilitating the collection of technical data by several NARS researchers. *The Synthesis Primary Technical Data* report covering the periods 1982-91 and the SAFGRAD Phase II final report of the OAU/STRC-SAFGRAD were essential sources of information.

For critical comments on the earlier draft of this report, we are grateful to Drs. B. Badu-Apraku, Alpha Oumar Diallo, CIMMYT Maize Breeder, IITA, Bouake, Côte d'Ivoire; Jojo Baidu-Forson, Economist, Sahelian Center, ICRISAT, Niamey, Niger; Elon Gilbert, Private Consultant, San Marino, California, U.S.A., F.M. Quin, Director, Crop Improvement Division, ICRISAT, Ibadan, Nigeria.

Following are the institutions and contact persons associated with this study and brief notation of their responsibilities:

Joint Network Steering Committee:

Met in November 1991 to discuss the concept, purpose, and plans for the SAFGRAD Impact Assessment Study. The Maize, Cowpea and Sorghum networks in West and Central Africa and the Eastern Africa Sorghum and Millet network met separately during May and June 1992 to review technical formats for data collection. About 50 NARS researchers participated.

Oversight Committee:

During its seventh meeting, it discussed the impact-assessment issue and suggested that the expected output of SAFGRAD Phase II should be the basis for the impact project.

OAU/STR - SAFGRAD Coordination Office:

Provided logistic support and facilitated the impact study.
Joseph M. Menyonga, International Coordinator
Taye Bezuneh, Director of Research
Evenunye A. Adanlete, Chief Accountant and Financial Officer
Yvonne Konsega, Secretary to Director of Research

SAFGRAD Network Coordinators:

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Nyanguila Muleba, West and Central Africa Cowpea Research Network (RENACO)
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NARS Researchers in the Eight Case-Study Countries:

Special thanks are also accorded to the various national research coordinators and scientists for their full participation in the collection of both technical and economic data.

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Ethiopian Science and Technology Commission
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M. Doumbia, Director, Sotuba Agricultural Experiment Station, and various researchers who participated in discussions and data collection

M.S. Sompo-Ceessay, Director General, Institute of Sahel, Bamako

Wayne McDonald, Acting Agricultural Development Officer, USAID/Mali during the Assessment Team's visit

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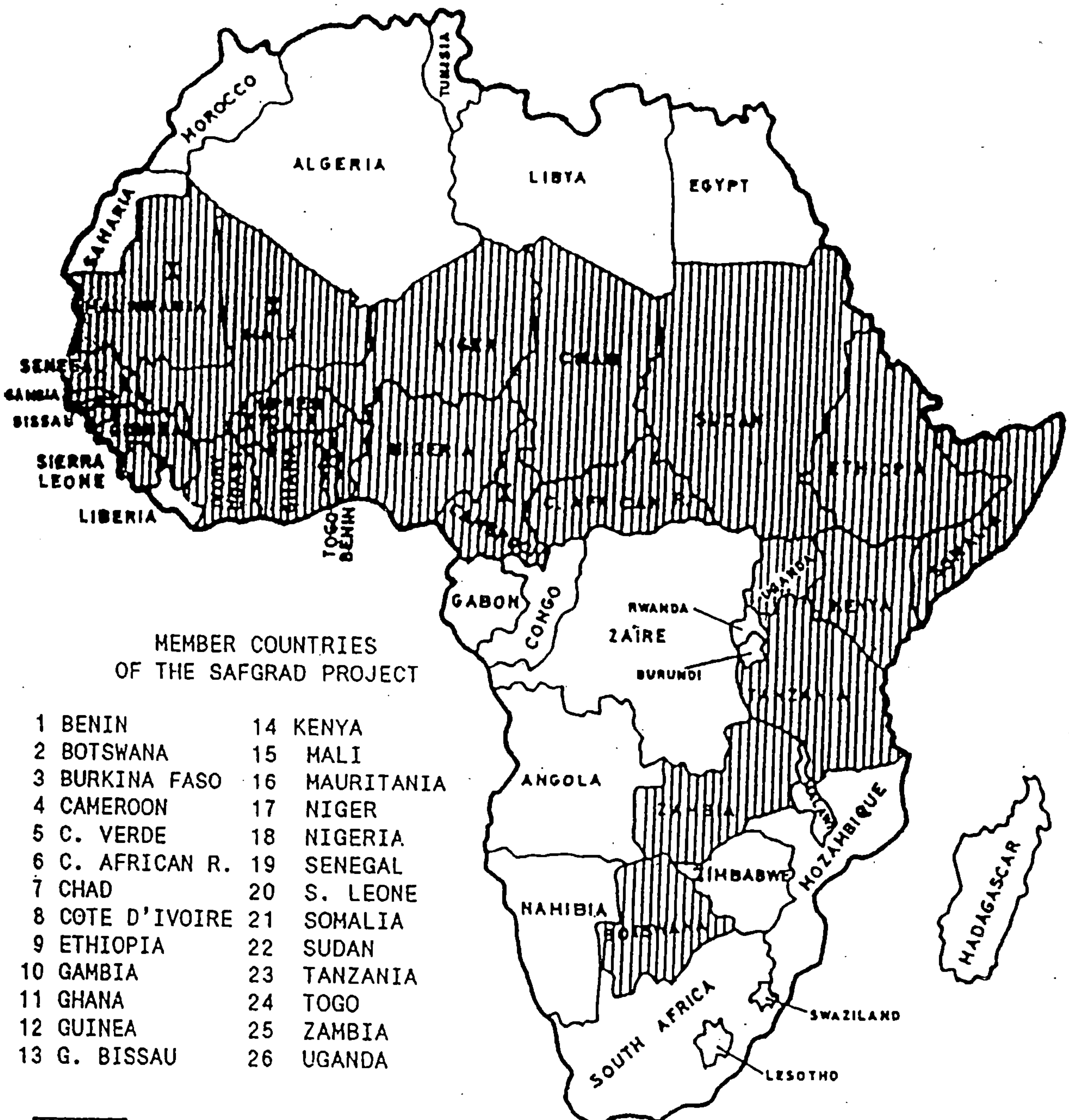
ACRONYMS

ACPO	Accelerated Crop Production Officer
ADB	African Development Bank
B.Sc.	Bachelor of Science
CIMMYT	International Maize and Wheat Improvement Center
CORAF	Conférence des Responsables de la Recherche Agronomique Africains (Network of African Agronomic Researchers)
EARSAM	Eastern Africa Regional Sorghum and Millet Research Network
FAO	Food and Agriculture Organization of the United Nations
FSR	Farming Systems Research
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Foreign Aid Organization of the German Government)
IARC	International Agricultural Research Center
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Center
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
INERA	Institut d'Etudes et de Recherches Agricoles (Institute of Studies of Agricultural Research)
INRAN	Institut National de Recherches Agricoles du Niger (Nigerien National Institute of Agricultural Research)
INSAH	Institut du Sahel (Institute of the Sahel)
KARI	Kenya Agricultural Research Institute
M.Sc.	Master of Science
NARD	National Agricultural Research Directors
NARS	National Agricultural Research Systems
NCRS	National Crop Commodity Research Systems
NCRE	National Cereals Research and Extension Program (Cameroon)
OAU	Organization of African Unity
OC	Oversight Committee
Ph.D.	Doctor of Philosophy
RENACO	West and Central Africa Cowpea Research Network
SACCAR	South African Center for Cooperation in Agricultural Research
SAFGRAD	Semi-Arid Food Grain Research and Development
SALWA	Agroforestry Network for the Semi-Arid Lowlands of West Africa
SCO	SAFGRAD Coordination Office
STRC	Scientific, Technical, and Research Commission
USAID	United States Agency for International Development
RUVT	Regional Uniform Variety Trials
WAFSRN/RESPAO	West African Farming Systems Research Network
WECAMAN	West and Central Africa Maize Research Network
WECASORN	West and Central Africa Sorghum Research Network

MAP OF AFRICA



MEMBER COUNTRIES
OF THE SAFGRAD PROJECT

1	BENIN	14	KENYA
2	BOTSWANA	15	MALI
3	BURKINA FASO	16	MAURITANIA
4	CAMEROON	17	NIGER
5	C. VERDE	18	NIGERIA
6	C. AFRICAN R.	19	SENEGAL
7	CHAD	20	S. LEONE
8	COTE D'IVOIRE	21	SOMALIA
9	ETHIOPIA	22	SUDAN
10	GAMBIA	23	TANZANIA
11	GHANA	24	TOGO
12	GUINEA	25	ZAMBIA
13	G. BISSAU	26	UGANDA

SAFGRAD Member Countries

0 500 1000 1500 2000 KM

EXECUTIVE SUMMARY

Introduction

The impact assessment of the SAFGRAD project was initiated in early 1992. The purpose of the impact assessment was to:

1. Determine the contribution of agricultural research to improving social welfare in the NARS countries.

2. Evaluate the performance of SAFGRAD-related activities in improving the technology base for development and in the building of NARS research capacity.

The synthesis of the impact-assessment findings discusses: (1) economic impacts, (b) development and flow of technology, (3) changes in the human and institutional base of NARS, and (4) future prospects.

Economic Impacts

There have been substantial impacts from the research on maize and cowpeas in West Africa. For example, in Ghana the area in improved maize cultivars increased from 20% in 1982 to 55% in 1991. From 1985-92, the annual social benefits from maize research ranged from $4.8 million to $84 million. The estimated internal rate of return to this investment in public research was 73%.

Maintaining yield gains or avoiding yield declines is a critical factor to consider in funding decisions on agricultural research. High social benefits were also estimated for maintenance research on cowpeas in Mali and Burkina Faso. These social benefits ranged from $800,000 to $12.3 million annually over the period 1984-91.

Farm-level diffusion of new varieties of sorghum was substantially less than for maize and cowpeas. Nevertheless, S-35 has been successfully introduced into northern Cameroon and more recently into Chad. During seven years of diffusion in Cameroon, the estimated social benefits were as high as $288,000 for the conservative estimate and $831,000 for the optimistic scenario.

Social benefits to research were only estimated for the three illustrative cases cited above. However, in this report there is substantial documentation of diffusion of new cultivars and, to a lesser extent, of improved agronomic techniques associated with the new cultivars. Again, the most successful and best-documented examples of successful diffusion were for maize and cowpeas. In the future it will be crucial to obtain these same success levels with sorghum and millet in the semi-arid regions. The overemphasis on breeding is hypothesized to be one of the main factors explaining the lack of success of new technology introduction for sorghum and millet. Achieving gains with sorghum and millet similar to those of maize and cowpeas is expected to require much more applied research on integrated agronomic improvements.

Most of the social benefits that consumers received resulted from lower food prices. Farmers benefitted from lower production costs. The net effect on producers from lower production costs and falling prices with technological change still needs to be calculated. Although it is difficult to separate the contributors to these successes, the research of national and international centers clearly has had high returns in Sub-Saharan Africa. The networks have performed an important role in accelerating the diffusion of technologies as they become available. For most food crops, these impacts appear to be in the initial stages. Therefore, it is important to maintain and, where possible, to accelerate the diffusion process.

With donor fatigue and donor demand for new projects and institutions, national governments will have to fund an increasing proportion of national research and diffusion expenditures. Impact studies will need to clearly document the social benefits of these research investments to support the case of research institutions for increased national funding. These benefits are not difficult to document for maize and cowpeas.

Increasing sorghum and millet productivities are critical to improving nutrition and raising agricultural income in much of Sub-Saharan Africa. Therefore, a principal focus needs to be put on future research activities for these two foodgrains. Maintaining the research and diffusion process in maize also is very important. However, in the drier areas, such as the Sahel, maize is a much less important crop than the two principal cereals, sorghum and millet.

Policy recommendations resulting from this fieldwork are that a greater emphasis be placed on (1) combined agronomic innovations, and (2) increased integration of IARC and NARS activities.

Development and Flow of Technology

Regional research networks were formed to improve collaboration among scientists in different countries (institutes) as well as to improve access to the international research community. This strategy is designed to:

- Accelerate the flow of agricultural technology between national institutions.

- Increase the NARS efficiency in generating profitable and sustainable agricultural technology and adapting it to local production environments.

SAFGRAD networks have been a major mover of technologies developed by diverse sources. In the countries examined, approximately half of the maize and sorghum varieties and almost three-fourths of the released cowpea varieties had been in SAFGRAD trials. These results are striking, given that varieties distributed through SAFGRAD cowpea trials represented only 14 to 54% of the total number of varieties tested in the five study countries. The same trend exists for maize: SAFGRAD-tested material represented only 6% in Cameroon and 32% in Mali of germplasm tested/used in research, yet half of the varieties released in these countries had been in SAFGRAD trials. These findings suggest that SAFGRAD-related material was an important source of better-performing germplasm for maize and cowpea research and development.

To determine whether spillover has taken place among the member countries of SAFGRAD networks, the released varieties were traced in each country along with the extent of their use. The most significant spillover effects occurred in the maize network where nine varieties were adapted and released in one country and, in turn, tested and released in other countries. The cowpea network had spillover of four varieties in the countries examined. The West and Central Africa Sorghum Network had spillover from one variety among the countries examined. The Eastern African Sorghum Network had spillover of three sorghum varieties in the countries examined. These results confirm the networks' successes in facilitating the movement of technology between NARS.

In the five study countries in West and Central Africa (Burkina Faso, Cameroon, Ghana, Mali, and Nigeria), SAFGRAD-related activities resulted in release of a substantial number of new technologies. The estimated yield effect from the new cultivars was estimated as 25 to 61% for maize varieties, 63% for sorghum varieties, 8 to 38% for cowpea cultivars.

Number of New Technologies Released in West and Central Africa.

Crop	1982-86	1987-91
Maize	45	19
Sorghum	8	4
Cowpeas	21	6

In East Africa, a total of 26 new sorghum and millet technologies were released in two study countries (Ethiopia and Kenya). These findings indicate that the SAFGRAD-related activities have resulted in a substantial increase in the availability of new technology.

Following is more detail on the technologies developed by NARS:

West and Central Africa — Sorghum:
7 promising genotypes with resistance to *Striga*

West and Central Africa NARS — Maize:
10 early, drought-tolerant varieties
15 extra-early maize varieties
3 improved agronomic practices (tied ridging, seed treatment, and fertilizer recommendations)

West and Central Africa - Cowpeas:
10 (plus) *Striga*-resistant cowpea cultivars
6 drought-resistant cultivars
7 aphid-resistant cultivars (in collaboration with IITA)

During the last five years (Phase II), the proportion of germplasm from the NARS in the SAFGRAD trials has increased. At present, approximately 50% of the cowpea germplasm and 60% of the sorghum germplasm tested in SAFGRAD trials come from NARS. Even though cowpeas and sorghum are indigenous to West Africa, the NARS-increased contribution indicates their growing research capacity. Maize entries from NARS have declined in SAFGRAD regional maize trials from 1982 to 1991, and the percentage contributed by other international sources has increased substantially to 75% in 1991. Maize is not an indigenous crop in Africa. It follows that the NARS would not be a continuous source of new genetic diversity. This diversity has been provided by outside sources, such as CIMMYT in Mexico, where maize is indigenous. In sum, these findings indicate:

- The networks have been successful in sharing of technology between countries.
- The national programs have taken on an increasing share of responsibility for the networks.

Institutional Evolution of the NARS

Significant building of research capacity has occurred during the last two decades. According to ISNAR data (1980-85), 43 Sub-Saharan NARS had a total of 4,870 researchers. Nearly a decade later, the eight case-study countries alone have almost 3,900 researchers. During the last decade (1982-91), the number of researchers has tripled in Burkina Faso, Ethiopia, and Ghana. In Kenya and Niger, the number of researchers has almost doubled. Also, there has been sustained improvement in the quality of research staff in the countries studied. Although a large number of researchers have limited experience, figures for six of the case-study countries indicate that about 40% have M.Sc. and 40% have Ph.D. level training.

Network	Crop(s)	No. of Researchers
West and Central Africa	Maize	105 (17 countries)
Eastern Africa	Sorghum and Millet	87 (8 countries)
West and Central Africa	Sorghum and Millet	83 (17 countries)
West and Central Africa	Cowpeas	75 (17 countries)

A critical mass of scientists is involved in the networks and in the lead institutions. However, in many countries the numbers of scientists does not reach a critical mass and countries therefore rely on network linkages. Each network has Lead Centers based on relative strength. Typically, the Lead Centers have a large proportion of scientists in the network. For example, in West and Central Africa, 50% of the scientists working on maize are in the Lead Centers for maize; 25% of the scientists working on sorghum are in the Lead Centers, and 60% of the scientists working on cowpeas are in Lead Centers. In East Africa, 35% of the scientists working on sorghum and millet are located in the Lead Center. By pooling research talents through networks, NARS have been able to attain the critical research mass for a sustainable research effort.

During the SAFGRAD project, more than 30 scientists received long-term training to M.Sc. and Ph.D. levels. Currently, several of them are research leaders in their respective countries. Short-term training in various aspects of crop improvement and farming systems was provided to nearly 400 NARS researchers and technicians in more than 22 countries.

Another vital activity of networks has been scientific-monitoring tours to different NARS and occasionally to IITA and ICRISAT programs. The scientific tours involved 65 and 100 participants during SAFGRAD I and II, respectively. The individual networks coordinated numerous short- and long-term training as well as conferences and workshops that have contributed to the improvement of research skills. In this regard, short-term training was offered to 250 participants during Phase I and 140 participants during Phase II. The SAFGRAD project has made a major contribution to the enhancement of the scientific and professional capacity of research systems.

During the 1980s, there was a two- to threefold increase in the number of NARS researchers, with doubling (tripling, in some cases) of the number of nontechnical personnel. However, at the same time, research expenditure per scientist has continuously declined. A large proportion of the finances contributed by national governments has been used to cover salaries. External funding support to national research is high in Burkina Faso, Mali, Niger (over 75% of the total budget) but relatively lower in Ethiopia and Ghana. In general, there has been a significant decline in the operating funds made available to researchers during the past 10 years. Given the high returns to agricultural research being documented elsewhere in this report, it is increasingly important that national policymakers in the NARS are informed of the large social impacts of this research.

The biennial conference of NARS Directors, seminars, symposia, conferences, and the network steering-committee meetings organized by the project allowed more than 2,500 researchers and technicians not only to exchange technical information, share experiences, and review agricultural research-policy issues and technical programs but also to gradually improve professional partnership among NARS as well as between IARCs and NARS researchers.

One of the major outputs of network activities was technical publications. About 500 publications, including annual reports, were generated through the project. Approximately 52% of the publications concentrated on technology generation and 48% on transfer of technology. The SAFGRAD project has facilitated the exchange of information across national, linguistic, and cultural boundaries, thereby contributing to professional development.

Future Prospects

The stronger NARS are supporting the networks with the contribution of their own cultivars for the regional trials. Moreover, with their increased investment in human capital, they are now able to do more of the conceptualization and implementation of the scientific programs necessary to find solutions to their local agricultural problems. In the future, the IARCs will increasingly concentrate on strategic research. To take advantage of the strategic research will require sustainable national and regional activities to support the adaptive, problem-oriented, and region-specific research that will be needed.

To date, networks have been largely viewed as a mechanism to link NARS with IARCs. However, the CRSPs also can help to link the NARS to a broader international, scientific network as well as putting them into contact with experienced, senior scientists. In most developing countries, the senior scientists either do not have advanced scientific training or have gone into administration. Hence, the recognized CRSP senior scientists, who are full-time researchers, could be very useful to the many younger scientists in the NARS.

How to achieve economies of scale in the smaller NARS systems still is an organizational dilemma. As with the stronger or Lead NARS, the small NARS need to be connected to international scientific networks of various types. However, these small NARS systems frequently fail to invest sufficiently in their human capital or to achieve the economies of scale from the multidisciplinary collaboration on well-defined research problems.

For a NARS system to be effective, it has to be insulated sufficiently from domestic political pressures so that it can work on the same research problems over a sufficiently long period. Frequently, this precondition for effective research has been easier to achieve in the IARCs than in the NARS. With the increased human capital now in the NARS and assuming that national policymakers in the NARS will increasingly recognize the high returns to research, the NARS should be able to become even more effective. Classic problems that must be resolved by all research systems are (a) tightly defining feasible research priorities, and (b) staying with them with multidisciplinary research long enough to obtain a payoff.

The prospects for achieving people-level impact from investments in agricultural technology development and transfer in Sub-Saharan Africa have improved over the past 10 years. As demonstrated in this report, the amount of technology available to influence productivity gains has increased. Technology in the pipeline suggests that future prospects are good for achieving further significant gains in productivity. Concurrently, progress has been made in the policy environment influencing the operation of input and output markets that have significant impact on the conditions and motivation for using agricultural inputs. However, these prospects are conditioned by the availability of finances to sustain the gains that have been achieved and by the need for attention to maintenance of the natural-resource base.

Economic Impact of the Commodity Research Networks of SAFGRAD

John H. Sanders

Introduction

SAFGRAD has served as an intermediary between the IARCs and the NARS. In the international research system the IARCs are responsible for strategic research. Since one principal characteristic of biological and chemical research is its location-specific nature, the NARS can then concentrate on the applied or adaptive research. In an effective partnership, there would be substantial interaction between the two types of research institutes. The NARS take technology concepts and material from the IARCs and increasingly from each other. The NARS then test and adapt the material and concepts and then pass the products on to seed producers or the extension service.

The problem of this impact evaluation is not to evaluate the returns to agricultural research. It is well known that these returns are extremely high both for the developed countries and for the developing ones including Sub-Saharan Africa (Karanja, 1992; Ahmed and Sanders, 1991). The problem here is to assess the impact of an intermediate agency. One principal function of SAFGRAD has been to help set up research networks to facilitate the transmission of information and material between the NARS. Another basic function of SAFGRAD was to help build up the capacity of the NARS to do applied research and to successfully interact with the IARCs. Unfortunately, it was not possible to differentiate sufficiently the separate impact of thes NARS. Consequently, the analysis of returns to research is done principally from the perspective of the NARS.

This paper will be concerned first with describing the impact of new technologies for three principal food crops of the semi-arid tropics. The development of some of this new technology precedes SAFGRAD; however, one of the main roles of SAFGRAD presently is to facilitate the movement of new germplasm and new technology concepts between countries. It is also important to stress the dynamic nature of African agriculture by reviewing the extent of new technology introduction. The second objective of the paper is to estimate the economic impact of several new technologies directly associated with SAFGRAD research and/or information sharing in the networks.

SAFGRAD facilitates communication between the IARCs and the NARS but its principal function is to empower the NARS to take on a larger role in the scientific system. In the past decade the NARS have substantially expanded the training and scientific capacity of their personnel and many have successfully produced and helped to extend new technologies on to farmers' fields.

SAFGRAD has been in existence almost 15 years. During that time there has been a substantial increase in the capacity of the NARS. The third section of this overall report concentrates on this capacity development. It is a popular misconception that there has been little progress in developing new technologies for the food crops of concern to the SAFGRAD program. There have been substantial successes with maize and cowpeas. There have also been new cultivar introductions of sorghum. But the changes have been less dramatic than in the cases of maize and cowpeas. This report documents first the introductions of new technologies to illustrate the dynamic nature of these agricultural systems. Networks help give the NARS access to new germplasm and technology concepts and, hopefully with professional intractions, help refine their critical ability to pick and choose those components which will be of most use to them.

A critical role of SAFGRAD is to facilitate spillover. Spillover is the movement of technologies between research systems and countries. Scientific interaction between researchers in developed countries goes on at such a high and regular level through journals and scientific meetings as well as frequent interaction with colleagues that few scientists even think about it. In Sub-Saharan Africa this interaction is much more expensive and difficult. Hence, one of the principal functions of SAFGRAD has been to finance and to facilitate these contacts between the NARS and between the NARS and the IARCs.

As illustrations of the economic impact at the farm level and the spillovers from research, the performance of three SAFGRAD commodities will be considered. The research strategies for all three were broadly similar. In all three commodities breeders looked for earliness and for resistances to different diseases, insects, and to a parasitic weed, *Striga*.

Finally, some comparisons will be made between the performance of the research systems for maize and cowpeas with those for sorghum and pearl millet. For a number of reasons important to future research performance, maize and cowpeas have been much more successful than sorghum and pearl millet in introducing new cultivars and associated technologies.

Food Crops of the Semi-Arid Zone

The SAFGRAD program and its predecessor programs were a response to the Sahelian droughts. The first major recent drought was 1968-1973 and the next one, extending over a wider area in Sub-Saharan Africa, was in 1982-84. Besides these acute droughts there has also been a chronic drought in the Sahel, as rainfall after the high rainfall period of the '50s and '60s was one standard deviation below the long-term normal from 1968 through the '80s (Glantz, 1987, p. 39). The basic concern of the SAFGRAD program was to increase the productivity of the food crops of the region to approach food self-sufficiency so that in the future the food supply would be less sensitive to climatic disturbances. This was to be done principally by strengthening NARS and facilitating exchange of materials and information. Unfortunately, in both the '80s and the '90s, civil wars and other domestic disturbances have been as important if not more important than climatic factors in disrupting food supplies.

The basic food crops of the semi-arid region are sorghum, millet, maize, and cowpeas. Research programs were already underway in three major IARCs, ICRISAT, IITA, and CIMMYT, on these commodities. SAFGRAD then sought to do complementary activities to accelerate the process of moving new technology from the research stations to farmers' fields. The principal emphasis of SAFGRAD has always been to build up the capacity of the NARS.

With the decline in the consumption per capita of sorghum/millet due to the substantially increased consumption of imported rice and wheat, concern has been raised over the commodity choices. Wheat and rice have two advantages over the traditional and predominant cereals of the semi-arid region: First, there has been substantial investment in preparation and processing of these two cereals in developed countries; hence, the time requirements for food preparation by women in urban areas of Africa are substantially reduced as compared with the traditional cereals. Secondly, overvalued exchange rates and economic policies to benefit urban consumers have been widely practiced in Sub-Saharan Africa and both end up giving price advantages to food imports over domestically produced cereals. There may also be a third factor in that higher-income people in Africa prefer wheat and rice over sorghum and millet. Unfortunately, in the econometric studies to date this possible taste-preference factor has not been separated from the convenience factor. Moreover, even with the decline in consumption of millet and sorghum, they are still the predominant cereals in semi-arid Sub-Saharan Africa and are expected to continue in that position for a long time. Presently, there are 8.5 and 10 million ha of sorghum and millet, respectively, in West and Central Africa. In Eastern Africa, where maize is the principal staple and most important crop, there are 6 and 2 million ha of sorghum and millet. So these traditional cereals continue to be very important crops for farmers' incomes and consumers' welfare.

Maize is the most important food crop in Eastern and Southern Africa. In West and Central Africa maize performs an important supplementary role in the food supply. In the drier, Sudanian climatic regions the early maize varieties become available before the sorghum and millet, thus providing food before the main cereal harvest. In Central Africa maize provides a supplementary source of calories and protein to the root crops. The root crops, especially cassava, generally have a very poor balance of nutrients but provide high levels of calories per area unit. In spite of maize's lesser importance in West and Central Africa, there has been a substantial increase in production here in the last two decades and some productivity growth (CIMMYT, 1990, p. 10).

Approximately, two-thirds of the world's cowpeas come from West and Central Africa, where they are extensively grown, predominantly in association with the cereals. They add protein to the diet and are especially important in the sandy-dune soils of the drier regions in association with millet. Yields in association in general are low, 100-400 kg/ha. Cowpeas are found all over these two regions but production is concentrated in Nigeria and Niger.

Maize in West and Central Africa

Maize is much less important in the production and food systems of West and Central Africa than it is in East and Southern Africa. Only 15% of the maize on the continent is produced in West and Central Africa. In this region maize is cultivated on 5 million ha with about 74% for human consumption (Badu-Apraku, 1992b, p. 3). In this region, 50% of the maize is produced in the northern Guinea savanna climatic region and 20% in the much drier, Sudan region (SAFGRAD, 1993, p. 10). In the Sudanian region maize is primarily produced in the small compound areas around the households where fertility and water retention are increased by the dumping of household refuse. These are generally very small areas, 0.1 to 0.2 ha, but maize plays a critical part in household consumption by becoming available before the harvest of the millet and sorghum during the "soudure" or hungry season. At this time, maize is a vegetable crop.

The SAFGRAD-supported research program in maize (implemented by IITA) has emphasized earliness and extra-earliness for the Guinean and Sudanian regions. Earliness is a method of drought escape. With SAFGRAD encouragement, IITA agreed to move outside of its mandate area for maize of the humid and semi-humid tropics into the semi-arid zone. Moreover, the breeding and other supplementary research for extra-early maize designed specifically for the Sudanian regions was being undertaken first by the SAFGRAD Maize Network. The IARCs (IITA and CIMMYT) are now continuing this work on extra-early material in Thailand, Mexico, and Cote d'Ivoire (A. Diallo, formerly the CIMMYT maize breeder seconded to IITA, who worked with SAFGRAD; personal communication, Aug. 1993). This extra-early material is an excellent example of the increasing scientific independence of the NARS in the network.

Since maize cultivars are planted in areas with higher rainfall or with better water-holding capacity, organic or inorganic fertilizers are generally used, especially nitrogen. Agronomic technologies to increase soil nutrients are expected to have a high return complementing the breeders' new cultivars.

Table 1 combines the CIMMYT data on the diffusion of improved maize varieties in West and Central Africa with the names of the new NARS cultivars and other new technologies. Some of the new varieties and the other technologies are associated with the SAFGRAD-supported research and networking. The cultivars released and sent by SAFGRAD to the NARS are identified in the second to last column. CIMMYT germplasm used in this new material is also identified.

For West and Central Africa there has been successful introduction of new cultivars, including some with earliness, in Ghana and Cameroon. In Ghana approximately 55% of the maize area was in improved cultivars in 1992. (Badu-Apraku, personal communication). Some, such as Abeleehi, have been developed locally, tested, and extended by an excellent local maize team. Others, such as the early SAFITA-2, were part of the SAFGRAD network exchange and have been successfully introduced. In Ghana maize production increased from 265,000 tons in 1982 to 932,000 tons in 1991 (Table 2) as the economy began to recover and prices of imported cereals were increased with the devaluations of the early '80s.

Table 1. Maize Production Trends and Adoption of Improved Maize Varieties in Some Countries of West and Central Africa.

Country	Production (1990)		Maize Area % of Cereals 1986/90	% of Total Maize Area Planted to Improved Varieties in 1988	Maize Varieties Exchanged Through Network and Released by NARS	Maize Varieties Based on CIMMYT Germplasm Exchanged Through Network and Released by NARS
	IN-1000 ha	IN-1000 tons				
BENIN	485	455	73	41	TZB, TZB-SR, TZESR, Poza Rica 7843-SR, PIRSABACK 7930-SR and DMR-ESRW	Paza Rica 7843-SR, PIRSABACK 7930-SR
BURKINA FASO	221	257	8	27	TZEE-WSR, TZEE-YSR, SR 22, MAKA, 8330-SR, 8321-18, TZESR-W and SAFITA-2	SR 22, EV8330-SR, EV8422-SR, SAFITA-2 (Pool-16)
CAMEROON	440	600	47	18	CMS8710, TZPB-SR, TZB-SR, Mexican 17E, SAFITA-2, CMS 8806, Pool-16-DR, CMS 8501 and CMS 8507	SAFITA-2, Pool-16 DR, CMS 8501(EV8149-SRxTZB)
CHAD	45	31	NA	NA	CMS 8501, CMS 8507	CMS 8501 (EV8149-SRxTZB)
CôTE D'IVOIRE	670	530	49	10	TZSR-Y, Pool-16DR, Maka	Pool-16DR
GHANA	567	750	47	43	Okomasa, Dobidi, Aburotia, Abelehee, SAFITA-2, Kawanzie, Golden Crystal, La Posta and Dorke-SR	Dobidi (Ejura 7843), Aburotia (Tuxpeno PB C16), SAFITA-2 (Pool-16), Kawanzia (TOCUM 7931), La Posta and Dorke-SR (Pool-SR)
GUINEA CONAKRY	94	108	NA	NA	Farak 88 Pool 16-DR, DMR-ESRY, TZEF-Y, CSP, EV 8420-SR, Ikenne 83, TZSR-Y	Farak 88 Pool 16-DR, CSP
MALI	126	228	20	36	SAFITA-2, TZESR-W, Golden Crystal, TZPB-SR, and TZEF-Y	SAFITA-2 (Pool-16)
MAURITANIA	4	3	NA	NA	Maka, CSP Early, SAFITA-2	CSP Early, SAFITA-2 (Pool-16)
NIGERIA	1500	1600	14	40	TZB-SR, TZPB-SR, TZESR-W, DMR-ESRW, DMR-ESR-Y, EV8418-SR, and Pool 16 DR	Pool-16DR (Pool 16)
SENEGAL	105	110	5	100	Maka, Tocumen 7835, Pool 16 DR	TOCUMEN 7835, Pool-16DR
TOGO	255	245	44	15	Ikenne 8149-SR and EV8443-SR	Ikenne 8149-SR and EV8443-SR

Source: Taken from SAFGRAD, 1993, p. 41. The last column was provided by the former maize breeder. See (4) below.
(1) Impact Assessment Study - Synthesis of primary data report of Maize Network May, 1991.
(2) 1989/90 *CIMMYT World Maize, Facts and Trends.*
(3) J.M. Fajemisin, 1991, *Outline of National Maize Research Systems in West and Central Africa* provided estimates in the second to last column of the cultivars released through the networks.
(4) Alpha Oumar Diallo, maize breeder in SAFGRAD, Apr. 1984 to Aug. 1988, seconded by CIMMYT to IITA, provided information in last column of this table about maize varieties based on CIMMYT germplasm.

In Cameroon the intermediate maize with streak resistance, TZB/TZB-SR, covers 15% of the maize area, 75,000 ha, with an estimated annual production of 90,000 tons. For the semi-arid region of Cameroon, where sorghum and millet production predominate, the introduction of new early maize cultivars has resulted in a doubling of maize area to 35,000 ha with an estimated 1,000 families producing these cultivars (SAFGRAD, 1993, p. 7). In Burkina Faso new maize cultivars occupy 65% of the maize area or 133,900 ha (SAFGRAD, 1993, p. 7).

The introduction of new maize cultivars combined with other new agronomic practices, especially chemical fertilizer and higher densities, has occurred at a rapid rate in the last decade in the Guinean savanna and in small areas of the Sudanian zone. However, for the latter zone, maize is a minor crop and serves mainly as food during the hunger period while farmers are waiting for the harvest of the major cereals, sorghum, and millet.

Returns to National and SAFGRAD-Promoted Research in Maize

New maize cultivars have been most successfully introduced in Guinea savanna regions. Here there is sufficient rain in most years to reduce the risks of fertilization. Also in these regions there have often been successful breeding and agronomic improvements with cotton. Hence, there is a research establishment that has worked with farmers and released new technologies. Moreover, farmers have seen the effects of chemical fertilizer and pesticides. Markets have been established for these inputs. Guinea savanna successes with maize include northern Ghana, Nigeria, Cameroon, southern Mali, and Burkina Faso.

Looking at one particular country program in more detail, the social benefits to the national program are compared with the benefits of the introduction of the early maizes in Ghana (Table 2). In the decade maize production approximately quadrupled. The area in improved cultivars increased from 20% to 55%. The social benefits reported in Table 1 were selected with the standard economic surplus economic techniques with a divergent supply (see Akino-Hayami, 1975) The additional input costs were then deducted from these benefits. They range from $4.8 to $154 million per year. These are substantial benefits for the Ghanaian NARS. To calculate the returns to society, the costs of extension and research were deducted and these social benefits were used to calculate the internal rate of return.

The development and extension were also supported by the Canadian-financed CIMMYT program to do adaptive research and extension. These research and extension costs of the other relevant agencies were also included in the cost accounting. When the research and extension costs are also considered, the internal rate of return to the public investment in the national maize program is 74% (see Appendix B for some details on this calculation; the tables are available from the author). This is an excellent return on a public investment.

Table 2. Areas and Benefits of Improved Maize Cultivars in Ghana, 1982-1991.

Year	Maize Production (000 m.t.)	% Area in Improved Cultivars	% Area in SAFGRAD-Improved Cultivars[a]	Social Benefits of National Program	Social Benefits of SAFGRAD Program[b]
				(Million dollars - 1991)	
1982	265	20		8.3	
1983	141	20		4.8	
1984	380	30		36.4	
1985	394	30		22.7	
1986	559	30	2.0	22.7	0.4
1987	558	35	3.0	20.4	0.4
1988	600	43	3.5	46.8	0.8
1989	750	47	3.5	154.1	1.1
1990	850	50	4.0	72.5	1.4
1991	932	55	4.0	83.6	1.4

[a] These cultivars were the early and extra-early cultivars distributed by SAFGRAD to the NARS (Badu-Apraku, conversation).

[b] This is the value of the yield advantage of the new early cultivar distributed by SAFGRAD minus the additional farmer costs.

Early cultivars, including SAFITA-2, Kawanzie, and Dorke SR — a streak-resistant successor to SAFITA, made their appearance in the second half of the decade. Over the six years since they have been introduced, the social benefits have ranged from $400,000 to $1.4 million per year. Some research and extension costs need to be deducted. However, this is already a substantial return on one research project and its impact in one country. In this economic impact analysis, this is the only estimate of benefits that can be attributed primarily to SAFGRAD. As was previously shown in Table 1, new maize cultivars are becoming widely adopted in Sub-Saharan Africa.

This type of network and SAFGRAD benefits for accelerating the between-country cultivar diffusion can be summed over a large number of regions mentioned above and in the cultivar description of Table 1. A recent study of the introduction of new maize cultivars in the high-rainfall Guinean region of Mali estimated a rate of return of 135% (Boughton and de Frahan, 1993). The Sahelian as well as the coastal countries are able to benefit from the new maize cultivars. But the major impact is still in the Guinean zones of both the coastal and Sahelian countries.

A Similar Story for Cowpeas in West and Central Africa

The cowpea experience is very similar to that of maize. There have been substantial successes in the introduction of new early cultivars in West and Central Africa. Unfortunately, there are fewer estimates of the extent of diffusion of these new cultivars than in the case of maize. The principal production areas are Nigeria and Niger with approximately one-half of world cowpea production (SAFGRAD, 1993, p. 42).

As in the maize case, breeders also worked on other resistances especially for *Striga*, aphids, thrips (field insects), bruchids (storage insects), and diseases. Agronomic research has shown the high return to phosphorous fertilizer in combination with new cultivars (SAFGRAD, 1993; also Shapiro et al., 1993). A devastating problem for cowpea is storage insects. The agronomic and the storage components of the new cowpea technologies are important additions to the breeding search for new cultivars.

As with maize, SAFGRAD was involved in improving the distribution of cultivars among the NARS. In Ghana a new cultivar, Vallenga, released in 1987, has been introduced on more than 20,000 ha in the north, raising farmers' yields to approximately one ton. In higher-rainfall southern Ghana, Asontem is cultivated on 29,000 ha. Still other new cowpea cultivars are being introduced in the savanna regions. As with the improved cultivars of maize, the introduction of new cowpea cultivars is associated with other new technologies, especially chemical control of insects and monoculture row planting (Dankyi and Dakurah, 1992, p. 4). New early cowpeas have also been successfully introduced and are now found in large areas of Burkina Faso, Mali, Senegal, and Nigeria (SAFGRAD, 1993, p. 8).

Benefits of Cowpea Research for Burkina Faso and Mali

Even though the area and production of cowpeas is not very large in these two countries compared with Nigeria and Niger, this crop is very important for improving nutrition and ultimately for improving the cropping system by providing the fertility and other system interactions between cereals and grain legumes. Moreover, as with maize, the cowpea-breeding work implemented here since the early '80s by IITA represents a movement north by IITA outside of its mandate area of the humid and semi-humid tropics. SAFGRAD was instrumental in getting IITA to work on the specific problems of the semi-arid regions in both maize and cowpeas.

Diffusion of the new cowpea cultivars in these two countries has been pervasive and this by itself is an important success story (see Tables C-1, C-2, and C-3 in Appendix C for documentation of this diffusion process in three different climatic zones of these two countries). Grain legumes are a vital part of the production system but are very difficult to produce in the tropics. Besides the increased incidence of droughts since 1968, *Striga*, field and storage insects, and several diseases are all serious production problems. The benefits to this cowpea research are the gains to maintaining yields over time in an increasingly difficult environment. When rust-resistance breaks down in the U.S., the new wheat cultivar

Table 3. Production and Social Benefits From the Introduction of New Cowpea Cultivars in Burkina Faso and Mali.

Year	Production (1,000 m.t.)	Social Returns (Million U.S. Dollars)	
		25% Yield Decline	50% Yield Decline[a]
1984	41.0	0.8	1.8
1985	103.9	1.9	4.4
1986	90.8	2.6	6.3
1987	46.4	2.5	6.2
1988	104.7	4.0	10.0
1989	78.7	2.9	7.5
1990	59.4	3.8	9.7
1991	80.9	4.8	12.3

[a] Yield benefits are calculated on the assumption that the new cultivars prevent farm-level yields from falling 100 to 200 kg/ha.

has a substantial effect on farmers' welfare by maintaining yields. Cowpea research has had this same maintenance effect in Burkina Faso and Mali. Production is predominantly in association.

So the annual economic benefits to maintaining farmers' yields range from $800,000 to $4.8 million, with the most conservative assumption about yield declines in the absence of the new cultivars (Table 3). With the more realistic assumption of a 50% decline in cowpea yields in the absence of the new cultivars, the social benefits to research range from $1.8 to $12.3 million per year. These are the benefits to society resulting from this cowpea research promoted by SAFGRAD and implemented by IITA.

Sorghum/Millet in West and Central Africa

Even though these two crops are more important in the region, there has been less diffusion of new material onto farmers' fields than in the case of maize and cowpeas. Maize and cowpeas have many production problems and are more difficult to grow than the hardier, more resistant sorghum and millet. Hence, sorghum and millet are concentrated in the more adverse climatic and edaphic regions.

Price collapses are a recurrent phenomenon with these two basic staples of sorghum and millet. In poor rainfall years, prices become very high until food aid or imports are obtained. Then in good rainfall years prices collapse. Recurrent drought, food aid, and price collapses all discourage farmers from investing in new technologies for sorghum and millet production.

To obtain the gains from new cultivars of millet and sorghum, higher input use will be necessary. This higher input use is riskier for sorghum than for maize since sorghum is grown on poorer soils with lower nutrients and poor water retention. On many of the soils on which sorghum is grown, increased use of water-retention methods will need to complement the use of increased chemical fertilizer in order to increase the returns and reduce the risks of the farmers' expenditures on chemical fertilizer (Sanders et al., 1990).

Nevertheless, there has been some progress in new sorghum technology introduction, especially in the Sudanian region. For example, in northern Cameroon S-35 has been successfully introduced. This Indian non-photoperiod sensitive, 90-day cultivar was found to be locally adapted in northern Nigeria. Rao made seed available for northern Cameroon and S-35 was tested in the on-farm trials supported by the Cameroon National Cereals Research and Extension Project and was successfully introduced into northern Cameroon (Johnson, 1987; Kamuanga and Fobasso,1992).

In northern Ghana and Togo and in the Manga region of Burkina the *Striga*-resistant Framida has been introduced (SAFGRAD, 1993, p. 31). The sorghum area in improved cultivars in Ghana increased from 10% to 17% and their importance in production increased from 13% to 24% over the period 1982-1991 (unpublished data from the Ghanaian national program). In a farm survey in northern Ghana, 20% of the farmers planted improved sorghum cultivars and half of this was in Framida. Even though farmers identified soil fertility as a major constraint, 84% raising red varieties, including Framida, do not use fertilizer. In contrast in the same region, 88% of the farmers raising white (improved) maizes did use fertilizer (Dakurah et al.,1992, pp. 5, 9, 10).

In northern Nigeria several cultivars (Farafara and SK-5912) associated with new industrial uses (beer and bread) for sorghum have been successfully introduced. The relative importance of these industrial uses of sorghum is still a very small part of sorghum consumption; however, the rapid introduction of SK-5912 came with the recognition of its favorable characteristics for beer. SK-5912 has been reported grown on 100,000 ha in Nigeria under contracts for brewing and infant food industry (Andrews and Bramel-Cox, 1993, p. 10). There is also increasing interest among researchers and development personnel in Cameroon in increasing the industrial demand for sorghum for both bread and beer. To stimulate local cereals and industrial utilization, Nigeria erected trade barriers to imported cereals. With rising food prices and increased smuggling, these trade barriers were eliminated in 1992. Cameroon has not imposed these barriers and is presently looking for alternative methods to increase the interest of local industries in these uses for sorghum (NCRE, 1989).

Finally, in Mali there is important ongoing collaborative research between entomologists and breeders on the headbug complex. Entomologists argue that this complex appears to be one of the critical constraints to new sorghum cultivars in the Sudanian and Sudano-Sahelian zones. Major research efforts are also underway in the networks and in the INTSORMIL CRSP on *Striga*, anthracnose, and drought tolerance.

Returns to National and SAFGRAD-Promoted Sorghum Research in West and Central Africa

In large-scale, on-farm testing of new technologies by the National Cereals Research and Extension Project (NCRE) of Cameroon there was a surprising result in 1984. In this drought year the yields of S-35 were almost double the local and the other new varieties (Kamuanga and Fobasso, 1992, p. 22; Johnson, 1987, p. 657). Trials continued another three years.In these normal and good rainfall years after 1984, the yield advantage to the 90-day, non-photoperiod sensitive S-35 was minimal. Nevertheless,when it was released in 1986, farmers began rapidly introducing this cultivar into the mix of cultivars of different season length that they employ, apparently appreciating its advantages in adverse rainfall years.

The NCRE final report (1992, p.108) estimated that there were 5,000 ha in S-35 in the Extreme North province. With another 5,000 ha in the North province, this would be approximately 10,000 ha in 1991. This is a conservative estimate of the extent of diffusion. Sorghum production is concentrated in these two provinces in Cameroon. Another diffusion study estimated that 8.7% of the sorghum area in the center north zone (Nord and Extreme-Nord) was in S-35. This 8.3% includes approximately 64% of the sorghum producers (calculated from the estimated 210,000 farmers in the survey area and estimates of 330,000 sorghum producers in Cameroon (Kamunga and Fobasso, 1992, p. 1). According to this estimate, there would be approximately 26,000 ha in S-35 in 1990. From these two point estimates of diffusion, 26,000 ha in 1990 and 10,000 ha. in 1991, two series of estimates of diffusion over the period 1986-1992 were made. These were then utilized to estimate the social benefits of the new technology introduction (Table 4). (For the technique used to estimate the changes in consumer and producer surplus, see Akino and Hayami, 1975).

Table 4. Diffusion and Social Benefits of the Introduction of S-35 Into Cameroon.

Year	DIFFUSION ESTIMATES (1,000 ha)		SOCIAL BENEFITS (1,000 U.S.$ - 1990)	
	Conservative	Optimistic	Conservative	Optimistic
1986	0.65	0.65	7.6	7.6
1987	4.00	5.00	13.0	17.0
1988	6.00	10.00	36.0	71.0
1989	8.00	15.00	41.0	91.0
1990	10.00	26.00	50.0	131.0
1991	10.00	28.00	288.0	831.0
1992	12.00	30.00	57.0	144.0

In 1992 S-35 was produced on 12,000 to 30,000 ha in the drier Sudanian regions of Cameroon. This introduction reduced the drought risk and encouraged some of the farmers to utilize higher inputs. After seven years of diffusion, the social benefits ranged up to $288,000 per year in the conservative estimate of diffusion and up to $831,000 per year with the more optimistic scenario. In either case, these are good initial successes in a difficult zone to improve farmers' productivity and welfare.

This reduction of drought risk is very important in this subsistence cropping system with an average farm size of 2.5 ha. In these low rainfall zones, the optimal technology-development strategy may be to raise expected incomes by reducing the income loss and increasing availability of food in adverse rainfall years. S-35 has been very successful for this type of strategy.

Except for poor rainfall years, the yield gains from S-35 were minimal. Two factors responsible for the lack of yield increase in normal and good rainfall years were: Earliness gives drought escape but reduces the potential of the plant to respond to better growing conditions since the plant will not be in the field long enough to have the advantage of better growing conditions, especially as compared with improved cultivars of longer duration. Since there were substantial drought problems in the '80s, the earliness of S-35 has been much appreciated. However, in good rainfall years there was no advantage to S-35 over local cultivars. Secondly, in contrast with the new maize cultivars discussed above, there has been little increased fertilizer use accompanying the introduction of S-35, except where sorghum was rotated with cotton and could take advantage of the residual effect from the cotton fertilization. Hence, the new cultivar only joins the farmers' portfolio collection of early, intermediate, and late cultivars without chemical fertilizer.

Many farmers are now using S-35 on small areas. However, unless new varieties are combined with higher purchased, chemical-input levels, yield gains will be limited. To raise yields substantially, as in the maize case in the Guinean zone, higher levels of chemical inputs will be necessary. Future sorghum yield gains will require chemical fertilizer and probably some improved intermediate and late cultivars and increased use of water-retention measures. Elimination of the sorghum-price collapse in good rainfall years by encouraging demand growth for alternative uses and with improved stockholding strategies would increase expected incomes and encourage new cultivar and fertilizer diffusion.

The success with S-35 also helps indicate the future research agenda. The earliness and the white, low-tannin, "sweet" grain make the taste appreciated by farmers and by birds. S-35 is also very susceptible to *Striga*. Presently, there is substantial sorghum research activity on *Striga* in the networks and in the sorghum CRSP.

Introduction of S-35 has been concentrated in the Sudanian zone since in higher-rainfall regions earliness can be a disadvantage. Late rains can cause serious problems with grain molds. For the Guinean region there has been continued work with the later S-34. As another example of the spillovers of new cultivars, S-35 has been introduced on 15,000 ha in Chad (NCRE, 1991, p. 108).

Sorghum/Millet in East Africa

There are two very important sorghum producers here, Sudan and Ethiopia. Both have had sorghum-breeding programs over several decades and have produced new cultivars. The first commercially successful sorghum hybrid in Sub-Saharan Africa, Hageen Dura-1, is now produced on 12% of the sorghum area in the Gezira irrigation scheme and is expanding rapidly there. (Nichola, 1993). The Gezira in the Sudan is one of the largest irrigation projects in the world. Also in the Sudan SRN-39, a variety resistant to *Striga*, has been reported as being produced on 50,000 ha in the mechanized drylands in 1992.

In both Sudan and Ethiopia, with collaboration from ICRISAT and SAFGRAD, integrated control programs have been developed for *Striga* including tolerant varieties, agronomic practices, fertilizer and herbicide use. In Ethiopia several new sorghum cultivars have been introduced including Gambella 1107. Again illustrating the spillover effect of scientific development, Gambella was also released in Burundi where this white sorghum is highly appreciated for food and for composite flour. Later Gambella was introduced in Burkina Faso as E 35-1. In Kenya a new variety, Kat 369, is being promoted for both composite bread and for other confectionery products. New varieties for the brewing industry have been identified for Burundi and Rwanda (SAFGRAD, 1993, pp. 6, 7).

In Eastern and Southern Africa (with the exception of Sudan and Ethiopia) in the colonial and post-colonial periods there had been much more research effort on maize than on sorghum. The development of early maizes has enabled drought escape and thereby facilitated the continuing substitution of maize for sorghum and millet. Maize is generally preferred for its taste and some nutritional advantages; however, the continuing substitution of maize and the previous failure to invest in sorghum/millet research makes many of the semi-arid regions of East Africa even more susceptible over time to climatic variation. Sorghum/millet have greater tolerance to climatic and soil-fertility stress than maize, but it is necessary to take advantage of these inherent favorable characteristics by continual improvements in breeding programs. More research and policy efforts need to be focused on sorghum/millet for the semi-arid regions in the countries south of Sudan and Ethiopia.

Evolution of the NARS in the '80s

One principal concentration of the networks and of the SAFGRAD research program in Phase I (1978-1986) was earliness for drought escape. Besides this characteristic, the research programs in the NARS looked for higher yields and for resistances to different diseases, insects, and the parasitic weed, *Striga*. In the '70s and '80s the IARCs had gathered large gene pools and substantially developed screening methodologies for identifying resistant germplasm so they were able to provide that expertise and their commodity-based organizational model to the NARS in the '80s.

In the '80s, there was a gradual evolution of commodity programs in the NARS. Trained national scientists in the '70s and '80s had returned with M.S. and Ph.D. degrees. In many countries in the '80s, financial resources became available to bring these scientists together into commodity research teams and to do on-farm technology testing. These programs provided additional resources and incentives to national scientists. One criticism of these programs was frequent dependence upon large numbers of expatriate scientists rather than on even larger investment programs for national scientist academic training.

By the end of the '80s, the NARS were making larger inputs into the research system. An increasing percentage of the material entering into the regional cultivar and on-farm trials was coming out of the NARS (SAFGRAD, 1993, pp. 32, 33, 39, 43, 44). Moreover, the networks began utilizing their different NARS member research systems for specialization in specific research problems identified as being principal constraints in their country programs. Lead countries for specific research areas, such as *Striga* or drought tolerance, were identified as the networks tried to obtain the comparative advantage from between-country research specialization (SAFGRAD, 1993, pp. 24, 26, 28, 30). But all countries shared germplasm and workshops so they could all take advantage of gains made in the other NARS as well as in the IARCs. Thus, in the '90s the NARS were producing new germplasm and also new concepts, especially on the applied side of technology development, such as the integrated control methods for *Striga* developed in Sudan and Ethiopia.

In the '90s the networks had developed regular interchanges of material, workshops, and directors' meetings. Among the stronger NARS there was a new pride in the system as the new technologies (new maize and cowpea cultivars and improved agronomy, especially higher use of chemicals) were finally moving onto farmers' fields (CIMMYT, 1991; Coulibaly, 1987).

Successful agricultural research systems deserve to be financed by their own governments. In developed countries farmers and other beneficiaries from technological change pressure legislatures to support public research institutions. In developing countries farmers often have little influence on the public funding process. Hence, it is very important that research institutions monitor and document well the diffusion process to demonstrate to public policymakers the returns to the research process.

Technologies in the Pipeline

In the second half of the '80s and early '90s, introduction of new maize technology and productivity increases were accelerating in various of the Guinea savanna regions, especially in Ghana, northern Nigeria, Cameroon, in southwestern Burkina Faso, and in southern Mali. These gains were periodically interrupted in good rainfall years with price collapses. Hence, to maintain momentum in this technology introduction, new industrial and feed uses for maize need to be identified and encouraged by government policy. These policies would encourage further economic linkages and development from this technological change in maize production and moderate price collapses. These supplementary policy measures and non-farm development seem to be critical components for more rapid successes of all crop programs.

New agronomic recommendations as well as new cultivars are available for this zone (Badu-Apraku, 1993, p. 9). Moreover, as the private sector evolves in seed production, substantial gains should be attainable with hybrid-maize introduction in West and Central Africa. So the most rapid future gains in new-technology introduction are potentially available in the Guinean region for maize. Two IARCs and several NARS have contributed to the stock of available technologies in maize.

In the Sudanian zone, there have been fewer successes with maize. In 1993 there were 15 extra-early maize cultivars in the pipeline of new materials to be made available to the NARS by the maize coordinator (Badu-Apraku, 1993, p. 6). Tied ridges for water retention have also been extensively field tested. Tied ridges combined with chemical fertilizer give the potential for substantial yield increases, especially on the small compound areas near the households. Moderate fertilizer use already accompanies the new maize cultivars in the Sudanian region of northern Cameroon (Bezuneh, 1991, p.6). Again, development of the non-farm sector may be critical here both to moderate the price collapses and to facilitate the introduction of one of the animal-traction implements for the construction of tied ridges developed in Burkina Faso by IITA or by ICRISAT. Two different type implements were tested and one was released in the mid-'80s by the public sector for distribution. Maize will continue to be a minor crop in the Sudanian zone because of its susceptibility to drought; nevertheless, the welfare gains from the increased productivity on these small areas can be substantial.

Cowpeas should not be neglected because they are difficult and principally used for household food and feed. There has been substantial introduction of new cultivars and there are also new materials in the pipeline. Morover, with phosphorus and chemical control of field and storage insects, yields and profitability of this crop can be substantially increased. Experiment-station yields of 1.5 to 2 t/ha are regularly obtained for monoculture cowpeas. Finally, once cereal yields are increased, improved production of grain legumes would have favorable effects on the soil with nitrogen fixation and would provide improved animal nutrition. Farmers are expected to be very interested in increased production of small animals once successes with cereals are achieved.

The two sorghum networks report numerous new cultivars in the pipeline with resistances to drought, cold tolerance (East Africa), *Striga*, head bugs, and several diseases. Nigeria, Cameroon, and Kenya have all been attempting to expand the industrial use of sorghum. Specialized cultivars for these purposes are being introduced.

Resource (soil and water) specialists need to have much more input into the planning process of these networks. Sorghum and millet are the most important crops of the semi-arid regions, especially the Sahelian countries. They are expected to continue to be the most important crops there. Planning for sorghum is more difficult because the production environments are more difficult and there have been fewer successes to build upon with sorghum than in the cases of maize and cowpeas. The NARS in the semi-arid regions need to concentrate more of their scientific resources on sorghum and millet in the future and reverse these trends.

Future Research Priorities

The commodity choices of SAFGRAD still appear to be the most important crops for human nutrition in semi-arid regions. Substantial gains in productivity for maize are beginning as new cultivars and higher input levels are becoming more widespread. Sorghum and millet are more difficult but productivity gains for these crops are expected in the next decade. Building up functional commodity programs and strengthening NARS are long-term commitments that need to be continuous. The networks are now progressing well and are increasingly developing self-confidence and becoming more assertive in the international research system. Solid research achievements are beginning to occur and the networks are helping the NARS to achieve more self-confidence and to further take over their research system choices.

Another important choice for the donors in the '90s is on which end of the research system to concentrate their resources. In 1992 the CGIAR system increased its number of supported institutions but did not increase its budget. Hence, there is presently substantial economic pressure on the IARCs. Is the pool of available scientific knowledge now being used up as the NARS have been increasingly successful at utilizing IARC material and concepts and the NARS are increasingly producing their own materials? Presently, basic investments in the IARCs and elsewhere are being made to produce a body of concepts and strategic research from which the NARS can continue to draw in the future.

In developed countries there is increasing concern with the exhaustion of the yield gains from traditional breeding and agronomic techniques even when the new cultivars are combined with high levels of conventional inputs. There is increasing research, popular discussion, and private investment in bio-technology. But even for developed countries, most of the yield gains for the basic crops over the next decade will continue to come from extensions of the conventional breeding techniques rather than from bio-technology (Ruttan, 1991, p. 402). Moreover, in Sub-Saharan Africa, substantial gains are still possible from increasing input levels and from adapting known research techniques including breeding. Being on the frontier or cutting edge of new technology production is extremely expensive for developed-country institutions. There will be gains to developing countries in adapting these bio-technology innovations but this is still a problem to be faced after the year 2000.

The other end of the research system is what happens to the new technologies after they have been successfully adapted or developed by the NARS. Private industries are generally necessary to produce seeds, distribute fertilizer, and market the product. Good extension services, such as the Global 2000 program, have been very successful at accelerating the introduction of new maize cultivars in Ghana and Hageen Dura-1 in the Sudan. Many African countries badly need basic improvements in infrastructure (roads, ports, communication networks) to reduce marketing costs of products and inputs and to improve information flows to farmers and consumers. The successes of the NARS in adapting new technologies and in building themselves up now serve to focus attention on the inadequate previous investments by both the private and the public sectors in developing the facilities and the institutions needed to support the NARS by accelerating the diffusion of new technologies from the experiment stations onto farmers' fields. Over the next decade these are expected to be the high payoff investments for the donors in Sub-Saharan Africa. Finally, the most important investments to facilitate technological change will need to be made by developing countries themselves in rapidly improving the education and health of their farmers and the rest of their population.

Conclusions

The network programs have facilitated the spillover and the successful introduction of the semi-arid food crops, especially maize and cowpeas. There has been rapid introduction of both maize and cowpeas in the higher-rainfall Guinean regions, such as northern Cameroon, northern Nigeria, and northern Ghana. Here increased chemical utilization on maize and cotton has been highly profitable so the soil-fertility levels for new cultivars have been much higher than in the harsher Sudanian region. Moreover, the risk of inadequate water availability during the growing season in the Guinean region is also less than in the Sudanian zone.

In the Sudanian zones the same breeding techniques were also applied. A new category of extra-early maizes was developed and introduced principally on the small compound areas with higher fertility. Even though the area in these new maizes is small, this increased maize production plays an important role in family nutrition at a time of food shortage before the harvest of the other cereals. The SAFGRAD-I project (USAID funds) specifically funded the breeding research for earliness and enabled IITA maize researchers to expand outside their mandate area for maize into the semi-arid tropics. Moreover, maize became a major success story in Sub-Saharan Africa with SAFGRAD playing a role especially in the successes in West and Central Africa.

Cowpea successes were based on earliness and also on insect/disease resistances that had a larger effect in the drier Sudanian and Sahelo-Sudanian regions than the maize programs. With the droughts of the early '80s, farmers often lost their cowpeas entirely, including seeds for the next year. This made them more receptive to trying out the new experiment-station cultivars, especially new varieties with earliness for drought escape. New cowpea diffusion also occurred at a rapid rate in the higher-rainfall Guinea savanna.

A number of new sorghum cultivars have been introduced in West, Central, and East Africa, including E 35-1, Framida, S-35, Serena, Seredo, Gambella, Hageen Dura-1, and SRN-39. Nevertheless, given the specific mandate of ICRISAT to work in the semi-arid regions on sorghum and millet and the large amount of financial and human resource commitment there, why was there much less success in the sorghum and millet programs than in the maize and cowpea programs? Some of the factors associated with the harsh production environment for sorghum and millet have already been discussed.

In the main sorghum regional program for West Africa in Burkina Faso, sorghum breeding attempted over almost 11 years to introduce Indian germplasm. With the exception of S-35 in the Sudanian zones of Cameroon and Chad, this attempt to introduce Indian material was not successful. The Indian sorghum and millet experience was very successful there; however, the production environments in the Sudanian and Sahelo-Sudanian zones of West Africa are apparently harsher. The very high temperatures at planting were a major constraint to the introduction of the Indian material (Matlon, 1987, 1990).

Higher-yielding material, earliness, and some resistances in new cultivars, associated with higher chemical use in the Guinea savanna zone were all substantial achievements. These were principally successes of the IARCs and the NARS with some contribution in orientation and diffusion from SAFGRAD; however, some of the credit for the gains in confidence and the empowerment of the NARS has to go to SAFGRAD. This was an important achievement for the '80s. In the '90s more of the research system will be client rather than donor driven.

The next round of new technologies will require varietal and agronomic improvements for sorghum and millet in the Sudanian and Sahelo-Sudanian zones, respectively. In the Sudanian zone water-retention techniques will need to be combined with increased use of chemical fertilizer (Sanders et al., 1990). In the Sahelo-Sudanian zone, improvements in millet cultivars and increased fertilization will be necessary (Shapiro et al., 1993). This will be difficult on these sandy-dune soils. For the lower-rainfall regions of the Sahelo-Sudanian zone, it will probably be more efficient to increase cereal yields in other climatic zones with higher crop production potential and encourage a shift in land use here to agro-forestry with grazing. This will be an especially difficult human adjustment problem in countries with high population densities in the Sahelo-Sudanian zone, such as Niger.

For the Guinean region new production systems including a legume are necessary to reverse the declining organic matter in the soil (Sanders, 1989). Chemical fertilizer use on cotton and maize is already at reasonably high levels and is increasing in these Guinean production systems even with the elimination of fertilizer subsidies. Economical methods to increase the levels of organic fertilization are now needed here. Also in these systems, improving the quality of forages and better integration of livestock and crops are important and difficult research areas. Moreover, continuing maintenance research is necessary to sustain the higher yields obtained since agriculture is a dynamic system and the sources of biotic and abiotic pressures are continuously evolving.

APPENDIX A

SAFGRAD Contribution

At the beginning of SAFGRAD in 1978, most of the germplasm and the technological concepts came from the IARCS. For example, for earliness in maize the gene pool came from CIMMYT, IITA, and local sources. With USAID resources, SAFGRAD-I funded the continued breeding activities leading to new early material, which was introduced and then imitated by other countries. Other cases of direct SAFGRAD support of research will be identified.

Perhaps the most important contribution of SAFGRAD has been its facilitation of training, scientific collaboration, and confidence-building to the NARS. Note that the IARCs and other institutions actually did the training but SAFGRAD helped the NARS define their training requirements and get access to the training.

In the late '70s the NARS received germplasm from the IARCs and an important proportion of the research funds came from the donors. Much of the NARS research was donor driven since donor funding predominated. Also in the '80s many countries received an important share of the funding for research from special donor-funded programs for cereals research and/or extension. By the second half of the '80s and in the early '90s the regional variety trials contained an increasing proportion of NARS materials (see the following section on technology development and transfer, starting on p. 30). In the '90s the NARS are increasingly making their own decisions on research priorities and research strategies with the technical backstopping of the networks, the IARCs, and a new player in the game, the CRSPs. The CRSPs are U.S. government-supported, multi-university commodity or resource programs to increase productivity in developing countries by building up the ties between scientists in developed and developing countries. As the NARS establish themselves with scientifically qualified personnel and functional institutions, they increasingly will expect to set their own research priorities. This has been a major evolution for the larger NARS, and SAFGRAD has played a major role in this empowerment of the NARS. How to achieve economies of scale, adequate training, and technical efficiency in the smaller NARS is a major technical question now for these NARS and for the donors.

Another major concern is that the donors are no longer supporting these national or regional cereals programs. Donors' interests change; there are substantial financial demands of assistance from the formerly Communist countries; and the economic problems in developed countries in the '90s, such as Canada, are leading to reductions of assistance to Sub-Saharan Africa. Increasingly, national governments in Sub-Saharan Africa will have to pay for much larger shares of their research and extension costs. Research is a high-cost investment but with very high payoffs. Some of these high returns have been documented here and others cited. However, this information on the very high social returns to research will have to reach national policymakers so that research is able to compete for its share of the national budgets in developing countries.

Table B-1. Introduction of New Maize Cultivars[a] Resulting From the Breeding Program Begun in 1968 and of the SAFGRAD-Supported Early Material in Ghana, 1968-1991.

Year	All Improved Material	SAFGRAD Material
1968		
1969		
1970		
1971		
1972		
1973	5%	
1974	5%	
1975	5%	
1976	6%	
1977	6%	
1978	15%	
1979	15%	
1980	18%	
1981	18%	
1982	20%	
1983	20%	
1984	30%	
1985	30%	
1986	30%	2.0%
1987	35%	3.0%
1988	43%	3.5%
1989	47%	3.5%
1990	50%	4.0%
1991	55%	4.0%

[a] Includes only the new cultivars attributed to the breeding program since 1968; hence, there were no new materials considered as resulting from this program over 1968-72. During this period, an estimated 5% of the maize was in new or improved cultivars. Only one-half of the new materials over the period 1973-77 and all new materials after 1977 were attributed to this program.

APPENDIX B

The Returns to All Maize Research and to SAFGRAD Supported Maize Research in Ghana

Maize is Ghana's most important cereal crop and it was grown on 610,000 ha in 1991. The analysis of the national maize program here begins with the return of a breeder in 1968 from CIMMYT. There had been activity and the release of some new material before that but the takeoff of the program as reflected in the steadily increasing proportion of new cultivars introduced took place in the late '70s and '80s. In 1979 20% of the maize area was in improved cultivars. In 1980 the program had expanded to three breeders, an entomologist, an agronomist, and half the time of a pathologist. CIMMYT estimated that 43% of the area was in improved maize cultivars in 1988. The estimate of the former coordinator of this Ghanaian program was that 55% of the maize area in 1992 was in improved cultivars. So this is an impressive success story. The procedure here will be to first make some estimates of the costs and benefits of the overall national maize program. Then those benefits to the national program of the technology specifically associated with SAFGRAD will be separately estimated.

The evolution of the national maize team is given below:

Personnel in the Maize team:

1968 - One breeder, ½ agronomist, 10% pathologist, 5% entomologist.
1975 - One breeder, two assistant breeders, 1 assistant agronomist, rest of above.
1979 - One breeder, two assistant breeders, 1 agronomist, 1 economist, rest of above.
1986 - 3 breeders, 2 on-station agronomists, 3 half-time on-farm agronomists, rest of above.
1991 - To rest of team above add 1 biochemist and one rural sociologist.

The success of the maize program is illustrated by the release of new material. The area in new cultivars increased from 5% in 1968 to 55% in 1991. In this analysis, none of the new materials introduced from 1968-72 were included and only one-half of the new materials from 1973-77 were included. The introduction of the new early material associated with SAFGRAD is also reflected in Table B-1.

The IITA-SAFGRAD program of the early '80s looked for earliness so that maize production could be expanded in the semi-arid zone, especially in the Guinean savanna and more recently for extra earliness into the drier Sudanian zone. This was a new area of research focus not pursued by either IITA or CIMMYT. CIMMYT has carried on a research program to identify plant characteristics associated with drought tolerance. This emphasis by SAFGRAD on plant characteristics to enable maize to attain higher productivity in semi-arid regions was consistent with the mandate of SAFGRAD. Successfully-released early, national varieties have been SAFITA-2 and Kawanzie. More recently the streak-resistant variety, Dorke SR, was released. All three new maize cultivars mature in 90 to 95 days. Material from the Ghanaian program exchanged in regional trials has also been released as new cultivars in Mali (Golden Crystal) and Cameroon (Mexican 17 Early). So successes with both a new direction of breeding and with the international exchange of material of SAFGRAD are reflected in this successful diffusion.

The diffusion of the new cultivars now needs to be converted into shifts of the supply curve in order to estimate the economic benefits of the introduction of the new cultivars.

ADDITIONAL INPUT COSTS OF THE NEW MAIZE CULTIVARS

The improved cultivars are associated with higher input costs for purchasing seed and chemical fertilizer. One of the main advantages to the new maize cultivars is to raise the returns to and encourage the introduction of increased chemical fertilizer. Moreover, there are additional expenditures for the improved seeds. To simplify these initial calculations, the 1991 prices in cedes were utilized for fertilizer, seeds, and for the exchange rate from cedes to dollars. Estimates of these prices and of the fertilization and seeding rates were obtained from the national maize program of Ghana. Increased expenditures for seeds and fertilizer purchases are first estimated and then deducted from gross benefits to give net social benefits.

Changes in consumer and producer surplus are calculated following the Akino-Hayami technique. Border prices were used for calculating the value of production (international prices and transportation costs from Salinger and Stryker, 1991). Then the costs of the additional seed purchases and fertilizers were deducted to give the net social benefits resulting to Ghana from the technological change in the maize program.

So the net social benefits for the entire maize program ranged from $4.8 to $154 million per year over the period 1982-1991. The benefits to the SAFGRAD-associated early cultivars were much smaller as they were only introduced on a small area, 2 to 4% of the Ghanaian maize area from 1986-1991. Moreover, their yield effect was estimated to be only 20%. The principal benefit of early cultivars is risk reduction through drought escape rather than substantial yield potential in normal and good rainfall years. The net social benefits from the SAFGRAD-associated, early cultivars ranged from $400,000 to

$1.4 million per year. SAFGRAD provided many other more intangible benefits to the Ghanaian maize program. Moreover, these estimated benefits to earliness came at no additional costs to the program outside of the usual research and extension costs that were undertaken anyway.

EXTENSION COSTS

The former head of the national maize program traveled to Ghana and obtained estimates of the total extension costs and the contributions for extension from the principal donors.The estimates were obtained in cedes and converted to dollars with the official exchange rates for 1991 and 1992.

Table B-2. Dollar Expenditures for Maize Extension in Ghana, 1991 and 1992.

		FUNDING SOURCE (U.S.$)		
Year	Govt. Ghana	Global 2000	World Bank	USAID
1991	1,900,457			
1992	1,443,662	410,485	65,904	298,946

For Global 2000 it was estimated that 60% of its expenditures were for maize. For the other three funders 40% was used for maize's share. The donors became interested in Ghanaian extension during the structural adjustment program of the mid-'80s.To approximate maize extension costs, it was assumed that these expenditures stayed at 1991-92 levels from 1986-1991. For the decade prior to 1986 the government of Ghana was assumed to have spent 85% of its 1991 budget. For 1973-1976, it assumed it had spent 65% of this budget. Obviously, these numbers could be improved with some systematic tracking of these expenditures. Extension costs are an important component of the costs of getting new material from the research station onto farmers' fields. Moreover, extension often is a substantial cost item, much larger than research costs since salaries and support of well-trained African scientists tend to be very low. Most studies of the returns to research have little to say about the extension costs.

APPENDIX C

Estimating the Returns to Cowpea Research in Burkina Faso and Mali

Increasing the yields of grain legumes is more difficult than that of cereals. The yield gains for sorghum and maize have been much more rapid and the absolute yield increases greater than for soybeans in the U.S. and other developed countries. Grain legumes in the tropics have a large number of insect pests and are a secondary crop generally grown in association with cereals and with minimal purchased inputs. Since insect problems can be devastating both in the field and in storage, farmers frequently lose their seed and then have to purchase seed from other farmers or from the public sector. This turnover of seed is often an advantage for the initial diffusion of new cultivars. However, the widespread selling of a new cowpea cultivar, as in 1985 after the drought of 1984, does not yet imply successful diffusion. It reflects the loss of the crop in 1984.

On the experiment station monoculture cowpea yields can range between 1 to 2 t/ha. This would include adequate fertilization, principally with phosphorus, frequent spraying to control insects, and good nitrogen fixation. In the farmers' fields, maintaining cowpea yields even at the low present levels is an achievement. Here, measuring the benefits to maintenance research will be attempted. Without the introduction of the new cowpea cultivars, drought, insects, and *Striga* would have even further reduced farmers' yields in the two Sahelian countries of Burkina Faso and Mali.

The breeders' objectives in these two countries were earliness for drought escape; resistances or tolerances to disease, insects, and *Striga*; favorable taste characteristics; and higher yields.If success is evaluated by diffusion onto farmers' fields, the cowpea program in these two countries was very successful. Tables C-1, C-2, and C-3 summarize the diffusion information for the three principal climatic zones in the Sahel.

Table C-1. Diffusion of New Cowpea Cultivars in the Guinean Zones of Burkina Faso and Mali.

REGIONS				
	SOUTHERN BURKINA			SOUTHERN MALI
Year	KN-1	TVX 32-36	KVX 396	KN-1
1982	Release			Release
1983				
1984		Release		
1985				
1986				
1987				80%
1988				
1989	80%	20%	Release	
1990				
1991				
1992	80%	10%	10%	

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

Table C-2. Diffusion of New Cowpea Cultivars in the Sudanian Zones of Burkina Faso and Mali.

	CENTRAL BURKINA REGION					CENTRAL MALI REGION			
Year	KN-1	TVX 32-36	KVX 61-1	KVX 30	KVX 396	KN-1	TN 88	KVX 30	KVX 61
1981	Release					Release	Release		
1982									
1983	60%								
1984	30%	Release							
1985		10%							
1986		40%							
1987	20%	40%				60%	20%		
1988	0	20%							
1989		10%	Release	Release	Release			Release	Release
1990		10%	10%	10%	10%				
1991			15%		15%			15%	15%
1992			20%		20%				

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

Table C-3. Diffusion of New Cowpea Cultivars in the Sahelo-Sudanian Zonaes of Burkina Faso and Mali.

	NORTH CENTRAL BURKINA REGION					NORTH CENTRAL MALI REGION		
Year	Suvita 2	KVX 61	KVX 30	KVX 396	IAR 71	Suvita 2	KVX 61	KVX 30
1984	Release							
1985								
1986						Release		
1987								
1988								
1989	100%	Release	Release	Release		80%		
1990	70%	10%	10%	10%		100%	Release	Release
1991	60%	15%	10%	15%	Release	90%	5%	5%
1992	55%	15%	10%	15%	5%	80%	10%	10%

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

CALCULATION OF THE BENEFITS TO COWPEA RESEARCH

The above data provided the base for the extent of diffusion. The proportion of the production in each zone was estimated to be: Guinean zone, 40%; Sudanian zone, 45%; and Sahelo-Sudanian zone, 15%. Yields on farmers' fields were estimated to be from 200 to 400 kg/ha in association with minimal purchased-input use.

In the absence of the new cultivars with the continuing problems of drought, *Striga*, insects and diseases of the '80s and '90s, farm yields would have fallen by at least 50% and perhaps by 100% since the new cultivars did largely replace the traditional ones. To be conservative, the benefits to research were calculated for 25% and 50% yield declines.

Technology Development and Transfer of Selected NARS

Alan Schroeder

INTRODUCTION

This section examines the steps involved in the development and transfer of new technologies by national commodity research systems. Findings highlight progress that has been made in developing, adapting, and disseminating technology and provide a better understanding of opportunities for increasing productivity of the commodities and countries examined.

The agricultural technology development and transfer process has been broken down into its components for this analysis of selected NARS. This process begins with the introduction/collection of potential technologies. These technologies are screened to determine their adaptability and potential for use. Technologies are tested on research stations to determine their yield potentials compared with farmers' practices.

Technology development occurs when existing technologies or techniques are modified to enhance their performance potential. Generally, technology development requires a higher level of skill and expertise than adaptation work. The potential for increasing the number of technology options available is enhanced in a system that is actively involved in development. New technology options either directly introduced from other regions or further developed are then compared with existing technologies in research-station trials.

Technologies that are high performers in research station trials are then tested on farms. If the technologies continue to perform well on the farm and are acceptable to farmers, then they may be recommended for release to the general public.

Following a process of review of the technology for performance and stability across a range of environmental conditions and years of testing, the technology may be officially released. Some NARS also have programs to demonstrate the new technologies on-farm to a wider group of clients. The release of new technology is generally accompanied by a technology-multiplication program to ensure provision of ample supplies for distribution and sale to farmers.

Technologies Released

The amount of time required to develop new agricultural technologies for release is generally about 10 years. Most of the technologies distributed by SAFGRAD in the early to mid-'80s were those from International Center germplasm banks or those locally collected. These were tested for adaptation to semi-arid conditions and specific regional constraints. Sometimes there was further breeding work. Then the new cultivars were distributed through regional trials. The first phase of the SAFGRAD project was primarily concerned with germplasm development and distribution, while the second phase concentrated more on networking and increased involvement of the NARS in supplying and testing technologies.

The maize network has the highest number of total releases for the five countries surveyed, that is, 78 new technologies (varietal and non-varietal) (Table 1). In fact, maize cultivar releases were more than twice those for the cowpea network and more than four times those for sorghum. Cowpea and sorghum follow with 32 and 17, respectively (Tables 2 and 3). Technologies released in two east African countries, Ethiopia and Kenya, number 26. All of the east and central African countries reported releases of new cowpea and maize technologies, while only Ghana and Mali reported releases of new sorghum technologies.

Cameroon, Ghana, and Nigeria released the largest numbers of new maize varieties, more than twice as many as Burkina Faso or Mali. Not surprisingly, these three countries also have much larger maize-production areas than Burkina Faso or Mali. The largest numbers of new cowpea varieties were released by Nigeria, twice as many as any other country. Again, Nigeria has a much larger cowpea-production area than any of the other countries.

Ghana released the largest number of new sorghum varieties, three times that of the only other country releasing new varieties. Given the large areas of sorghum production in Burkina Faso and Nigeria and the paucity of new technologies, more effort needs to be undertaken in these countries to move technologies on the shelf to the release stage and onto farmers' fields. In fact, streamlining the process of review and release of new technologies remains a major challenge for future investments in technology development.

Almost half of the new sorghum technologies released in Ghana, Mali, Kenya, and Ethiopia were non-genetic in nature; for example, methods for planting, fertilizing, and processing techniques. Conversely, about 90% of the maize and cowpea technologies released were genetic in nature, while only 10% were non-genetic.

Some attention has been given by the NARS to the development of water- and soil-conservation measures, integrated pest-management strategies, and processing, marketing and policy studies, and other off-farm constraints.

Kenya has recommended more sorghum production techniques for farmer use than new varieties. Ethiopia recommends not only techniques for sorghum production but also storage and processing technologies. Both Kenya and Ethiopia have released about the same number of new varieties.

Table 1. Development of New Maize Technologies in Selected NARS, 1982-1991.

Varietal Technologies	Burkina Faso	Cameroon	Ghana	Mali	Nigeria	TOTAL
	Number	Number	Number	Number	Number	Number (%)
Varieties Multiplied	13	16	12	5	9	40
Multiplied Varieties that were in SAFGRAD trials	3	8	6	2	4	23 (58%)
Varieties Released	8	24	13	9	15	69
Released Varieties in SAFGRAD trials	5	9	7	6	5	32 (46%)
Released Varieties Developed by SAFGRAD	4	7	1	2	2	16 (23%)
Most Promising Varieties On–Farm Verified	5	24	15	8	9	61
Promising Varieties that were in SAFGRAD trials	3	10	8	5	3	29 (48%)
Most Promising Varieties Finally Released	2	24	8	8	9	51 (84%)
Varieties Demonstrated On–Farm	57	0	12	3	36	
Farmers	–	0	4012	–	345	
Variety Entries in Verification Trials On–Farm	38	103	191	61	42	
Non–Varietal Technologies						
Non–Varietal Technologies Released/Recommended	5	3	1	–	–	9
Types of Technologies in On–Farm Verification	8	18	24	9	5	
Trials	33	1089	1005	235	32	
Treatments	51	218	437	148	75	
Types of Technologies in On–Station Performance	55	21	59	18	18	
Trials	194	164	254	232	182	
Treatments	2058	553	1027	404	671	

Table 2. Development of New Cowpea Technologies in Selected NARS, 1982-91.

Varietal Technologies	Burkina Faso	Cameroon	Ghana	Mali	Nigeria	TOTAL
	Number	Number	Number	Number	Number	Number (%)
Varieties Multiplied	9	–	10	13	3	35
Multiplied Varieties that were in SAFGRAD trials	8	–	6	9	2	25 (71%)
Varieties Released	6	4	4	5	11	30
Released Varieties in SAFGRAD trials	6	3	4	5	4	22 (73%)
Released Varieties developed by SAFGRAD	6	0	0	4	1	11 (37%)
Released Varieties developed by IARC	0	3	4	?	2	9 (30%)
Most Promising Varieties Tested in On–Farm Verification	8	9	4	4	5	30
Promising Varieties that were in SAFGRAD trials	7	4	3	4	1	19 (63%)
Most Promising Varieties Ultimately Released	5	4	3	4	1	17 (57%)
Varieties Demonstrated On–Farm	0	0	25	0	0	
Farmers	0	0	2004	0	0	
Variety Entries in Verification Trials On–Farm	32	–	125	33	–	
Non–Varietal Technologies						
Non–Varietal Technologies Released/Recommended	–	2	–	–	–	2
Types of Technologies in On–Farm Verification	5	4	13	–	–	
Trials	1254	100	392	–	–	
Treatments	60	39	296	–	–	
Types of Technologies in On–Station Performance	14	5	18	47	50	
Trials	108	63	88	291	528	
Treatments	486	217	528	1139	2940	

Table 3. Development of New Sorghum Technologies in Selected NARS, 1982-91.

Varietal Technologies	Burkina Faso	Cameroon	Ghana	Mali	Nigeria	TOTAL
	Number	Number	Number	Number	Number	Number (%)
Varieties Multilplied	9	–	12	–	–	21
Multiplied Variëties that were in SAFGRAD trials	1	–	5	–	–	6 (29%)
Varieties Released	0	–	7	2	–	9
Released Varieties in SAFGRAD trials	–	–	3	2	–	5 (56%)
Released Varieties Developed by SAFGRAD	–	–	1	0	–	1 (11%)
Most Promising Varieties On–Farm Verified	22	–	10	6	9	47
Promising Varieties that were in SAFGRAD trials	9	–	4	3	1	17 (36%)
Most Promising Varieties Ultimately Released	0	–	6	2	–	8 (17%)
Varieties Demonstrated On–Farm	–	0	14	0	0	
Farmers	19	0	–	0	0	
Variety Entries in Verification Trials On–Farm	17	0	78	115	0	
Non–Varietal Technologies						
Non–Varietal Technologies Released/Recommended	0	–	5	3	–	8
Types of Technologies in On–Farm Verification	7	8	19	35	1	
Trials	18	752	78	520	83	
Treatments	22	163	246	1593	16	
Types of Technologies in On–Station Performance	9	13	17	31	5	
Trials	19	23	74	111	19	
Treatments	114	608	399	1023	270	

SAFGRAD Transfer of Released Technologies

SAFGRAD networks have been a major mover of technologies developed by diverse sources. Approximately half of the maize and sorghum varieties released had been in SAFGRAD trials. Almost three-fourths of the released cowpea varieties by the NARS were from SAFGRAD trials. These results are all the more striking since varieties distributed through SAFGRAD cowpea trials represented only from 14% to 54% of the total numbers of varieties tested in the five west African study countries. The same trend is seen for maize; the amount of SAFGRAD trials germplasm tested represented only 6% in Cameroon to 32% in Mali, yet half of the varieties released in these countries had been in SAFGRAD trials.

These results indicate that technology offered through SAFGRAD's trials proved to be extremely useful to the NARS. The other major donors of technology were the International Agriculture Research Centers, followed by locally collected technologies and those from other NARS.

Spillover of Released Varieties

By tracing the released varieties by name in each country, the pace of spillover can be evaluated, especially the amount of time from release in one country to release in another. Here, only the varieties released in more than one country are examined (Table 4). The greatest amount of spillover occurred in the maize network, followed by the cowpea network, and only one for the sorghum network.

Table 4. Spillover of Released Technologies

Crop	Technology	SAFGRAD/ Year	Country/ Yr. Released	Country/ Yr. Released	Country/ Yr. Released	Country/ Yr. Released
COWPEAS	KN-1	1980	Burkina 82	Mali 86		
	TVX 3236	1981	Burkina 83	Mali 85	Nigeria 85	
	Gorum	1980	Burkina 83	Mali 88		
MAIZE	Safita-2	1982	Cameroon 82	Ghana 83	Mali 84	Burkina 86
	Gold Crystal	1982	Ghana 82	Mali 86		
	TZE SR-W	1982	Burkina 83	Mali 90		
	Pool 16	1983	Burkina ?	Mali 83	Cameroon 91	
	Mexican 17-E	--	Cameroon 82	Ghana ?		
	Maka	1991	Burkina 86	Mali 91		

Nine new maize varieties, five of which appeared in SAFGRAD regional trials, were released by more than one country. Burkina Faso, Mali, Cameroon, and Ghana benefitted from these exchanges. Four cowpea varieties offered in SAFGRAD regional trials were released in more than one country. In this case Burkina Faso and Mali are the primary sharers of three of these technologies.

The year of release of technologies in each country reveals that it has taken several years to review and release these same high-yielding technologies in other network countries. Again, these results emphasize the need for streamlining the process of technology review and release. One of the goals of networking is to get high-yielding technologies moving quickly from farmers' fields in one country to farmers in the other network countries.

SAFGRAD Development of Released Technology

More than one-third of the released cowpea varieties were developed by SAFGRAD in collaboration with IITA. Sixteen percent of the released maize varieties and 11% of the released sorghum varieties were developed by SAFGRAD with IARC collaboration. The remainder of the released technologies were developed either locally or solely by the International Centers. These findings indicate that SAFGRAD's role as a collector and distributor of technologies has been more important than its role as a developer of technologies. Three, or half, of the varieties released in Kenya were developed by ICRISAT/Kenya, while only one of the six released in Ethiopia was developed by ICRISAT.

NARS Development of Released Technology

Again the maize network comes out on top with the greatest number of locally developed technologies being released, 18. Cameroon and Ghana are the countries that helped achieve this success, with nine varieties each. Some of the varieties released in Burkina Faso and Nigeria were developed collaboratively between scientists from the NARS and IITA.

The sorghum network comes in second, with four released technologies being locally produced. Ghana and Mali developed two varieties each that were released in their countries. Only one locally produced cowpea variety was released, in Nigeria. In East Africa, it appears that Ethiopia is the largest producer of new varieties for diffusion to other network countries. Ethiopia is hypothesized to be the center of origin for sorghum.

MULTIPLICATION OF VARIETIES

Varieties Multiplied

Seed of released varieties of cowpeas, sorghum, and maize is being multiplied for use by farmers in most of the countries reporting. In several countries, only a fraction of the varieties released were multiplied. For instance, only one-fifth of the cowpea varieties released in Nigeria have been multiplied for farmers. Only a third of the maize varieties released in Mali and Nigeria were multiplied. Unreleased varieties make up the remainder of those multiplied in these countries.

Information on the multiplication of seed of cowpeas, maize, and sorghum shows that varieties that have not been released are often being multiplied by farmers themselves. For example, in Ghana and Mali, twice as many cowpea varieties are being multiplied as have been released. There is a two-year lag between the time cowpea varieties are first multiplied in Ghana and the year they are released. The varieties, Valenga and Black Eye, were first multiplied in 1984 and 1987, respectively, whereas they were first released in 1986 and 1989. Some of the cowpea varieties released and multiplied in Mali and Nigeria show the same trend.

Maize seed multipliers in the five countries produced seed of many of their released varieties and seed of varieties not released. More varieties of maize have been multiplied than cowpeas or sorghum. Only two countries in West Africa, Burkina Faso and Ghana, reported the multiplication of sorghum for farmers. Kenya and Ethiopia both multiplied seed of most of their released varieties of sorghum, and even some varieties not listed as released.

SAFGRAD Transfer of Technologies Multiplied

Large percentages of the multiplied varieties of the three commodities were present in SAFGRAD regional trials. Cowpeas are first with an impressive 71%, followed by maize with 58% and sorghum with 29%. Again, SAFGRAD was a major mover between countries of technologies, which had been multiplied in one of the NARS.

TECHNOLOGY IN THE PIPELINE: PRE-RELEASE TECHNOLOGY

Technologies in the Pre-Release Stage

Maize network countries have had the largest number (61) of most promising technologies tested in on-farm trials. Moreover, they also have the largest percentage of these released, 84%. This leaves fewer promising maize technologies in the pipeline but indicates maize-network countries are more effective at pushing the promising technology to the release stage. The opposite is true for the sorghum network countries, where only 17% of promising technologies have reached the release stage. However, the sorghum network countries do come in with the second highest number of promising technologies, 47. Cowpeas follow with 30 promising technologies, and more than half of these were released.

A major future emphasis of the sorghum and cowpea networks should be intensified on-farm work to move more of the promising technology to the release stage. The maize network has substantial emphasis on farm-level verification and release; however, increased attention to soil and water management, marketing, processing, and policy studies could further strengthen their position.

Half of all promising maize and sorghum technologies and a third of the promising cowpea technologies have been transferred through SAFGRAD's regional trials. The fraction of SAFGRAD maize technologies present in the pipeline matches the fraction that has been released. However, the fraction of SAFGRAD cowpea and sorghum technologies in the pipeline is substantially lower than the fraction released. The on-farm development stage is where higher proportions of SAFGRAD cowpea and sorghum technologies are advanced in comparison with promising technologies from other sources.

None of the unreleased promising sorghum technologies and only one of the maize technologies have been developed by SAFGRAD. Conversely, five (40%) of the pre-release cowpea technologies were developed by SAFGRAD. The majority of the promising sorghum, maize, and cowpea technologies were developed by the IARCs.

INTRODUCTION AND COLLECTION OF TECHNOLOGIES

Technology Sources

Locally collected germplasm forms the largest proportion (about half) of that made available for testing by the cowpea and sorghum network-member countries, whereas it forms the smallest proportion for maize. Since cowpea and sorghum are indigenous to the Sahel, local collections should provide a large proportion of new cultivars.

Almost two-thirds of the maize technology provided to network countries was from the International Centers, IITA and CIMMYT. Maize is not indigenous to Africa, so there would not be a wide local genetic base to work from. Most of the germplasm containing genes for drought tolerance has come from CIMMYT in Mexico, and most of the germplasm with resistance to maize streak virus was developed at IITA.

An increasingly larger portion of the SAFGRAD trials contain technologies developed by the NARS. And the proportion of SAFGRAD's contributions to the total germplasm pool available to the NARS has increased from 1982-1986 to 1987-1991. These results indicate that the networking mechanism implemented in the second phase of SAFGRAD has been successful in increasing the involvement of the NARS in technology transfer.

Composition of SAFGRAD Regional Germplasm Trials

SAFGRAD has been a major contributor of germplasm to the NCRS for adaptation and use in breeding. Each year, SAFGRAD collects germplasm from diverse sources for its regional trials in the NARS (Figs. 1-3).

During the past five years, the percentage of germplasm donated by the NARS to the SAFGRAD trials has increased for cowpeas and sorghum to around 50% to 60% of the total. The number of entries from the IARCs has decreased to 40% to 50%. The rapid dropoff in percentage of SAFGRAD-developed germplasm present in the regional cowpea trials was caused by the increased crediting of this germplasm to the Burkina Faso NARS scientists instead of to the SAFGRAD/IITA project. The NARS developed the germplasm in collaboration with the SAFGRAD cowpea coordinator, and thus they were given major credit for its development.

Maize entries from NARS have declined in SAFGRAD regional maize trials from 1982 to 1991, and the percentage contributed by SAFGRAD has increased measurably, tailing off at about 75%. The amount contributed to SAFGRAD trials from the IARCs remains around 20% to 30% of the total.

The amount of germplasm in each regional trial has generally remained the same (usually between 10 to 15 entries per trial) while the number and diversity of trials has increased. Thus the overall amount of germplasm made available through SAFGRAD has increased. This indicates a diversification of technologies available as more of them are classified by resistance to constraints and as evolving NARS gain increasing abilities to identify and work with these additional constraints. The SAFGRAD Phase II networking thrust has been successful in building up the NARS and helping them take over technology generation.

Fig. 1. % MAIZE GERMPLASM, BY SOURCE, IN ALL WECAMAN REGIONAL TRIALS

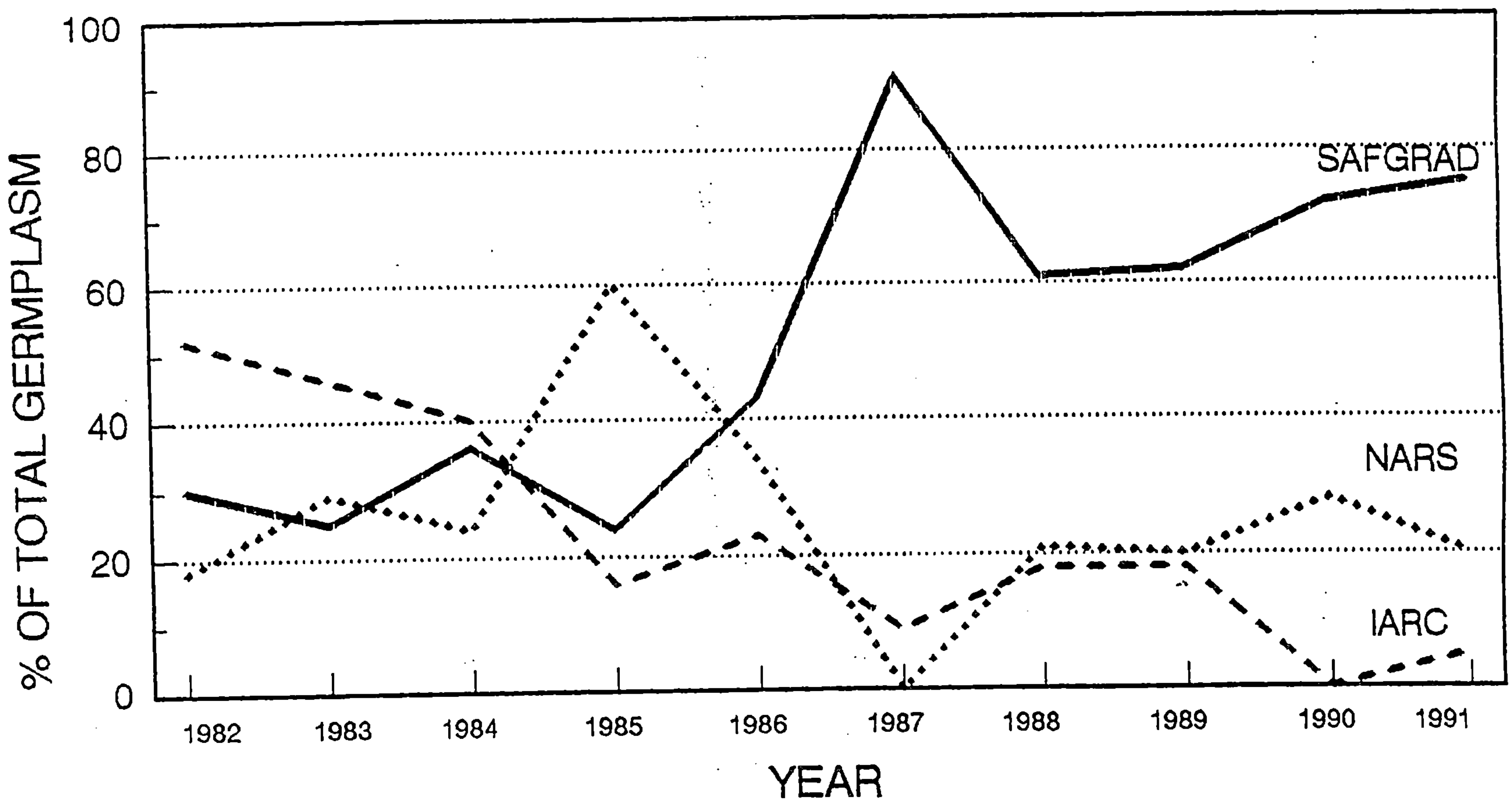


Fig. 2. % COWPEA GERMPLASM, BY SOURCE, IN ALL RENACO REGIONAL TRIALS

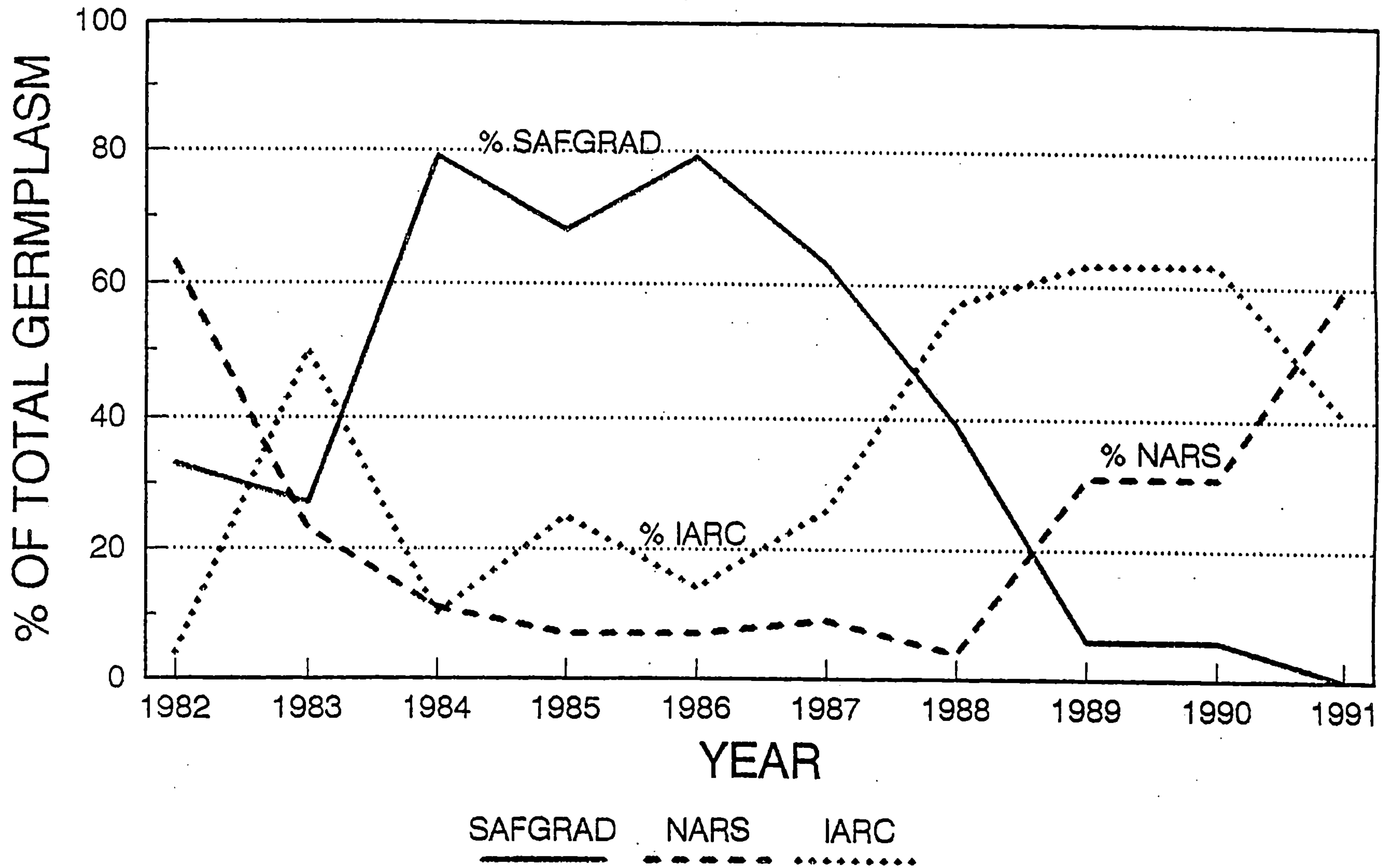
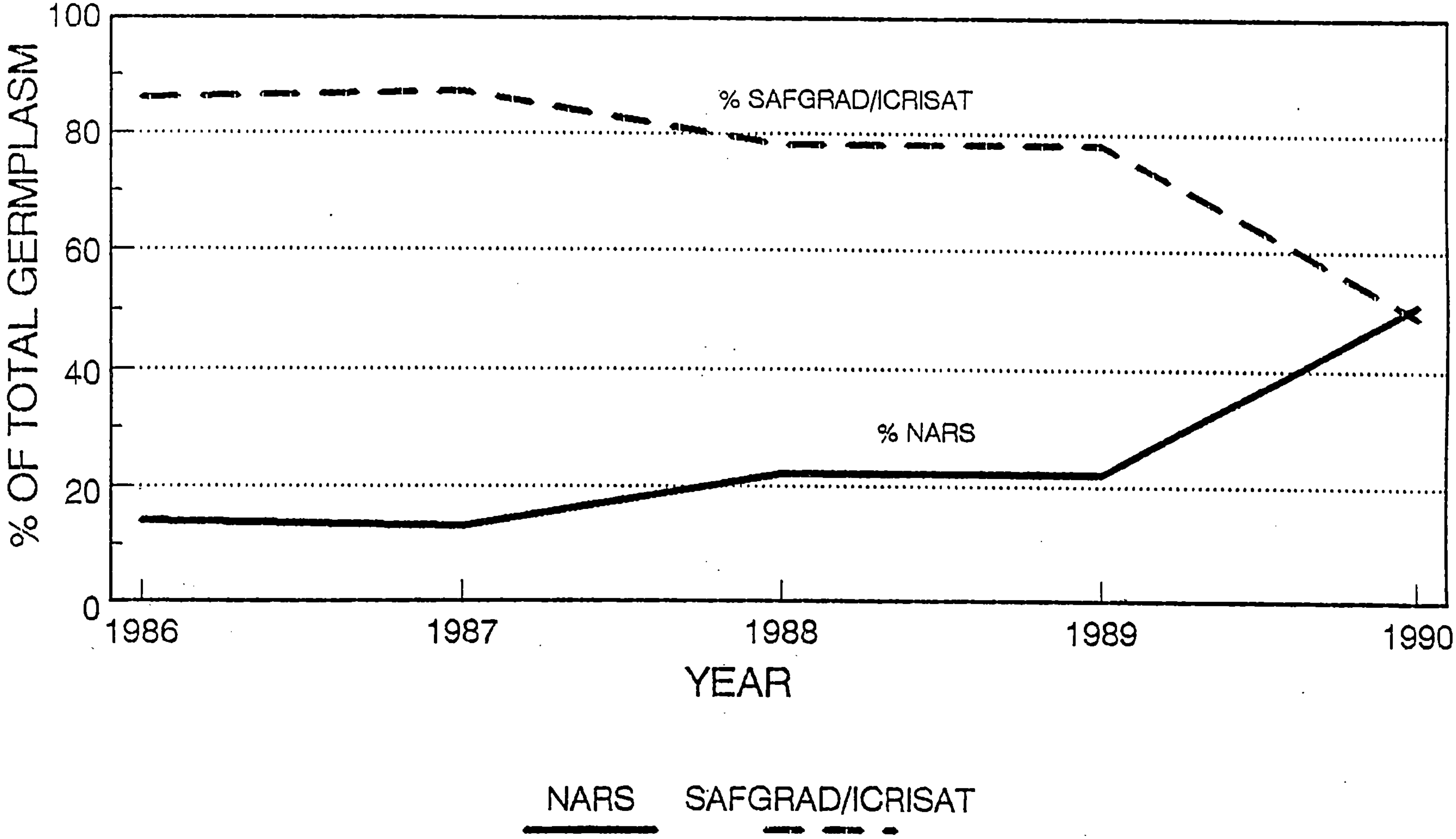


Fig. 3. % SORGHUM GERMPLASM, BY SOURCE, IN ALL
WECASORN REGIONAL TRAILS



ADAPTATION AND DEVELOPMENT OF GERMPLASM

Ratios of Development: Adaptation Work

The proportion of technologies developed or adapted should prove important in examining the capabilities and accomplishments of the NARS. Here we examine the amount of effort, in terms of entries tested for adaptation or first developed locally and then tested. The emphasis of substantial NARS effort was on germplasm improvement.

Results of this analysis show that most of the NARS in each network are performing development work and, in several cases, much more work in development than in adaptation. This result is generally due to the presence of breeders in the NARS. This analysis does not take into account the adaptation and development of other types of technologies besides new cultivars.

Burkina Faso cowpea NARS performed 21 times as much work on development of new cowpea technologies than on testing of existing technologies. This ratio is also supported with the above data on the increasing percentage of the SAFGRAD-trials' germplasm coming from the Burkina Faso NARS scientists, indicating high levels of germplasm development. Ratios for Mali and Ghana show that they each performed two to four times more work on development than on adaptation.

Burkina Faso cowpea NARS also performed five and 10 times more varietal development work than Ghana and Mali, respectively, with more than 37,000 breeding progenies tested. In addition, the number of entries tested for adaptation was one and a half times higher for Burkina Faso and Ghana than in the other three countries.

Nigeria NARS released the most new cowpea technologies and has the highest cowpea production area, but performed the least amount of development work. It is possible that the IITA program in Nigeria supplanted the Nigeria NARS with development of the new varieties that were released, and the scientists in these IITA cowpea development programs claimed no credit for the work.

Cameroon, Ghana, and Nigeria are the most active in the development of new maize technologies, with around 10 times more development work than adaptation work each. Although Cameroon and Ghana both show 11 times more maize varietal development work than adaptation work, Cameroon actually performed about four times more development *and* adaptation work than Ghana, with more than 54,000 breeding progenies tested. Nigeria, with a ratio of eight, performed only half as much maize development and adaptation work as Ghana.

Mali and Burkina Faso are the only countries with significant sorghum development work that exceeds adaptation by margins of 6 and 1.4 to one, respectively. Cameroon, Ghana, and Nigeria each performed sorghum germplasm development work; however, this represents only a fraction of that performed on adaptation.

ADAPTATION AND DEVELOPMENT OF ALL TECHNOLOGIES

SAFGRAD Network Influence on On-Station Experiments

Each SAFGRAD network supports collaborative research projects of production constraints at Lead and associate NARS. The projects are chosen according to each country's identified production constraints and its subjective estimates of being successful in these research areas. Duplication of research effort is minimized by dividing up the responsibilities among member countries. Since the experiments completed on-station are certified by research constraint, progress of each NARS on the specific constraints can be identified.

By totalling the number of experiments that deal with some aspect of each country's chosen network collaborative research constraints, changes from SAFGRAD Phase I to II can be tracked. An increase in numbers would indicate an increase in ability to accomplish such research. This increase could be attributed to several factors including increased levels of training, numbers of human resources, or funding levels.

Measurable increases in the numbers of experiments completed on-station for production constraints were recorded from Phase I to II of SAFGRAD for all five west African countries involved in the cowpea network.

Maize network collaborative research projects deal primarily with germplasm development and improvement, which is performed on-station. Burkina Faso, Cameroon, and Ghana have all increased in the amounts of germplasm development work performed from SAFGRAD Phase I to II; thus, the amount of on-station work has increased. In East Africa, Ethiopian scientists performed markedly more on-station network constraints research during Phase II of SAFGRAD than in Phase I.

Measurable increases in the numbers of on-station experiments on SAFGRAD sorghum-network constraints have occurred from Phase I to II in all five West African countries. The Mali NARS performed its first ever on-station trials on *Striga* in Phase II of SAFGRAD.

SAFGRAD Network Influence on On-Farm Experiments

As with on-station experiments, in the countries performing on-farm experiments, greater numbers of experiments on network constraints have been performed on-farm for all commodities in the last five years than had been performed in the preceding five years. In fact, many of the countries did not perform on-farm experiments on these constraints during the first phase of SAFGRAD. Thus in the span of time from SAFGRAD Phase I to Phase II, trials on SAFGRAD constraints have moved from the station to the farm, an impressive improvement.

APPENDIX A

Response to This Report From J.P. Eckebil
Associate Director of International Cooperation
IITA, Ibadan, Nigeria

In 1990, SAFGRAD and the IITA Maize Program reached an agreement meant to harmonize germplasm delivery to NARS so as to avoid duplication of efforts and overburdening national scientists. According to that agreement, SAFGRAD was responsible for the organization of international testing of all early and extra-early maturing varieties in the sub-region and IITA was responsible for the coordination of the late/intermediate variety trials. It is in this latter maturity group that the NARS traditionally made major contributions in terms of varietal development.

These contributions since 1990 seem not to have been taken into consideration by the impact assessment study which focused mainly on purely SAFGRAD activities, hence the impression created of decline of NARS' maize varieties in regional trials during that period. So far as the early and extra-early group is concerned, NARS have nominated some early varieties to regional trials since 1990. But for the extra-early group, it should be noted that they constitute a new generation of technology initiated in 1987 by SAFGRAD and that no NARS or IARCs had ever worked on them — which explains that nomination of varieties to this maturity group for regional trials was made exclusively by SAFGRAD.

The increasing importance of the extra-early and early varieties in the semi-arid zone (especially in the Sudan savanna) for filling the hunger gap has aroused interest of NARS in maize of the two maturity groups. Also, extra-early germplasm with desirable attributes is now available from the resident research program of the Maize Network Coordinator. It is anticipated that NARS personnel assigned responsibility for generating varieties of different maturity groups for the Maize Network would be encouraged to take over the breeding work on the extra-early varieties from the Maize Network Coordinator in the future with germplasm now available to them.

In conclusion, we would like to stress that although the contribution of NARS vis-à-vis SAFGRAD to the regional trials declined during SAFGRAD II. This has nothing to do with maize not being indigenous to Africa. We all know there is a wide collection of germplasm from all over the world under storage in CIMMYT, IITA, USDA, and in several national programs in West and Central Africa. These germplasm banks are at the disposal of national programs, and exotic germplasm can be requested for use in the national breeding programs at any time to broaden the genetic base of breeding populations, pools, and so forth. Therefore, the problem is not with the lack of availability of genetic diversity.

APPENDIX B

Response to This Report (With Minor Deletions) of F.M. Quin, Director, Crop Improvement Division IITA, Ibadan, Nigeria

We recognize that IARCs need to report on their achievements, not least so as to assure donors that their support is worthwhile. However, we are of the view that we should endeavor to move away from attributing germplasm and breeding materials to specific institutes. In addition, in the case of a project like SAFGRAD, NARS' work efforts clearly contributed to the further development of IARC germplasm. In many cases, NARS tested IARC varieties extensively in their countries before releasing them, often without changing the name from that which it was given by an IARC.

Work is still continuing on problems specific to the semi-arid zone, e.g., extra-earliness, drought resistance. Extra-earliness, which has the potential for becoming a highly significant breakthrough for the semi-arid area, is entirely a SAFGRAD project and illustrates SAFGRAD's contribution to building up the research capacity of NARS. The development of earliness and extra-earliness is, in fact, an excellent example of IARCs and NARS collaboration in a common goal of improving food security in marginal areas.

We know that some of the favorable attributes for tolerance of dry conditions can be traced to CIMMYT germplasm. Equally, we know that those materials would not have reliable performance without conversion to resistance to maize streak virus. This conversion is feasible, both at IARC and NARS levels, because of IITA's extensive work on this disease in identifying sources of resistance and developing appropriate methods for incorporating this resistance into susceptible varieties. Finally, we have the increased capability at NARS' level of using and building upon the technologies that IARCs can offer. In sum, there is a strong case for a more nonspecific view of the institutional aspects of germplasm improvement.

The fear raised in a section of the report that "research capital stock of technology in the African pipeline (is) being exhausted" is not justified. New germplasm resulting from intensified research efforts at IARCs on other African-specific problems (for example, on *Striga*, stem borer, and adaptation from improved drought resistance and standability) are continuously being made available to NARS through international trials. Germplasm from CIMMYT is also being adapted through a CIMMYT liaison Breeder based in Cote d'Ivoire who integrates his efforts through IITA.

Institutional Evolution of the NARS in the SAFGRAD Networks

Taye Bezuneh

The Research Policy and Planning Process

The institutional capacity of five NARS covered by the impact assessment study is summarized in Table 1. The research policymaking and management of case-study countries varied considerably. In some countries, the national agricultural system is under the supervision of a Council comprised of various development, planning and finance ministries as in Burkina Faso. Other NARS operate under a Board of Governors or Directors, as in Ethiopia, Kenya, and Niger. A few NARS are managed by a Supervisory Committee comprised of technical ministries and research agencies including universities, or technical committees comprised of senior researchers and policymakers, such as in Cameroon, Ghana, and Mali.

Councils or Boards of Governors of specific NARS vary in their mandate, legal framework, and authority provided to them to initiate policy reforms and to forcefully monitor and ensure that research priorities and programs are based on the national agricultural development policies. The planning process of most NARS is still weak since researchers in various countries do not fully participate at the level of national planning ministry or the Ministry of Agriculture in the development of the agricultural sector national plans.

In Nigeria, because of its size, the NARS structure and management is unique and relatively complex. Until very recently, the Federal Ministry of Science and Technology (FMST) was responsible for the coordination and management of all agricultural research in the country. There is discussion of shifting this responsibility to the Ministry of Agriculture to bring research and extension under the same umbrella.

Research policy coordination in Nigeria is quite different and complex because of the large number of institutes. Presently, there are 18 agricultural research institutes under the Federal Ministry of Science and Technology (FMST). These institutes are semi-autonomous in their planning and management of research. Some of them are affiliated with faculties of agriculture in the universities. Although the identification of research priorities and planning of programs is not centrally coordinated by a Scientific Council or Policy Board, technical committees at each institute level review and approve research programs. A joint inter-institute technical committee further scrutinizes all the institutes' research budget and programs prior to approval. Linkage between the planning and agriculture ministries seems to be adequate. Since agricultural research institutes are under the umbrella of FMST, the participation of researchers in the national economic planning has been on an ad-hoc basis.

Table 1. **Analysis of the Institutional Base of Five National Agricultural Systems Covered by the Impact Assessment Study.**

Country	Research Policy and Management Apex	Organization of Research	Environment for Research (Human Resources, Funding, and Linkages)
BURKINA FASO 1. Institut d'Etudes et de Recherches Agricoles (INERA) 2. Institut de Recherches en Biologie et Ecologie Tropicales (IRBET) For more details, refer to the Appendix.	The National Agricultural Research System is under the management of the Council comprised of the Ministry of Higher Education and Scientific Research (Chairman), the Ministry of Agriculture and Livestock (Vice-Chairman), Ministry of Finance, Ministry of Planning. The Council ensures that research programs are based on national development policies. Existing processes are adequate and participatory for setting research parities and for allocation of resources. These two institutes enjoy reasonable autonomy as specialized agencies of the National Center for Scientific and Technical Research (CNRST).	The National Agricultural Research Institute (INERA) at its headquarters has research and resource management divisions. The research division coordinates activities of the eight major programs and the resource division, provides financial procurement and administrative services to the agriculture experiment stations through the station managers. INERA has eight major programs including crops, livestock, and FSR. INERA need to establish a unit for monitoring and evaluation of research performance. IRBET conducts ecosystems forest ecology research.	As of 1990-/91, INERA had 93 researchers, 172 technicians, and 186 support staff. About 25% of researchers held doctorate degrees, 36% M.Sc. or equivalent, 40% B.Sc. degree or equivalent. The National Scientific Committee has an established research-career development and promotion scheme. Most of NARS projects thrive on donor funds. About 77 and 23% of the budget resources are from external and government sources respectively. INERA needs to improve its linkages between its own programs and between extension and research. There is good collaboration between INERA and international and regional organizations, such as CIRAD, IITA, ICRISAT, SAFGRAD, ISNAR, and ICRAF.
CAMEROON 1. Institute of Agricultural Research/Institut de la Recherche Agronomique (IRA) 2. Institute of Animal Research and Veterinary Sciences/Institut de Recherches Zootechnique et Vétérinaire (IRZV).	IRA performance contract with the government calls for a supervisory committee comprised of these technical ministries: The Ministry of Scientific and Technical Research conducts most agricultural research. Others that conduct adaptive and applied research are: Ministry of Agriculture, Ministry of Livestock, Fisheries and Animal Industries, Ministry of Environment and Forestry, and Ministry of Higher Education. Research is not adequately coordinated at planning and at policy level. A Council or Management Board comprised by above-mentioned ministries is not in place. Existing separate institutional arrangements are not adequate to set research priorities based on national development policies. The crops (IRA) and animal (IRZV) institutes,as well as others,operate independently. IRA has managerial autonomy.	IRA, established in 1974, has the mandate for crops, forestry, soil, and land-studies research. Crop research is undertaken by four regional centers and sub-stations. IRA has 16 programs being carried out at different ecologies. The animal science research institute (IRZV) has 13 programs, the main ones being beef, small ruminants, fishery, diary, poultry and agrostodogy. Both IRA and IRZV have collaborative programs in agriculture and in socio-economics research with University Center Dschang. IRA has a Testing and Liaison Unit (TLU) to enhance the transfer and adoption of technology. This activity also provides feedback to the IRA system on the performance of technologies. Perhaps merging IRA and IRZV into one institute could enhance multidisciplinary research in resource management.	The Cameroon NARS (IRA and IRZV) has 320 researchers, about 480 technicians, and 2160 support staff. About 24% and 43% have Ph.D. and M.Sc. degrees, respectively. Most of the operational cost for research projects is supported from external sources. About 80% or more government-allocated funds is for personnel costs. Linkages between and among programs need to be improved. There is good cooperation between technical-development ministries and the above-mentioned research institutes in crops and animal production. Inter-institutional collaboration, for example, between IRA and IRZV on research programs needs to be strengthened. Funding is the major constraints for agricultural research because of declining revenue after the mid-'80s. Personnel costs of IRA is estimated to be about $7 million for 1992-93. International collaboration of IRA includes IITA, CIRAD, SAFGRAD, ISNAR, ICRAF, and ICRISAT.

Table 1 (cont.)

Country	Research Policy and Management Apex	Organization of Research	Environment for Research (Human Resources, Funding, and Linkages)
ETHIOPIA 1. The Institute of Agricultural Research (IAR).	The policy and research management apex is the Ministerial Board of Directors comprised of the Minister of Agriculture (Chairman), State Farms Development, Commissioner for Science and Technology, Higher Education Commission, the Office for Central Planning,etc. IAR enjoys reasonable autonomy in its research-management and operation. The existing process for the identification and setting research priorities involves participation of research, extension, and relevant development agencies. Participation of farmers would be essential to improve relevancy of research. IAR needs to improve its capacity for effective monitoring and evaluation of research. The IAR Board of Directors has the final authority for approving programs and budgets and to make policy changes.	IAR was established in 1966 as a semi-autonomous public organization under the general supervision of a ministerial Board of Directors. Its mandate is to formulate national policy for agricultural research, to coordinate agricultural research programs carried out by various organizations, and to carry out research in relevant agricultural sectors. It has 11 main research stations and more than 20 sub-stations. IAR has 12 programs or operational divisions. These include field crops, horticulture, tree crops (such as coffee), agronomy and physiology, crop protection, soil science and water management, animal production, animal health, agricultural economics, food science, etc. The research planning process starts with commodity teams that review past results and then initiate development follow-up programs. Research divisions further screen and consolidate the commodity-team proposals. Then a joint meeting of heads of research divisions scrutinizes proposals. External reviewers from development agencies and peer scientific groups participate in the annual programme review.	IAR has about 345 researchers, 800 technicians, and 2,000 support-staff. About 35% of research staff have Ph.D. and M.Sc. degrees. The number of qualified and experienced research staff is low. The budget allocation for 1986-87 has been about $22 million, and 53% and 43% of the budget was utilized for recurrent and investment costs. IAR has established research ranks and promotion criteria used by the institutes' promotion committee. Internal linkages of IAR include universities, Ministry of Agriculture and other development agencies. The IAR/Extension Department of the Ministry of Agriculture jointly conducts on-farm verification trials in different ecological zones (since 1970). IAR has good linkages with IARCs (ILCA, CIMMYT, CIAT, CIP, IITA, ICARDA, ISNAR, ICRAF, SAFGRAD, etc.).
NIGER 1. Institute of Agricultural Research /Institut National de Recherche Agronomique du Niger (INRAN).	INRAN operates under the supervision of the Board of Governors comprised of representatives of the Ministry of Agriculture and Environment, Ministry of National Education and Scientific Research, Ministry of Livestock and Natural Resources, Ministry of Finance, and the University of Niamey (Chairman). INRAN lacks adequate autonomy in its research management and operation. The Board, as an umbrella research apex, approves research proposals and programs that emanates from research departments of INRAN. As a scientific and technology policy body with legal entity, it is yet to evolve to provide policy and guidance for effective research coordination and management.	INRAN was established in 1975 to provide technical and scientific support for agricultural and rural development. It has six major programs. These include: agriculture, ecology, rural economics, forestry, veterinary and animal science. Other units of INRAN are finance, planning and programming, training, documentation, pre-extension, and administration department. Management of INRAN is highly centralized and all decisions are channelled to the office of Director General of the Institute. Five Technical Working Groups (i.e., rainfed crops, irrigated crops, livestock, environment, and farming systems) identify research priorities and develop programs. INRAN major research facilities include the National Research Center at Tarama Maradi, the Research Station at Kolo, and 27 sub-stations and field-support points (often with inadequate facilities).	As of 1992, INRAN had about 65 researchers, 140 technicians, and 600 support staff. About 50% of researchers and technicians were trained in crops improvement and production; about 22 and 5% of the scientists were engaged in ecological and forestry research; about 10% and 15% of researchers had Ph.D. and M.Sc. degrees or equivalent training, respectively. The majority of researchers were young with limited experience. Government contribution to INRAN budget remained at the level of about $1,345,000 per year during the 1982-86 and increased to almost $2.3 million by 1990. About 80% of the budget was spent on personnel costs. External funding support (grant and loan) was about $2.0 million/year between 1982 and 1986 and increased to about $5.0 million/year between 1988 and 1990. INRAN has established regional (INSAH and SAFGRAD) and international organizations (ICRISAT, CIRAD, ISNAR, ICRAF, ILCA).

Table 1 (concl):

Country	Research Policy and Management Apex	Organization of Research	Environment for Research (Human Resources, Funding, and Linkages)
GHANA NARS 1. CSIR Institutes: Crops Research Animal Research Food Research Aquatic Biology Soil Research Oil Palm Research 2. Other National Research Institutes: Cocoa Research Institute of Ghana Forestry Research 3. Ministry of Agriculture Related Research Units: Fisheries Research Dept. Crop Services Dept. on Adaptive Research	The Council for Scientific and Industrial Research (CSIR) has the main responsibility to coordinate and promote research in agriculture and other areas. CSIR has 12 research institutes, six of which devote their activities entirely to agricultural research. Each institute has a Management Board and a Director, also appointed by the Council. Agricultural research policy, planning, and priority-setting activities are not effectively coordinated. Each institute sets its own research plans. The government of Ghana, aware of the problem, has established a National Agricultural Research Committee, chaired by the Secretary of Agriculture. This unit is expected to facilitate the formulation of policy and to coordinate agricultural research efforts in line with national agricultural development policy. Linkage mechanisms among the various agricultural research institutions and users of technology have not been effective since the latter had very little input into the program foundation and planning of these various institutes. The reorganization and integration of all agricultural research institutes under the same policymaking and Management Council, composed of various development ministries and universities, is crucial for Ghana NARS in the 1990s.	The National Agricultural Research Policy Committee (NARC), as a coordinating and management entity, is expected to be fully operational. Among the six agricultural research institutes under CSIR, the Crops Research Institute (CRI) is mandated for the improvement of cereals, legumes, root and tuber, vegetables, fruits, plantains and banana, and industrial crops. CRI is a semi-autonomous organization of CSIR. Periodic review of progress of research programs, financial requirements, and budgetary expenditures and execution of capital development of the CRI are made by the Management Board, composed of 16 members from the Ministry of Agriculture, University, farmers, and others. CRI functions through 12 technical research divisions and 2 non-teaching divisions (documentation and administrations). Research is organized and also supported through a number of projects; these focus on the improvement and production grains and root and tuber crops. CRI headquarters are at Kwadaso, Fumesua, near Kumasi. It carries out research activities at 15 stations scattered in the coastal savanna zone, high rain-forest zone, semi-deciduous forest zone, forest savanna-transition zone, Guinea savanna zone, and Sudan savanna zone. Adequate linkages between CRI and the Extension Services Dept. of the Ministry of Agriculture Global 2000 extension program were established.	As of 1991, CRI had 85 researchers, about 315 technicians, and 724 support staff. About 13 of its professional staff are in administration and supporting services. About 23% of the researchers have an M.Sc. degree and 42% a Ph.D. Government has been the main source of funding for supporting agricultural research. External funding support had been almost 3% of the CRI research budget in 1982 and increased to almost 51% as of 1990. Between 65% and 90% of government funds allocated to research is for salaries. Funds available to scientists have declined threefold, to $10,000 between 1974 and 1990. Other sources of CRI funding have been bilateral and multilateral donors, including the World Bank. There is no formalized mechanism for monitoring and evaluating CRI's research programs as a whole. Externally funded projects within CRI were evaluated at the end of each phase. CRI has established good linkages with a number of regional and international organizations, such as CIMMYT, CIRAD, FAO, IITA, INIBAP, ICRISAT, SAFGRAD, and SPAAR. Within the national system, CRI maintains linkages with several research and development organizations.

Sources:
Institut d'Etudes et de Recherches Agricoles (INERA) Gestion de Resources Humaines Etat du Personnel, 1990-91.
Briefing note on Institute of Agricultural Research (IAR), Ethiopia, 1986, and data collected and compiled by IAR staff, July-Sept. 1992.
Ghana Crop Research Institute (CRI), 1991-92.
World Bank, *Staff Appraisal Report*, Cameroon Agricultural Research Project, 1988.
World Bank, *Staff Appraisal Report*, Burkina Faso Agricultural Research Project, 1988.

The organization of research of each of the above-listed countries differs somewhat. Some NARS are well-structured and better coordinated with clearly defined objectives and programs (Table 1). In other countries, several ministries and parastatals have their own research institutes. For example, the organization of research in Ghana, Nigeria, and Cameroon is administratively fragmented. Thus, both research-policy direction and planning are not adequately coordinated. In the case of the NARS of Niger, even though its Council is comprised of various development ministries and the University of Niamey, it has not yet become a forceful scientific and technology policymaking body with its own mandate and legal entity.

Except for Mali, agricultural research and extension under two or more separate ministries has contributed to the poor linkages that exist between these two essential units for agricultural development.

Research programs are developed by commodities or by disciplines (i.e. in Burkina Faso, Cameroon, Ethiopia). Monitoring and evaluation systems of research are not fully developed in most of the NARS studied (Ethiopia, Ghana, Niger, Mali, Nigeria). Improvements in the research-staff budget and in the quality of facilities were not commensurate with the expansion of programs.

Development of Human Resources

Data on research manpower in various NARS has been very difficult to obtain. This section discusses first the current situation and then focuses on the contribution of SAFGRAD to the improvement of research skills. During the last two decades, the number of researchers in a number of countries has increased substantially. Qualifications of researchers and the time (full time and part-time) they spent on the improvement of a specific crop varied among networks (Table 2, Fig. 2). For example, nearly 105 researchers were involved in the improvement of maize in the 17 countries of West and Central Africa. About 26 and 33% of the scientists have Ph.D. and M.Sc. level training, respectively; and others have up to B.Sc. or equivalent level of training. About 50% of the qualified scientists, however, are based at lead NARS centers. In Eastern Africa, sorghum and millet improvement, there are 87 researchers in the eight network countries. About 27 and 31 of the researchers have Ph.D. and M.Sc. level training, respectively (Table 2). More than 50% of sorghum and millet researchers with Ph.D. degree training are based in the Sudan. The most dramatic increase has been in Ethiopia (Fig. 1, Table 6), from 120 in 1982 to 306 in 1991.

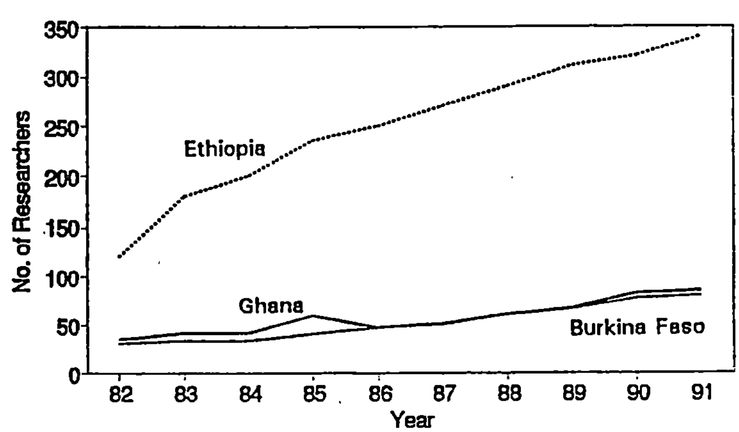


Figure 1. Research manpower in three national agricultural systems — Burkina Faso, Ethiopia, and Ghana — 1982-91.

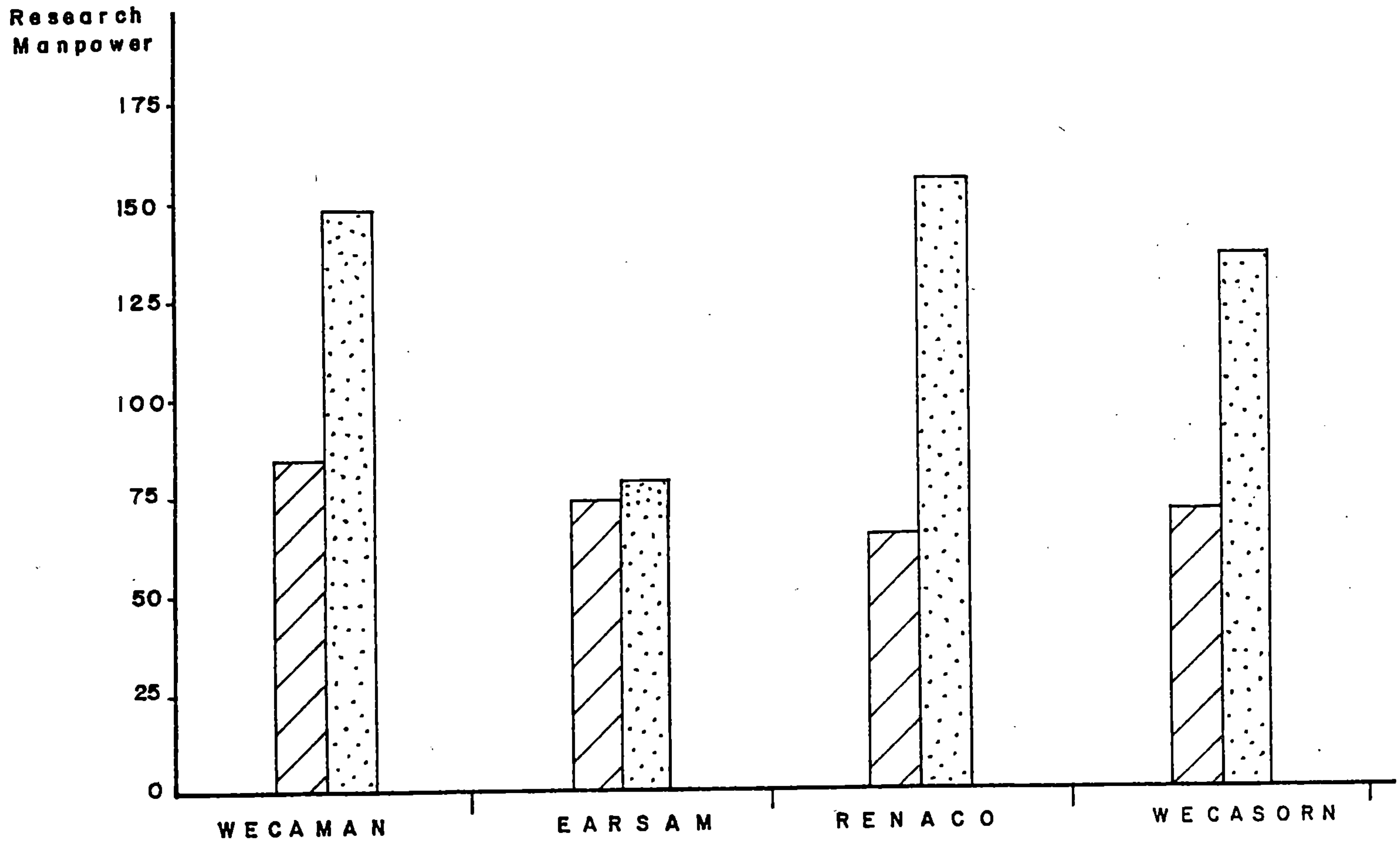


Fig. 2. Current and Future Research Manpower Requirements of SAFGRAD Networks (1990-2000)

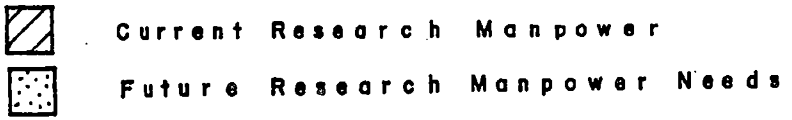


Table 2. Current Research Manpower in Foodgrain Improvement in West, Central, and Eastern Africa, 1990-91.

Network	Number of NARS	Number and Training Level of Researchers		Research Time		Location of Qualified Researchers
				Full Time	Part-time	
WEST AND CENTRAL AFRICA: SORGHUM RESEARCH NETWORK	18	Ph.D. Ms.C. B.Sc. Subtotal	23 27 33 83	38%	62%	About 25% based at lead NARS
WEST AND CENTRAL AFRICA: MAIZE NETWORK	17	Ph.D. M.Sc. B.Sc. Subtotal	28 35 42 105	60%	40%	About 50% based at lead NARS
EAST AFRICA: SORGHUM AND MILLET NETWORK	8	Ph.D. M.Sc. B.Sc. Subtotal	27 31 29 87	70%	30%	About 35% based in two countries
WEST AND CENTRAL AFRICA: COWPEA NETWORK	17	Ph.D. M.Sc. B.Sc. Subtotal	20 30 25 75	35%	65%	About 60% based at six NARS centers

In the 17 countries of West and Central Africa, 83 researchers work on sorghum improvement. Twenty-three percent and 27% of the scientists have Ph.D. and M.Sc. level training, respectively, and about 45% are junior researchers who could benefit from post-graduate level training. Almost 30% of the qualified researchers are based at the five Lead Centers. The acute shortage of experienced and qualified researchers and the proportion of research time allotted to cowpeas have been a crucial constraint to the cowpea-improvement effort. Nearly 75 scientists are engaged in cowpea research in the 17 countries. Only 35% of the researchers work full time and about 65% of them are part-time. Most of the qualified researchers are based at the six lead NARS centers.

Contribution of Networks in the Institutional Building of NARS

Network activities — training (short-and long-term), workshops, seminars, scientific monitoring tours, and special and general conferences — have directly or indirectly contributed to the improvement of research skills (Table 3). During SAFGRAD I (1979-86), long-term training was provided to eights and 22 people from member countries at Ph.D. and M.Sc. levels, respectively (Table 4). Short-term training that lasted from a few weeks to nine months was offered to 250 and 140 participants during SAFGRAD Phases I and II (1987-91), respectively. This training was based on improving research skills needed by various SAFGRAD-member countries.

Table 3. Improvement of Research Skills Through Training, Workshops, and Monitoring Tours.

Network Activities	Number of Participants		Total
	SAFGRAD I (1979-86)	SAFGRAD II (1987-91)	
Workshops/Seminars	764	900	1664
Short-Term Training	250	140	390
Long-Term Training (M.Sc. & Ph.D.)	30	-	31
Monitoring Tours	65	100	165
General Conferences	130	165	295
TOTAL	**1239**	**1305**	**2545**

Table 4. SAFGRAD Long-Term Training Support, December 1986.

Country	Level of Training		Total
	M.Sc.	Ph.D.	
Botswana	1	-	1
Burkina Faso	3	6	9
Cameroon	2	-	2
Chad	1	-	1
Guinea, Conakry	4	2	6
Mali	6	-	6
Senegal	2	-	2
Somalia	1	-	1
Togo (French Support)	2	-	2
TOTAL	**22**	**8**	**30**

Source: SAFGRAD I Synthesis Report, 1977-1986.

Scientific tours involved 65 and 100 participants during SAFGRAD Phase I and II, respectively. These scientific tours not only enabled NARS scientists to jointly evaluate the performance of elite germplasm and related technologies in different ecological zones but also facilitated the exchange of research experiences and linkages between senior and young researchers.

The potential intermediate impact of training, seminars, and scientific-monitoring visits for improving research skills are summarized in Table 5. Some of the immediate impacts on NARS institutions follow:

1. Increased research output, as shown by the number of research programs executed at the national level (for example, collaborative project activities at Lead Centers).

2. Increase in the type of networks, regional trials, and improvement of data recovery from participating NARS.

3. Improvement of capabilities in data analysis, as shown by the quality and quantity of technical reports.

4. Release of improved varieties and related technologies.

5. Improved understanding of cropping systems and the need for employing soil/water conservation practices.

The following discussion focuses on the trends of qualified research, manpower development, and SAFGRAD input for the improvement of research skills in the case-study countries:

Sorghum. The research manpower statistics in this report attempt to exclude expatriate (non-native) researchers. The evolution of research manpower for the improvement of sorghum in West and Central Africa has changed very little over the last decade, as summarized Table 3-A in the Appendix. Except for crop breeders, the data show that research time of specialists (such as those of agronomists, pathologists and entomologists, agricultural economists, and for processing technologies) are shared among two or more crops. There has been some improvement in the number and quality of sorghum research staff in Burkina Faso, Mali, and Kenya; a slight decrease in the number of qualified researchers in Ethiopia, Cameroon, and Nigeria. The Ghana national program has sustained the number of young researchers on sorghum improvement during the last five years.

The input of the SAFGRAD project to the development of research manpower capacity varied in the eight case-study countries. For example, in Burkina Faso, three researchers were trained at the Ph.D. level (i.e., breeder, soil scientist, and agricultural economist) and two at the M.Sc. level. The sorghum breeder who was trained through SAFGRAD is the current leader and coordinator of sorghum and related cereals research for INERA in Burkina Faso. Several technicians have received on-the-job-training through the ICRISAT/SAFGRAD collaborative efforts.

Table 5. Indicators of Network Performance in the Improvement of Research Skills through Short-term Training, Seminars, and Monitoring Tours (1987-1991).

Networks and Types of Training	Output	Potential Impact on NARS Institutions
WEST AND CENTRAL AFRICA MAIZE RESEARCH		
Five-month practical training in field plot techniques, data and trial management, variety maintenance, seed multiplication, interpretation and analysis of research results (1988, 1989, 1990)	During the 1988-90 crop season, 15 technicians from Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Gambia, Ghana, Guinea, Guinea Bissau, Mali, and Togo received training	Improved output of research as demonstrated in the implementation of research trials at the national level and increased data returns from regional trials
Computer course in the use of MSTAT for data analysis (1991)	6 NARS scientists from weak and Lead Centers were trained in data analysis	Exposure to various software of statistical analysis to improve capabilities of interpreting research results
Research fellowships at IITA	IITA fellowships for four scientists improved their research output in the utilization of available maize germplasm	Maize cultivars for the Sudano-Guinean zones were developed and released by NARS
Inter-network agronomy seminar (1991)	7 maize researchers attended the integrated cropping systems short course	Improved understanding and practices of cropping systems and the need for employing soil- and water-conservation practices
Scientific monitoring tours (1988 and 1990)	20 NARS scientists with some IITA researchers visited NARS of Burkina, Cameroon, Ghana, and IITA/Ibadan. They jointly evaluated the performance of regional trials and collaborative projects. The tours enabled researchers to know each other's programs.	Facilitated exchange of germplasm, improved research collaboration and understanding of problems common to agricultural production
WEST AND CENTRAL AFRICA SORGHUM RESEARCH		
Striga-control training on research methodology and development of integrated practices (i.e., breeding, agronomic practices, herbicides, and land-preparation systems).	12 researchers from Burkina Faso, Cameroon, Gambia, Ghana, Kenya, Mali, Niger, Nigeria, Sudan, Togo, and Uganda benefitted from the two-weeks intensive course held in 1987 in Ouagadougou, Burkina Faso (ICRISAT/SAFGRAD Project)	Researchers from these NARS realized the increased threats to crop production from *Striga* infestation and called for standardization of screening techniques for identifying resistant cultivars and recommended each NARS to pursue integrated control methods to minimize yield losses
Two-week training on agronomic research and on-farm testing (1989)	13 researchers from Côte d'Ivoire, Gambia, Ghana, Mauritania, Niger, Nigeria, Senegal, and Sierra Leone attended the course (held at ICRISAT West Africa Sorghum Improvement Program/Mali). Emphasis was on soil fertility, on-farm testing, and the integration of animal-production systems.	Improved research skills in cropping systems and on-farm verification trials as evidenced from increased activity on inter-cropping trials
Crop-protection training to enable researchers to identify and control diseases and pests (1991)	12 NARS researchers from seven countries attended the two-week intensive course	Improved research skills in plant pathology, entomology, and weed science. Facilitated exchange of results in plant protection. Substantially improved data returns from regional trials on disease and pests.
Inter-network agronomy seminars (1991)	6 sorghum researchers attended an integrated cropping systems short course at IITA/Ibadan	Understanding and practices of cereal/legume cropping systems and the application of soil- and water- conservation practices enhanced

Table 5 (cont.)

Networks and Types of Training	Output	Potential Impact on NARS Institutions
WEST AND CENTRAL AFRICA COWPEA RESEARCH		
High-level research seminar on cowpea research in the subregion (1988)	10 researchers from Burkina Faso, Cameroon, Ghana, Niger, Nigeria, and Senegal attended the seminar at Ibadan. State-of-the-cowpea research in the subregion was reviewed	The review identified areas of research collaboration and orientation on cowpea research. New cowpea varieties were nominated by Burkina Faso, Niger, Nigeria, and Senegal for regional testing. Capabilities for developing germplasm by lead NARS were documented and regional collaboration on the improvement of cowpeas was streamlined.
In-service training on appropriate technology development and transfer, Kamboinse Agricultural Experiment Station (1989)	10 researchers from Benin, Chad, Côte d'Ivoire, Guinea, Guinea Bissau, Mali, and Niger attended the course. Some suitable technologies for different ecological zones were identified. Problems of seed production of improved cowpea cultivars were stressed.	Seed production of improved cowpea cultivars by the network was enhanced. Some NARS facilitated seed multiplication through NGOs and parastatal organizations. Linkages between research and extension development institutions were emphasized.
Computer training course in the use of MSTAT for data analysis (1991)	10 NARS researchers from six countries attended the course	Exposure to various software helped to improve quality of data analysis
Scientific monitoring tours (1988 and 1990)	18 NARS researchers and 6 IITA and other researchers from regional organizations participated in the scientific-monitoring tour. The Burkina Faso, Niger, Nigeria, and IITA/Ibadan research programs were visited. The performance of elite germplasm included in the regional trials was evaluated and progress of collaborative projects at the above lead NARS was assessed.	Participants compared and exchanged research results. The tour enabled NARS' scientists to know each other's programs and their comparative research advantages. NARS researchers broadened their scope on cowpea improvement.
EASTERN AFRICA REGIONAL SORGHUM AND MILLET RESEARCH		
Seed-production technology course for technicians (1987)	35 technicians from Burundi, Ethiopia, Kenya, Rwanda Somalia, Sudan, Tanzania, Uganda including technicians from private companies, attended the training.	NARS technicians acquired techniques in seed production and processing.
Insect control (entomology) short course to improve research skills in entomological research (1989)	17 researchers from Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan and Uganda attended the course. Control methods of insect pests, such as sorghum stemborer, shootfly, headbugs, midge, and storage insects, were emphasized. Each participant was given a training manual.	NARS researchers were exposed to basic skills of conducting entomological research and control of insect pests.
Training to upgrade research skills in the identification and control of sorghum and millet diseases (1989)	12 researchers from Burundi, Kenya, Rwanda, Somalia, Sudan, Tanzania, and Uganda attended the course. Measurement of disease incidence, severity, and control was emphasized. Each participant was given a training manual.	The most important diseases and pests of sorghum and millet in the subregion were discussed. Researchers were exposed to basic skills of conducting plant pathology research and disease control methods.
Short course on plant breeding for researchers (1991)	6 researchers (except from Ethiopia and Somalia) attended the course	Breeding techniques were discussed. Participants included NARS, ICRISAT researchers, and the network coordinator. This activity is expected to improve research skills in the improvement of sorghum and millet in the subregion.

In the North and Far North provinces of Cameroon, an expatriate extension agronomist through the SAFGRAD Accelerated Crop Production Program (1982-87) has facilitated the diffusion of foodgrain technologies. Consequently, several early-maturing cultivars, including S-35 and S-34, were released. An extension agronomist trained at M.Sc. level through SAFGRAD is currently working with the Testing and Liaison Unit (TLU) of IRA in the Far North Province of Cameroon.

In Ethiopia and Kenya, a number of technicians were trained in plant protection and seed production. Financial support through the network also facilitated the screening of sorghum genotypes resistant to long-smut and drought in Kenya and the screening of several sorghum cultivars with resistance to *Striga* in Ethiopia.

Mali has been one of the major beneficiaries of the SAFGRAD project. As indicated in the Appendix, two sorghum breeders and agronomists were trained at the M.Sc. level. More than 10 technicians were trained to assist in evaluating sorghum varieties and agronomic practices at on-farm level. The sorghum network (1987-91) provided some financial support that enabled Mali NARS to screen several sorghum genotypes for resistance to head-bug. As a Lead NARS in this research area, the Mali NARS has contributed sorghum germplasm to other network member countries where the head bug is a major pest in sorghum production.

During SAFGRAD Phase I, the ICRISAT/SAFGRAD program for the improvement of sorghum and millet was based at IAR, Samaru. The new generation of technologies, the short-cycle sorghum cultivars (for example, S-35 and S-34) were developed there. The introduction of these cultivars to Cameroon and elsewhere indicated that they were promising for the dry Sudanian and wet North Guinean zones, respectively.

The exchange of germplasm through the regional trials of the network has enabled the Ghana NARS to release varieties resistant to *Striga*, such as Framida, to the northern part of the country.

Cowpeas. There has been little change in the development of qualified researchers for the improvement of cowpeas during the last decade, except in Ghana where the research staff changed from three in 1982-84 to 11 in 1991-92. In Ghana, about 30% of the research staff has Ph.D. level training in breeding, entomology, or pathology. In Niger, the number of cowpea researchers has almost tripled. In Nigeria, the number of researchers working on cowpeas decreased 33%. In Mali, the number of cowpea researchers has doubled. Through the IITA/SAFGRAD and ACPO programs, more than 15 technicians were trained in cowpea improvement and production. One extension agronomist also was trained at M.Sc. level; he also evaluated cowpea cultivars to fit different cropping systems. In Burkina Faso, the multidisciplinary cowpea research team represents various specialties, enabling it to generate and evaluate cowpea-production technologies. (Also see Table 4-A in the Appendix.)

External funding for agricultural research has become very high. These graphs chart research expenditures and percentage of funding from external sources for Burkina Faso, Ghana, Niger, and Mali, 1982-91 (see Tables 7, 8).

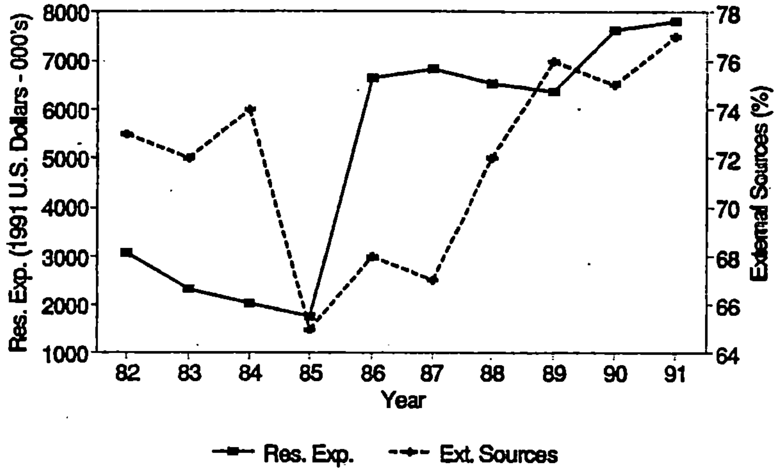


Figure 3. Burkina Faso.

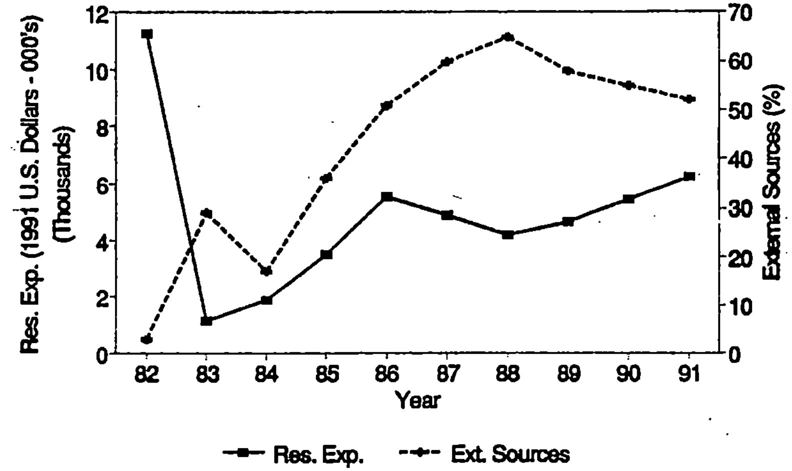


Figure 4. Ghana.

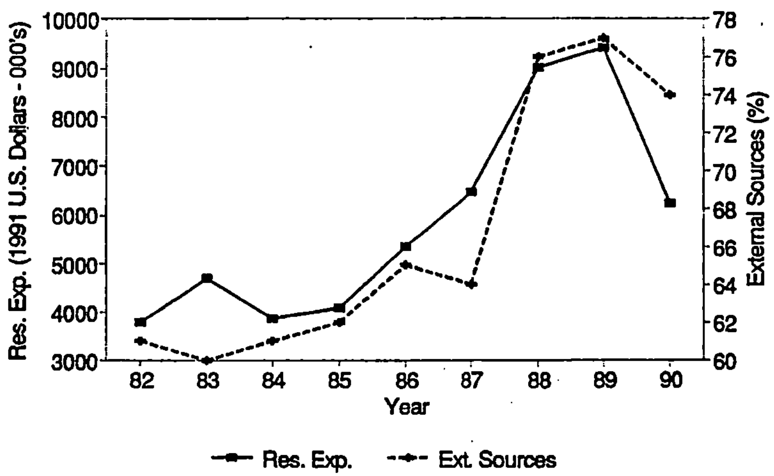


Figure 5. Niger.

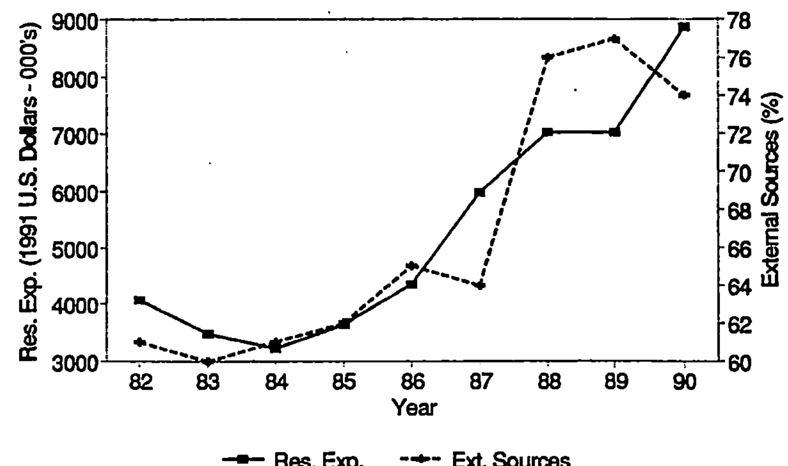


Figure 6. Mali.

Maize. There has been substantial increase in staff development for maize improvement in Burkina Faso, Cameroon, Ghana, and Nigeria of 50, 87, 60, and 58%, respectively, between 1982-84 and 1991-92. In Mali, approximately the same level of research staff was sustained. SAFGRAD support to strengthen maize research has been in the training of technicians in field-plot techniques and variety maintenance. The exchange of germplasm and development of the early and extra-early maize cultivars and support for on-farm verification trials enabled many NARS to release their own short-cycle maize varieties.

In Mali, however, the project provided training for one maize agronomist at M.Sc. level and placed an expatriate agronomist in Mali for the promotion of on-farm adoption of maize technologies between 1979 and 1985. As a result, a number of maize varieties were released to farmers. More than 20 technicians were trained in maize improvement and production through the IITA/SAFGRAD and the Accelerated Crop Production Program (ACPO).

Funding. There was a two- to threefold increase in the number of researchers and doubling or tripling of the number technicians. Based on available data, the funding of agricultural research during the decade 1982-91 in four case-study countries is summarized in Table 6. However, funding increases did not accompany these personnel increases. Hence, expenditures per scientist have continuously declined. The growth of scientific manpower (for example, in Burkina Faso, Ghana, Niger) has been at the expense of other scientific expenditures. Budgets had to be shifted to cover salary payments (Table 7). Research manpower and budget expenditures as 1990-91 in six case-study countries are summarized in Table 8.

External funding support (i.e., bilateral and multilateral) to national research in Burkina Faso, Mali, and Niger has been quite high, over 75% of the total budget. On the other hand, external funding support in Ethiopia and Ghana was 37 and 3%, respectively, in 1982 and decreased in Ethiopia to 28% in 1991 (Table 7; Figs. 3, 4, 5). In Mali, external funding was almost 55% in 1982 and increased to 72% in 1990 (Fig. 6).

Large proportions of the national research budget contributed by governments were used to cover salary costs. For example, in 1982, about 52, 20, 75, 54, and 61% of the budget allocated by governments in Burkina Faso, Ethiopia, Ghana, Mali, and Niger, respectively, was used for payment of salaries. By 1990-91, the number of research personnel increased by two- to fourfold. However, allocation of funds from national resources did not increase substantially. Thus, over the last 10 years, there has been significant decline in the operating funds made available to researchers.

Budget allocation by programs of countries studied has not been fully elaborated due to limitation of data. In general, there seems to be shift in emphasis of budget allocation to resource-management research to enhance the development of sustainable agriculture. An illustrative budget by programs of the Burkina Faso NARS is summarized in Table 9.

Table 6. Resources for Scientific Manpower and Support Staff for Agricultural Research in Three Case-Study Countries.

Year	BURKINA FASO[a]				ETHIOPIA[b]				GHANA[c]				Researchers/Total Staff Ratio		
	Research	Technician	Total	R/T/R	Research	Technician	Total	R/T/R	Research	Technician	Total	R/T/R	Burkina Faso	Ethiopia	Ghana
1982	31	17	177	1:1.8	120	324	1160	1:2.7	35	185	798	1:5.2	1:5.7	1:9.7	1:23
1983	34	17	200	1:0.5	140	432	1515	1:3.0	42	204	824	1:4.9	1:5.9	1:1.0	1:19.6
1984	34	20	220	1:0.7	165	440	1625	1:2.7	42	221	864	1:5.3	1:6.5	1:1.0	1:20.5
1985	40	22	274	1:0.55	180	480	1872	1:2.7	59	228	908	1:3.8	1:6.8	1:1.0	1:15.3
1986	48	22	292	1:0.5	200	459	1990	1:2.2	47	234	1155	1:5.0	1:6.1	1:1.0	1:24.6
1987	51	137	347	1:2.6	214	520	2631	1:2.4	49	237	1397	1:4.8	1:6.8	1:1.2	1:28.3
1988	61	150	270	1:2.4	265	515	2750	1:2.0	61	264	1211	1:4.3	1:6.0	1:1.0	1:19.9
1989	66	161	395	1:2.4	285	500	2830	1:1.7	68	271	1239	1:4.0	1:6.0	1:9.1	1:18.3
1990	77	170	428	1:2.2	281	550	2860	1:1.9	81	290	1128	1:3.6	1:5.6	1:1.0	1:13.9
1991	93	172	435	1:2.2	306	600	2910	1:2.0	85	315	1124	1:3.8	1:5.4	1:9.5	1:13.4

a Research manpower statistics include expatriate staff and covers crops and animal science and husbandry research.
b Statistics for all agricultural research and exclude expatriate staff.
c Research manpower statistics include only for crops research institute.
R/T/R : Research/Technician Ratio.

Sources:
a Institute of Agricultural Research, (IAR), Ethiopia 1986-87 and 1991.
b Institut d'Etudes et de Recherches Agricoles (INERA) Gestion des Ressources Humaines Etat du Personnel, 1990-91.
c Ghana Crop Research Institute (CRI), 1991-92.

Table 7. Funding of Agricultural Research in Five Case-Study Countries, 1982-1992 (US$).

Year	BURKINA FASO				ETHIOPIA				GHANA				MALI		NIGER			
	Total Budget	Recurrent Cost	External Funding	Govt. Funded Salaries	Total Budget	Recurrent Cost	External Funding	Govt. Funded Salaries	Total Budget	Recurrent Cost	External Funding	Govt. Funded Salaries	Total Budget	External Funding	Total Budget	Recurrent Cost	External Funding	Govt. Funded Salaries
1982	2,170,000	1,200,000	73%	52%	5,000,000	4,130,000	37%	20%	7,996,363	7,356,000	3.0%	75%	2,900,000	54.9%	2,664,000	1,028,830	61%	79%
1983	1,697,000	969,000	72%	50%	6,815,000	5,000,000	23%	20%	857,714	617,714	26.8%	76%	2,547,000	55.2%	3,438,683	1,377,427	60%	71%
1984	1,542,300	938,230	74%	69%	6,021,108	5,000,100	30%	27%	1,440,000	1,201,142	16.7%	87%	2,454,000	68.3%	2,933,800	1,123,667	61%	74%
1985	1,365,868	986,000	65%	57%	17,760,200	6,300,000	45%	37%	2,740,758	1,746,560	36.2%	91%	2,667,000	61.7%	3,212,350	1,217,593	62%	72%
1986	5,330,000	3,665,000	68%	56%	24,632,000*	9,061,300	41%	38%	4,445,646	2,198,184	50.5%	95%	3,520,000	63.4%	4,300,400	1,485,795	65%	74%
1987	5,700,000	3,280,000	67%	63%	30,120,000*	16,475,000	NA	29%	4,083,111	1,688,347	60.2%	93%	4,981,000	67.4%	5,400,900	1,910,190	64%	75%
1988	5,660,000	3,500,000	72%	67%	18,644,000	15,000,000	NA	32%	3,658,019	1,132,388	65.0%	76%	6,102,688	68.0%	7,830,000	1,935,416	76%	80%
1989	5,800,000	3,460,000	76%	79%	16,000,000	16,000,000	NA	35%	4,216,777	1,388,110	58.0%	82%	6,394,287	69.0%	8,550,000	1,935,384	77%	82%
1990	7,300,000	4,360,000	75%	80%	23,616,300	14,000,000	NA	38%	5,191,550	1,801,182	55.0%	80%	8,518,440	72.0%	5,973,000	1,555,500	74%	83%
1991	7,800,000	4,900,000	77%	83%	22,196,012	13,722,560	28%	42%	6,225,561	2,098,594	61.5%	84%			NA	NA	NA	NA

NA: Data not available

Percentage salary expenditures were computed from funds contributed from national sources.

Sources:

Niger Ministère des Finances et du Plan.
Staff Appraisal Report 1990, National Agricultural Research Project, World Bank.
Data collected and compiled by ICRISAT/Agricultural Economist, 1992 ICRISAT Sahelian Center, Niamey, Niger.

Ethiopia Briefing note on Institute of Agricultural Research (IAR), 1986.
Data collected and compiled by Staff of Institute of Agricultural Research, July-Sept. 1992.
* About 43% of the Ethiopian NARS budget has been for capital development.

Burkina Faso INERA Rapport Financier Exercice 1991 et Budget Prévisionnel Exercice, 1992.
CNRST (National Center for Scientific and Technical Research) data compiled by staff of the Center).
INERA - Gestion des Ressources Humaines et du Personnel, 1990-91.
Staff Appraisal Report 1988, Agricultural Research Project, World Bank.

Ghana Crops Research Institute (CRI), Council for Scientific and Industrial Research, Institutional Project Funding.
Staff list, CRI Institutions, 1982-1992 (details of staff budget were provided through the courtesy of the Director of CRI and Director of Nyankpala Agricultural Experiment Station).
Review of Ghana Agricultural System, Vol. 1, 1989, CSIR and ISNAR.

Table 8. Research Manpower and Budget Expenditures (US$) for Agricultural Systems in Seven Case-Study Countries, 1990-91.

	Burkina Faso	Cameroon	Ethiopia	Ghana	Kenya	Mali	Niger
RESEARCH MANPOWER							
Number of researchers[a]	95(12)[b]	300(51)[b]	306(16)[b]	90(360)[b]	575	215(39)[b]	83(27)[d]
Number of technicians[b]	180	490	600	315	1300	380	140
Number of support staff[c]	180	2160	2910	1124	3500	750	600
Research/Technician ratio[d]	1:2.2	1:1.5	1:2.0	1:4.0	1:2.2	1:1.8	1:2.1
Researcher/Total staff ratio	1:6		1:9.5	1:13.4	1:8.3	1:70	1:12.3
RESEARCH EXPENDITURES							
Total research budget	7,800,000	18,000.000	22,198,012	6,225,561	19,000,000	8,427,495	5,973,000
Recurrent cost	4,900,000	7,200,000	13,722,560	2,098,594	2,880,000	5,477,870	1,555,500
Recurrent cost expenditure per researcher	57,647	24,000	40,360	24,689	17,182	23,000	18,740
Research budget as percent agriculture GDP	1.8%	1.3%	0.3%	0.86%	1.5%	1.2%	NA

[a] Number of researchers also includes expatriate staff.
[b] Number in parentheses refers to expatriate staff.
[c] Budget total of local and external funding.
[d] Number of researchers and budget for Ghana is for the Crop Research Institute only. Figure in parentheses indicates the number of researchers for the entire Council for Scientific and Industrial Research Institute (CSIR).

Sources:
Staff Appraisal Report 1990, National Research Project, Niger, World Bank Document.
The Agricultural Research Impact Indicators Matrix, 1991.
Office of Technical Resources, Bureau for Africa; Publications Series No. 91-6, USAID/Washington, DC (information on Kenya Agriculture AGDP).
Rapport Financiaer Exercise 1991 et Budget Prévisionnel Exercice 1992.
INERA Rapport au Conseil de Gestion, Gestion des Ressources Humaines, Etat du Personnel 1990.
L'Institut d'Economie Rurale (IER), Mali, 1990
Analyse du Systѐme National de Recherche Agronomique du Mali (ISNAR), 1990
Crops Research Institute (CRI), Ghana
Institute of Agricultural Research (IAR), Ethiopia, 1990-91

Table 9. Approximate Budget by Programs of the Burkina Faso National Agricultural Research Institute (INERA), 1991-92 (US$).

Program	Budget Allocation (US$)	% of Program Budget	No. of Researchers	No. of Techni-cians	Ratio of Researchers to Technicians	Expenditure Per Researcher (US$)
Farming Systems Research[a]	874,309	24.8	23	45	1:2.0	38,013
Soil-Fertilization, Water/Agriculture, and Mechanization[b]	1,233,019	35.0	12	20	1:1.7	102,751
Animal Science and Production	139,900	4.0	8	19	1:2.4	17,488
Cereals (Sorghum, Maize, Millet) Improvement	358,767	10.1	17	28	1:1.7	21,104
Legume and Oil Crops	226,669	6.4	14	27	1:2.0	16,198
Rice Research and Production	354,733	10.0	6	29	1:4.8	59,122
Cotton Program	252,907	7.2	5	11	1:2.2	50,581
Horticultural Crops	82,000	2.3	5	11	1:2.2	16,400
Total for Programs	**3,527,304**	**99.9**	**90**			**Average: 40,207**

Sources:
[a] INERA Rapport Financier Exercice 1991 et Budget Prévisionnel Exercice 1992.
[b] INERA Gestion des Ressources Humaines; Etat du Personnel 1990-91.

Sustaining Professional Linkages Through the Diffusion of Technical Information

There has been continuous flow and exchange of technical information among NARS as well as among faculties of agriculture of African universities through the circulation of various publications, including the SAFGRAD newsletter (Fig. 7) published quarterly. Assessing the activities of each network, it is evident that the workshops, thematic seminars, general conferences, the biennial conference of National Agricultural Research directors and the networks Steering Committee meetings enhanced not only the exchange of technical information, sharing of experiences, addressing of agricultural research-policy issues, and the review of technical programs, but also gradually forged professional partnerships among NARS and between IARCs and NARS researchers.

At the network level, the technical workshop composed of the assembly of national scientists, was held each year during SAFGRAD Phase I (1979-86) and biennially during Phase II (1987-1991). This enabled researchers from various countries to review results of the previous seasons and to plan collaborative research projects for the subsequent season. During the workshops, technical papers were presented and views were exchanged on the performance of elite germplasm in the various regional trials carried out at different ecological zones. Thus, the biennial technical workshop also served not only to address network issues but also to revitalize regional trials through the nomination of new elite germplasm for evaluation the following two years.

One of the major outputs of the above-mentioned network activities has been technical publications. A total of 519 publications, including annual reports, were generated by the project partners, IITA, the Farming Systems Unit of Purdue University, ICRISAT, and OAU/STRC. About 52% and 48% of the publications were on the development of foodgrain production technology and on the evaluation and transfer of technology through the on-farm trials, respectively.

More than 500 technical publications and annual reports were produced by the project during the last 12 years. The evolution of SAFGRAD II to networking also changed the nature of publications (Table 10 in the Appendix). For example, 23% were related to network-management reports, such as the Steering Committee, the Oversight Committee, and the Conference of National Agricultural Research Directors. About 10% were published in professional journals, and 12% were in conferences and workshop proceedings.

NARS Achievements

The following conclusions can be drawn from data presented in the preceding pages. Significant agricultural research capacity has been attained over the last two decades. According to ISNAR data (1980-85), 43 Sub-Saharan countries had a total of 4,870 researchers, excluding the scientists in universities. Almost 12 years later, the eight countries considered for the impact-assessment study alone have close to 3,850 researchers. For example, in Burkina Faso, Ethiopia and Ghana the number of

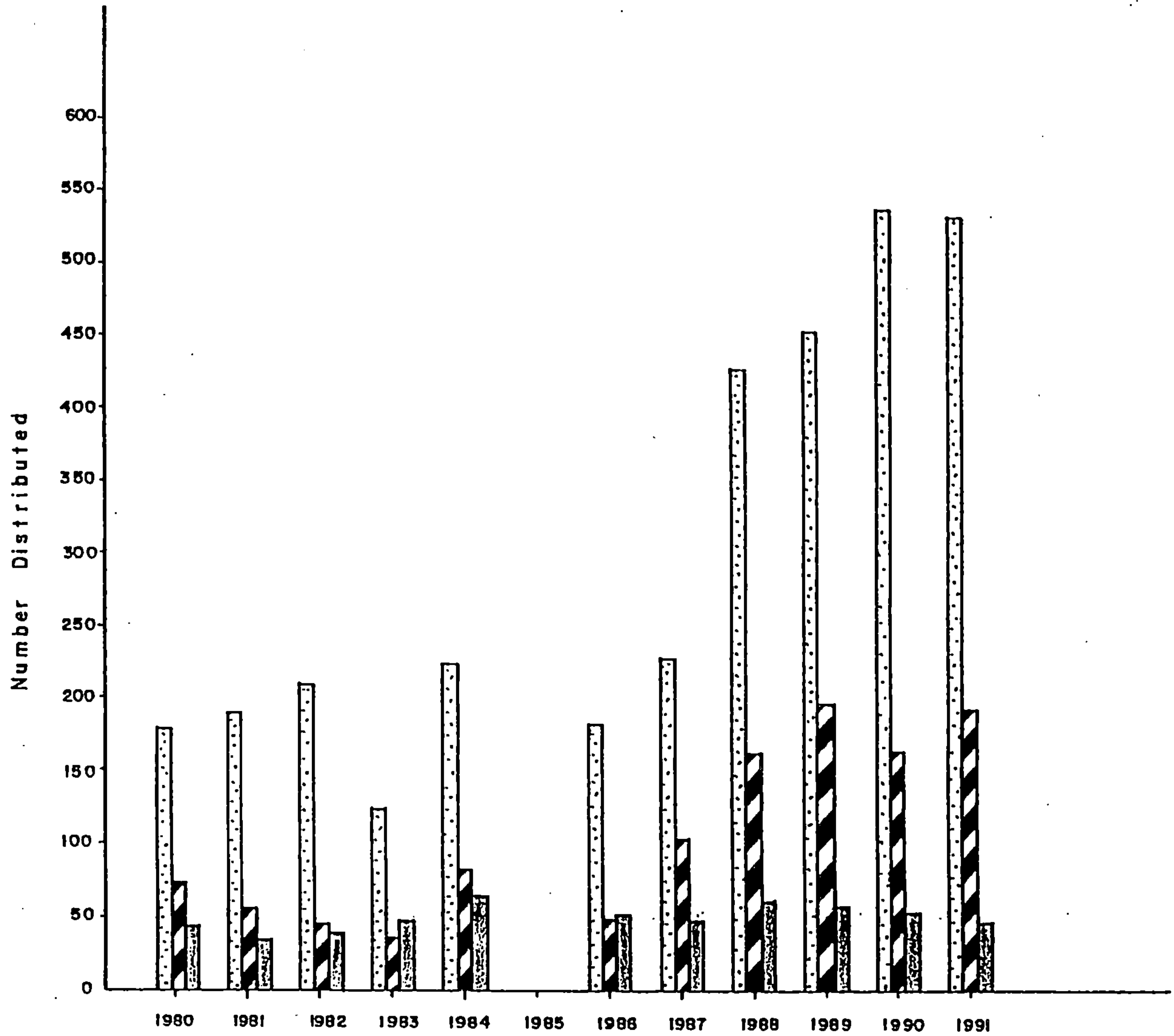


Fig. 7. **Diffusion of Technical Information through SAFGRAD Newsletter**

Distribution to West and Central Africa 18 NARS

Distribution to Eastern Africa 8 NARS

Distribution to Others Agencies

researchers has almost tripled to 85, 340 and 90, respectively. The number of researchers indicated for Ghana is that for the Crop Research Institute only (CRI) and therefore does not include the other research institutes under the Council for Scientific and Industrial Research. Similarly, the number of research technicians increased by tenfold, 2.5 times, and by twofold in Burkina Faso, Ethiopia and Ghana respectively. In Niger, the number of researchers almost doubled from 27 in 1975 to 60 in 1990-91. In Mali and Kenya, the number of researchers has increased to almost 275 and 575 researchers respectively.

There has also been a substantial change in the quality of research staff in the eight case-study countries. Although a large number of the researchers have limited experience, the percentage of scientists holding post graduate degrees has increased. In the eight study countries more than 25 and 45% of researchers (except Niger) have Ph.D. and M.Sc. level training respectively. A considerable number of qualified scientists based in the faculties of agriculture of universities also are involved in research for the improvement of foodgrains and in the development of farming-systems research. This includes Burkina Faso (to a limited extent), Cameroon, Ethiopia, Ghana, Kenya (large extent), Mali (limited extent), Niger, and Nigeria.

A more serious problem in various NARS is that a number of qualified scientists are part-time researchers (Table 2). For example, only 35, 38 and 60% of the researchers in West and Central Africa work full time on the improvement of cowpeas, sorghum, and maize, respectively . The situation is different in Eastern Africa where 70% of the researchers work full time on sorghum and millet improvement. Across the continent, except for breeders, the other disciplines, such as agronomy, pathology, and entomology, share their research time on a number of crops. The problem of scientists not spending time on research in many NARS is compounded due to lack of funds for recurrent costs. A number of highly qualified researchers (for example, in Cameroon, Ghana, and Nigeria) serve as consultants to gain extra income to compensate for the low level of salaries in the agricultural research system.

Lessons learned from the SAFGRAD I and II project activities have been that by pooling together research talents through networks, NARS were able to attain critical research mass at regional levels, which has influenced agricultural development at national levels. For example, about 25, 50, and 60% of scientists working on the improvement of sorghum, maize, and cowpeas, respectively, in West and Central Africa and 35% of the researchers working on the improvement of sorghum and millet in Eastern Africa are based at the respective lead NARS centers. Through coordinated research activities of networks, these centers were able to generate technologies that alleviated common biotic and climatic constraints to the production of foodgrains.

The partnership of the Organization of African Unity (OAU) through its Coordination Office, with IARCs and donors such as USAID not only enhanced the building of research capacity in NARS but also developed African scientific leadership and confidence.

ANALYSIS OF THE PERFORMANCE OF NARS ENTITIES IN THE MANAGEMENT OF NETWORKS

This section focuses on the analysis of the performance of the network entities established by the NARS institutions. Other NARS institutions (Table 12) include: (1) Council of National Agricultural Research Directors of the 26 SAFGRAD member countries, (2) Oversight Committee (management unit of SAFGRAD activities), and (3) Steering Committee (technical management units) of the respective networks. Since the final evaluation of SAFGRAD II, completed in July, 1991, largely assessed the performance of network partners, the IARCs — IITA and ICRISAT and the OAU/STRC, this impact assessment looked into the global contribution of the implementing agencies that were brought under the umbrella of the USAID-funded SAFGRAD project in strengthening NARS institutional capacity. SAFGRAD, as discussed below, therefore refers to the three above-mentioned organizing committees.

Council of the National Agricultural Research Directors

Policy Guidance and Management. SAFGRAD derives its legal entity and administrative support from OAU through the Scientific, Technical, and Research Commission (STRC). To enhance the development of national leadership in directing and managing agricultural research network activities, the Council of National Agricultural Research Directors of SAFGRAD's 26 member countries was established. It met every two years to review common agricultural research problems and to provide policy guidance for network operation and management. The first meeting of the Council that took place in 1987 was attended by representatives from 18 member countries.

The Council agreed that the networking approach was an appropriate mechanism for cooperation in regional research and training. From the analysis of the experiences of SAFGRAD I, the Council paid particular attention to the main constraints to development of national agricultural research, such as poor allocation of resources, weak national agricultural research structures and under-utilization of qualified national researchers. As a prerequisite to developing network programs, an essential directive of the Council was to initially undertake inventories on: (1) common research needs; (2) identification of constraints to agricultural production, and (3) available research manpower and infrastructure.

First Conference of National Agricultural Research Directors

Output. During the 1987 conference of the Council, network policy and operational guidance were established. The collaborative mode (networking) was endorsed as the main strategy for regional research cooperation and the SAFGRAD Coordination Office (SCO) was requested to undertake an impact appraisal of the eight-year USAID- funded on-farm trials pilot project in four SAFGRAD member countries. As a component of SAFGRAD Phase I, this technology transfer and adoption effort through improved extension/research/farmer linkages is referred to as the Accelerated Crop Production Program.

Second Conference of National Agricultural Directors

During its 1989 conference, the Council approved guidelines for managing networks, channelling resources to participating NARS, stressed the need to improve linkages between research and extension, and approved the concepts of proposed outline for the development of a Strategic Plan for SAFGRAD.

Output. Thirty-nine participants from 22 countries attended the conference.
To enhance the development of productive research collaboration among participating countries, the Council stressed the following issues:

1. The rationale for participating in collaborative research networks. It was emphasized that each country should examine and determine if the activities of the network coincided with its research interests and priorities and the extent to which it could contribute or facilitate participation of its staff and also share resources, including available technology.

2. Improving the perceptions and commitments of respective governments. It was suggested that research administrators and leading scientists of member countries, as well as the OAU/STRC-SAFGRAD Coordination Office, should sensitize appropriate ministries in charge of research and development to the need for joint effort and commitment of resources to promote collaborative research to solve food-production constraints that transcend the frontiers of participating NARS.

3. Enhancement of NARS leadership. The initiative to create networks should also come from participating countries, not necessarily from IARCs and donors. NARS should also accept leadership in the generation of technology and management of networks.

4. Harmonization of the activities of SAFGRAD and CORAF maize networks. In its 1989 conference, the Council resolved that the two networks should merge by creating sub-networks and having joint coordinators responsible to one Steering Committee. As a follow-up to this recommendation, the SCO arranged a joint CORAF and SAFGRAD technical meeting of researchers from both networks to address the issues. The ecological mandates and the areas of maize research focus of each network were analyzed. Not only were the similarities of maize research activities evident but also the same NARS researchers and institutions were involved in both networks. The major difference was that research carried out by the respective networks is targeted to the semi-arid zone in the case of SAFGRAD and to the humid, sub-humid and irrigated zones in the case of CORAF. Both networks have similar constraints, except for the physical soil characteristics apparent in different ecologies. Based on technical analysis, the CORAF and SAFGRAD harmonization committee recommended the merging of both networks within two years, by 1989.

5. Channelling network resources to NARS. As soon as the networks became operational, mechanisms for disbursement of funds and accountability were discussed. It was agreed that funds should be channelled through National Agricultural Research Directors who would also account for them.

6. Improving the Research Environment. The Council strongly recommended that respective governments of SAFGRAD member countries take appropriate steps to alleviate some of the following constraints to both agricultural research and extension so that these two sectors could play catalytic roles in agricultural development:

   - Gross insufficiency of budgetary allocation for agricultural research by SAFGRAD member countries

   - Lack of attractive service conditions for retaining highly trained manpower in agricultural research in member countries

   - The usually weak or unsatisfactory linkage between research and extension, often to the detriment of farmers in member countries

   - Under-utilization of the limited number of trained agricultural research and extension personnel.

Oversight Committee (OC)

The Oversight (management) Committee was established by the Council of National Agricultural Research Directors. It has seven individuals elected by the Council on the basis of their personal competence in either agricultural research and management or in teaching in a faculty of agriculture of an African university. Specifically, five of the members represent agricultural research institutes, while the remaining two are from agricultural faculties of universities.

The Oversight Committee is directly responsible to the Council of Directors and serves as a management board to SAFGRAD. From 1987 to 1991, it held seven meetings; five were fully attended. Major issues deliberated by the committee are summarized in Table 6-A in the Appendix.

Improving the Effectiveness of Networks.

1. Internal appraisal of networks. The Oversight Committee (1990) contracted a four-man team to carry out an internal appraisal of four commodity networks in West, Central, and Eastern Africa. The appraisal involved national scientists, research managers, IARCs and the SAFGRAD Coordination Office (SCO). The major findings were: (a) networks have effectively facilitated the exchange of germplasm both for the creation of new varieties and testing, (b) the SCO should enhance the transfer of network coordination and management to NARS, and (c) IARCs participated in SC meetings and invited SC members and SAFGRAD Management to their program-planning and evaluation meetings.

Table 10. Extent of Technical Papers and Annual Reports Generated Through the SAFGRAD Project, 1979-91).

Project Entities	SAFGRAD I		SAFGRAD II					Total	% of Total Publications
	1979-82	1983/86	1987	1988	1989	1990	1991		
IITA	5	18	25	14	16	18	14	110	21.1
		26	-	-	-	-	-	47	9.1
Farming Systems Unit, Purdue University	21	19	15	17	16	22	13	106	20.4
OAU/STRC-SAFGRAD									
SCO/ACPO	4	35	3	2	3	2	2	72	13.9
IFAD-Funded FSR	25	13	19	12	10	4	-	58	11.2
Farming Systems Research Network	-	-	-	3	2	6	5	16	3.1
SAFGRAD Newsletters	4	10	2	3	4	4	2	29	5.6
Other Publications	18	14	16	12	6	6	9	81	15.6
TOTAL	**77**	**135**	**80**	**63**	**57**	**62**	**45**	**519**	

2. Urged the publication of SAFGRAD achievements to enhance the dissemination of technical information. Action taken in response to the above recommendation included:

- A brochure was prepared entitled *The SAFGRAD Networks - Serving National Agricultural Research Systems and Food Grain Farmers in Sub-Saharan Africa*. It has been widely distributed to member countries, research institutions, regional and international agricultural research agencies.

- The SAFGRAD Newsletter was revitalized to extensively cover network activities. Published quarterly in English and French, it has more than 500 readers including national researchers, managers, policymakers, and regional and international agencies.

- A consolidated *Annual Report of SAFGRAD* was produced. It is distributed to member-country institutions, network entities, regional and internal organizations.

- Published and distributed workshop proceedings and other related technical publications.

3. Recommended broadening membership of Steering Committees. So far, representation of the Steering Committee (SC) membership of professional disciplines and countries in SC membership has been poor. For example, for the Maize Network the six SC members represent approximately 35% of network member countries in West and Central Africa. SC members of networks were made up entirely of crop researchers and so research programs were biased towards crop improvement and excluded essential disciplines such as socio-economics and utilization of farm produce.

Improving the Effectiveness of the SAFGRAD Coordination Office.

1. Streamlining program activities. A consolidated work program of six months for SAFGRAD was developed and regularly approved by the Oversight Committee. This program effectively streamlined network activities, such as movement of germplasm, visits to countries to provide advisory technical services, coordinating workshops, and meetings with IITA and ICRISAT and other organizations. This has enabled the SAFGRAD Coordination Office (SCO) and coordinators of the respective networks to budget their time and save resources in dispatching regional trials, publications to various NARS, and interactions with other networks and institutions.

2. Institutionalization. Through full participation of OC members, peer NARS scientists, research managers and two consultants, SCO undertook a study and prepared a document, "Institutional Framework of SAFGRAD". The study was followed by an internal OAU meeting on SAFGRAD, convened by the Secretary General of the Organization of African Unity in Addis Ababa, Ethiopia, September 17-19, 1991. A recommendation was made to gradually transform SAFGRAD into an institution to advise, elaborate, and implement food and agriculture research policy in Africa.

3. Strengthening the core staff of SCO. The critical level of staff that SCO needs to accomplish its mission was determined and three professional positions recommended (project planning monitoring and evaluation officer, communication officer, and liaison officer for East and Southern Africa). Action has not been taken to fill the above positions due to lack of funds.

4. Solicit funds to support project activities. Action taken included:

   - The OAU raised its initial contribution by nearly fourfold to cover most of the costs of the Coordination Office and also provided for funding positions of NARS coordinators as the process of institutionalization of SAFGRAD progresses as a permanent agency of OAU.

   - The African Development Bank provided financial support to the Food Grain Production Technology Verification Project activities in eight member countries.

   - The in-kind contribution of member countries increased to about 40% of the total cost of the project during Phase II .

   - Financial support to the Farming Systems Research Network was also obtained from IDRC, Ford Foundation and the French Ministry of Cooperation.

Impact Assessment Study

The Oversight Committee recommended that the study should be focussed largely on SAFGRAD II project outputs. The study objectives were: (1) Evaluate specific contributions of networks to strengthening research capabilities of national agricultural research systems of participating countries and to analyze the impact of network technologies in improving productivity of foodgrains, namely, maize, sorghum, millet, and cowpeas; (2) determine how best to re-orient future network activities in order to make them more responsive to farmers' needs.

Performance of the Steering Committee in the Technical Management of Networks

The Steering Committee (SC) is one of the NARS structures established to technically manage networks. The members were elected based on their individual competence and research recognition by the workshop assembly of national researchers of the respective networks.

Composition and Representativeness. Analysis of the structure of the SC showed that most of the members of this committee initially (1987) were breeders. The representation of countries in each SC has been the subject of debate during SAFGRAD Phase II. As of 1988, the EARSAM network made adjustments to increase the number of its SC members from five to eight so that each participating country of the network is represented. In the case of West and Central Africa, the six members of the SC represent 35% of the network member countries. More than 50% of SC membership, however, is replaced every two years by members from other countries. Of 10 SC meetings held by the respective networks, full attendance of members was attained twice for WECASORN and EARSAM; four and five times for maize and cowpea networks, respectively. At least four members have attended each SC meeting.

A number of biotic, socio-economic, climatic, and agronomic constraints to production of foodgrains were identified (Table 2-A in the Appendix). Research programs of the networks, in general, and at Lead NARS centers in particular, were developed principally to address the main biotic and some of the climatic and agronomic constraints. There has not been a systematic follow-up and technical direction for networks to address most of the socio-economic constraints, such as technology transfer and adoption. Climate changes and accelerated degradation of the resource base for productive agriculture during the last two decades have enabled *Striga*, once important only in limiting the production of sorghum and millet, to also reduce the production of maize and other cereals.

Organization of Research. The analysis of data on available human resources, research infrastructure and constraints to a particular crop commodity enabled each network to organize research according to levels of NARS research development. Research capabilities of network-participating countries' were categorized into technology-generating and technology-adapting NARS. Lead NARS Centers were identified in countries with relatively strong research programs. Based on their comparative research advantages, the Lead Centers accepted regional responsibility to undertake the implementation of collaborative research to alleviate food production constraints of mutual and common interest in the sub-region. The technology-adapting NARS have relatively weak national programs concentrated on adaptive research and verification of technologies to farmers' conditions.

The review of collaborative projects and conduct of regional trials were important agenda items for each SC meeting, during workshop sessions and monitoring tours. The status of generation of technology at Lead Centers, recovery of regional trials data from NARS, standardization of trials, and stability analysis of data across locations were assessed. The type and number of regional trials that were evaluated by each network for the adaptation to different ecological zones were also reviewed twice or three times a year.

Weakness. There seems to be an obvious weakness in the way the network Steering Committee allocates funds to support research activities in various NARS. First, grants provided were not on a competitive basis. This may be due mainly to the small amount of money available. Secondly, regardless of the amount available, specific criteria for allocation of funds for project support should have been established. Thirdly, the reporting system is not well defined, even though the progress of each project was regularly reviewed by the SC and network coordinators.

Comments. The Council of Directors has not been effective in implementing its own decisions probably due to lack of specific mandate and terms of reference. There have been no noticeable policy reforms to improve the environment for research. Most NARS Directors did not stay long enough as managers of research to make the desired changes or were not mandated to initiate policy reforms. Another problem common to all countries was lack of commitment of the policy and decision-making body for research management (referred as the Board of Research Management or Scientific Council in various NARS). With few exceptions, the policymaking body of several NARS, composed of various ministries of development and finance, are more inclined to reduce budget resources, than to initiate research policy reforms so as to increase the relevance of research to agricultural development and also to enhance output by establishing a good environment for research such as conducive long-term staff and research-career development.

Donors and regional and international agencies have at various times called for research-policy reforms. These same organizations have contributed to instability and shift of national research strategy. During the last 15 years, several national institutions and affiliated development ministries have spent considerable effort and resources (up to 1000 man days)in the reorganization and restructuring of agricultural research. Following such a planning and project development phase, it will take another three to five years to raise the financial resources for the implementation. Reorganization and reviews of NARS have thus become a continuous activity.

Network Research Process and Strategy. The network model (Table 12) involved the mobilization of resources of the national agricultural system of 17 and eight countries, respectively, in West and Eastern Africa and the technical backstopping of the IITA for the improvement of maize and cowpea and of ICRISAT for the improvement of sorghum and millet. The OAU/STRC had a logistic and legal framework for network operation, facilitated policy reviews and promoted the transfer and adoption of technology.

Identification of Research Priorities. Figure 8 shows that the identification of research priorities at national level was based on the qualitative data obtained from reconnaissance and on-farm socio-economic surveys, review of the extension and rural development programs, annual research reviews, and through occasional farmers' participation. Although the capacity to undertake the above-mentioned surveys varied considerably among countries, the process is repeated at the regional level. The Networkshop Assembly of NARS researchers, normally held in alternate years, was an important technical forum to review research plans, to effect the exchange of technical information, and to identify and prioritize constraints to production of foodgrains.

Those constraints of regional dimension became the basis for setting research priorities and formulating network programs. Assessment of NARS research capacities by each network resulted in the stratification and categorization of national systems into Lead Centers and Technology Adapting NARS. Thus, given the widely different levels of NARS research capabilities, a strategy was adopted whereby the relatively strong national programs accepted research responsibilities to serve as Lead

Fig. 8. Identification Process of Network Research Priorities.

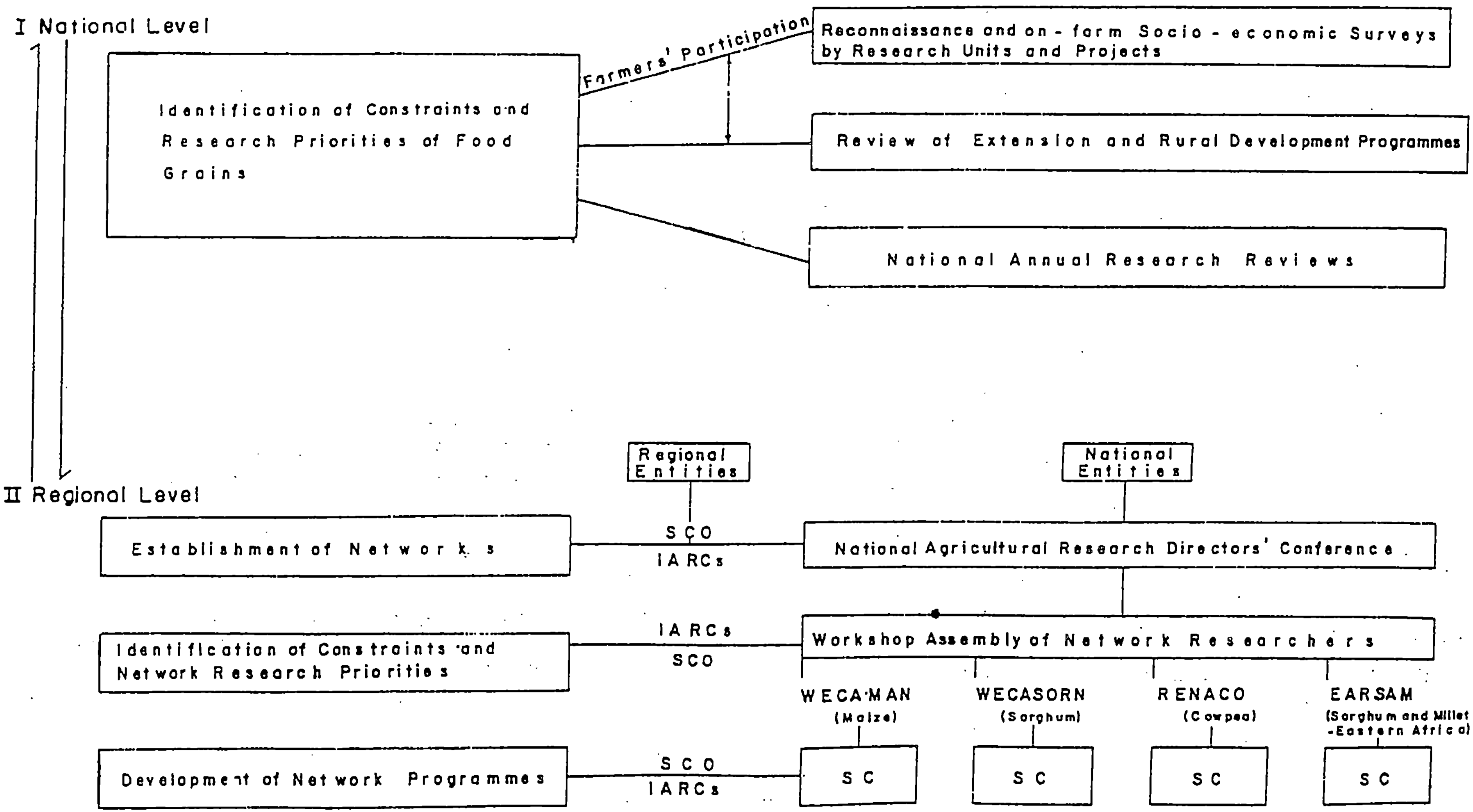


Table 11. SAFGRAD Networks Committee* Structure and Performance, 1987-92.

Activity	WECASORN[a]	RENACO[b]	EARSAM[c]	WECAMAN[d]
Organization of Steering Committees:				
Network Participating Countries	17	17	8	17
Steering Committee Members	6	6	8	6
% Representation of Network Countries	35	35	100	35
Meetings Per Year	2	2	½	2
Full Attendance of 10 Meetings	2	5	2	4
Disciplinary Composition, 1987	BR[e]	MIX	BR	BR
Disciplinary Representation, 1989-91	MIX[f]	MIX	MIX	MIX
Identification of Constraints:				
Main Biotic	10	15	13	11
Main Climatic	2	4	2	2
Socio-Economic	6	8	4	7
Main Agronomic	3	4	4	4
Organization of Research:				
Main Research Priorities	6	6	8	8
Available Research Manpower	78	67	82	80
Lead NARS Centers With Research Responsibility	5	6	5	6
Associate Centers	0	3	0	0
Technology-Adapting NARS	12	8	4	11
Collaborative Projects	6	6	8	6
Regional Trials:				
In 1987-88	4	7	3	3
In 1988-92	5	5	3	3
Monitoring Implementation of Network Research Activities:				
Frequency Per Year	3	3	4	3
Review of Regional Trials	2	2	2	2

(cont.)

Table 11 (cont.)

Activity	WECASORN	RENACO	EARSAM	WECAMAN
Training Seminars:				
Short-Term Training Courses	3	2	4	3
Benefitting Countries, 1987-91	15	12	8	11
Financial Allocation for Network Research Support, 1987-91:				
Technology-Adapting NARS				
Lead NARS Centers				
Monitoring Tours, 1987-91:				
Number of Tours	5	2	4	2
Number of NARS Participants	32	13	27	14
Number of Countries Visited	11			
Workshops:				
Number of Workshops	2	3	4	3
NARS Scientists Attending	70	98	225	80
Participating Countries, 1987-92	17	15 (17)[g]	8	15 (17)[g]
Technical Advisory Services, 1987-91:				
Visits by Coordinators, Man Days	75	200	NA	107
NARS-to-NARS Advisory Visits, Man Days	25	45	NA	75

Note: Research reviews were done about three times per year by each network during the biennial Steering Committee meetings and monitoring tours and workshops in alternate years.

* Steering Committee members are elected based on their research qualifications, experience, and competence.
[a] WECASORN: West and Central African Sorghum Research Network
[b] RENACO: West and Central Africa Cowpea Research Network
[c] EARSAM: East Africa Regional Sorghum and Millet Network
[d] WECAMAN: West and Central Africa Maize Research Network
[e] BR: Breeding
[f] MIX: Multidisciplinary
[g] Figures in parentheses indicate number of participating countries in alternate years of the workshop.

Centers in specific research areas in which they had comparative advantage. Each network has developed four to six such Lead Centers with responsibilities to screen and identify foodgrain (sorghum, maize, millet, and cowpea) cultivars resistant to several biotic and abiotic constraints.

Research at Lead Centers focused on priority constraints in specific ecological zones. The network scheme, outlined in Fig. 9, enabled NARS and IARCs to streamline the various (germplasm) nurseries and regional variety trials in such way as not to overburden the weak national programs. The strategy enabled technology-adapting countries to concentrate their efforts on adaptive research.

Research Performance of Lead NARS Centers. Collaborative projects were formally started in 1988. More than 25 projects were implemented by Lead NARS Centers of the crop commodity networks. Major emphasis was placed on screening and developing technologies that would alleviate various biotic and abiotic stress factors, such as *Striga*, drought, soil fertility, moisture stress, insect pests, and diseases. Attention also was given to improvement of nutritional value of the grains and their agro-industrial uses. Whereas the IARCs have provided broad germplasm and related technologies, the Lead and Associate NARS Centers of the respective networks conducted applied and adaptive research.

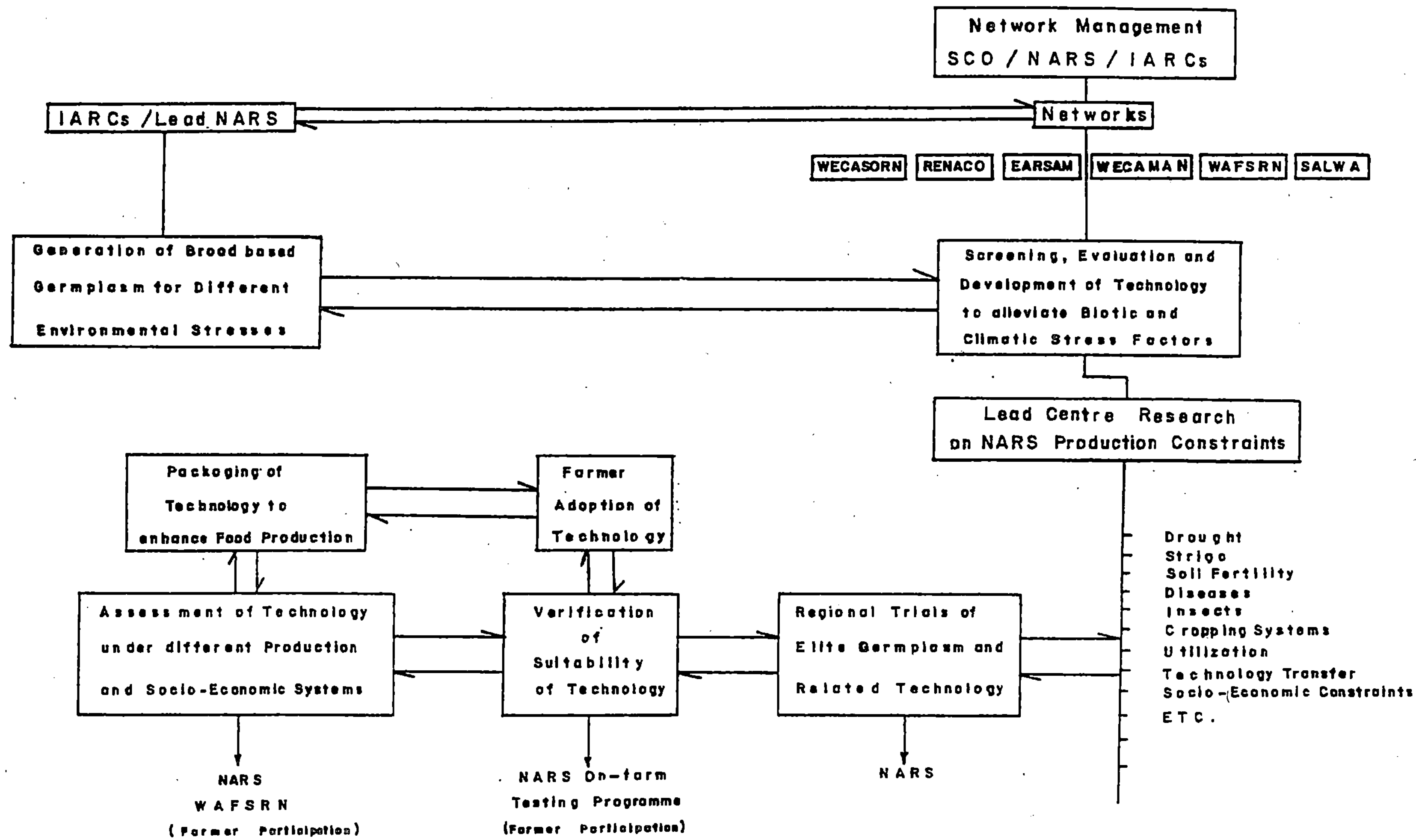
The collaborative research projects were developed to provide solutions to production constraints of common interest. The mechanism optimizes the research strength and comparative advantage of strong NARS (Lead Centers) which are relatively endowed with qualified research personnel, infrastructure, facilities, and ecological potentialities for the generation and evaluation of technologies. How did this process work?

West and Central Africa Sorghum Research Network (WECASORN) and Eastern Africa Regional Sorghum and Millet (EARSAM) Network. The collaborative project activities of WECASORN and the EARSAM network include leaf anthracnose (*Colletotrichum graminicola*), a major disease in West, Central, and Eastern Africa. The Burkina Faso and Ethiopia Lead Centers have identified sorghum cultivars resistant to this disease in their respective regions. In cooperation with ICRISAT, these cultivars and the extent of the variability of the anthracnose pathogen, are being further evaluated (Tables 13 and 14).

Long smut of sorghum is another important disease both in West and Eastern Africa. The Kenya Agricultural Research Institute (KARI), as a Lead Center for EARSAM, has developed screening techniques for the disease and identified 18 resistant lines. The resistance of IS 8595 sorghum cultivar was confirmed. Similarly, the Niger National Program served as the Lead Center of WECASORN to screen sorghum cultivars for resistance to long smut. Some progress was reported the following year when 11 out of 75 genotypes appeared to be highly resistant to long-smut, from natural innoculum.

Striga is one of the major constraints to the production of foodgrains throughout Sub-Saharan Africa. The depressing effect of *Striga* on food production has become quite substantial. Within the EARSAM Network, 25 resistant sorghum genotypes were identified by the IAR, Ethiopia. The most promising cultivars are SAR-24, Gambella 1107, N-13, ICSV-1006, and ICSV-1007 (Tables 13 and 14).

Fig. 9. The Network Scheme for the Generation and Evaluation of Technology



- SAFGRAD — Semi- Arid Food Grain Research and Development
- IARCs — International Agricultural Research Centres i.e International Institute of Tropical Agriculture and International Crops Research Institute for the Semi-Arid Tropics
- SCO — SAFGRAD Coordination Office
- NARS — National Agricultural Research Systems
- WECAMAN — West and Central Africa Maize Research Network
- RENACO — West and Central Africa Cowpea Research Network
- EARSAM — Eastern Africa Regional Sorghum and Millet Research Network
- WECASORN — West and Central Africa Sorghum Research Network
- WAFSRN — West Africa Farming Systems Research Network
- SALWA — Agroforestry Network for the "Semi-Arid Lowlands of West Africa"

Table 12. Components of SAFGRAD Network Model.

Network Partners	Network Entities	Responsibilities
NARS 18 countries in West and Central Africa, 8 countries in Eastern Africa	Directors of Agricultural Research of National Programs Oversight Committee Network Steering Committees	Policy guidance, addressing research, and development issues Monitoring the implementation of SAFGRAD project activities Management of SCO and appraisal of networks Technical management of networks
IARCS IITA ICRISAT ICRAF The IARCs provide technical backstopping to the networks	Maize Network Coordinator Cowpea Network Coordinator Sorghum Network Coordinator in West and Central Africa Eastern Africa Sorghum and Millet Network Coordinator Semi-Arid Lowlands Agro-Forestry Network in West Africa	All network coordinators undertake technical execution of network programs
OAU/STRC Scientific, Technical and Research Commission of OAU provides political and administrative support	SAFGRAD Coordination Office	Coordinates research activities among NARS and with relevant government bodies. Provides legal and logistic framework for network operations. Serves as secretariat to network entities. Facilitates review of policy issues through regular channels of OAU. Promotes adaptation and transfer of network technologies to farmers in different national programs.

Note: The West African Farming Systems Research Network, administered by SCO, also executes technical programs of the network.

Table 13. Research Output of Lead Centers of the West and Central Africa Sorghum Research Network.

Collaborative Project Activities	Constraints Addressed	Lead NARS	Number of Researchers	Research Output
Screening sorghum genotypes resistance to Anthracnose	Disease	Burkina Faso	6	In 1989, identified 74 lines resistant to foliar infection; in 1990, about 44 lines from local germplasm were found resistant to leaf, grain, and stem infection. In 1991, 22 more tolerant lines were identified.
Identifying sorghum cultivars resistant to head bug	Insect Pest	Mali	12	More than 25 sorghum lines resistant to head bug were identified. The insect biology and its economic importance were studied. Early planting recommended. The resistance of nine cultivars also was confirmed by artificial inoculations.
Broadening the use of sorghum	Utilization	Nigeria	10	Local sorghum variety Farafar was found suitable for wheat sorghum composite bread and confectionery. Variety SK5912 developed by IAR is utilized to produce malt for the production of industrial beer. Non-alcoholic beverage are also produced from sorghum.
Screening resistant sorghum cultivars to long smut	Disease	Niger	4	Methodology for screening was developed; 24 cultivars resistant to long smut disease were identified.
Identification of *Striga*-resistant sorghum cultivars	Parasitic weed	Cameroon	5	More than 10 tolerant sorghum lines were identified which are being further evaluated through regional trials. Some varieties have been released.

Table 14. Research Output of Lead NARS Centers of the Eastern Africa Sorghum and Millet Research Network.

Collaborative Project	Constraints Addressed	Lead NARS	Number of Researchers	Research Output
Development of sorghum cultivars resistant to *Striga*	Parasitic weed	Ethiopia	7	Identified 25 *Striga*-resistant sorghum genotypes
Screening Anthracnose-resistant sorghum cultivars	Disease	Ethiopia		17 sorghum lines from Ethiopia and 50 lines from ICRISAT were found promising
Screening drought and *Striga*-resistant sorghum cultivars	Drought and parasitic weed	Sudan	17	Developed integrated method of drought and *Striga* control
Screening for host-plant resistance to stalk borer	Insect pest	Somalia	18	Research facilities developed but work discontinued
Identification of finger millet blast-resistant genotypes	Disease	Kenya	8	Several accessions were evaluated by ICRISAT and KARI
Screening sorghum cultivars resistant to long smut	Disease	Kenya		18 lines of sorghum were identified
Screening sorghum cultivars resistant to *Ergot*	Disease	Rwanda	2	8 and 6 resistant lines from Rwanda and Ethiopia were identified
Evaluation of nutritional and food quality of sorghum	Grain quality	ICRISAT		16 cultivars from the region were evaluated. Varieties with higher rating included SPV475 (India), Dabar (Sudan), and IS24129 (Tanzania).

Table 15. Research Output of Lead NARS Centers of the Cowpea Network in West and Central Africa.

Collaborative Project	Lead Center Country	Number of Researchers	Research Output
Breeding for drought, *Striga*, insect pests, and disease resistance	Burkina Faso	5	Identified cowpea lines with combined resistance to insect pests and diseases. These include KVX 402-5-2, Kvx 402-19-1, KVX 402-19-5, and KVX 396-4-5-20. Developed *Striga*-resistant cowpea cultivars. These include SUVITA-2, TN27-80 KVX 61-1, and KVX 402-5-2.
Control of cowpea storage insect pests	Cameroon	2	Storage technologies developed: 1) Use of a plastic cover and an insulating cushing made of cowpea pod husks or any other plant material to permit temperature to rise up to 65°C to kill the bruchids. 2) Use of ash: 4 volumes cowpea + 3 volumes ash mixed together destroyed weevil population. 3) Use of botanical products: neem-seed oil protects cowpea grain from bruchids.
Development of cowpea for sub-humid and coastal zones and control of storage pests	Ghana	10	Line CR-06-67 was the most promising. Four plant products, namely neem-seed oil, Jatropha seed oil, groundnut oil, and black pepper powder were as effective as acetellic 2% dustin protecting cowpea grain from weevils for at least six months.
Development of drought, *Striga*, insect-and-disease resistant cowpea cultivars	Niger	9	Identified cultivars resistant to *Striga*, namely: TN 93-80, TN 121-80, and B 301.
Development of improved cowpea cultivars resistant to insect pests, *Striga* control through crop management, and control of seed-borne diseases	Nigeria	8	Suitable dual-purpose cowpea cultivars developed for Northern Nigeria. Land races resistant to insect pests were identified. Increased levels of application of phosphorus up to 60 kg P_2O_5/ha improved cowpea yields. IT86-D-1056 was found to combine resistance to *Septoria* leaf spot and scab. IAR/IITA determined genetics of importance to *Striga*.
Development of multiple pest/disease-resistant cowpea cultivars and breeding for drought resistance	Senegal	3	Identified three lines (IS 87-416, IS 87-432, and IS 87-437) with combined resistance/tolerance to insect pests (such as thrips) and diseases (bacterial blight and virus). Lines IS 86-275 and B 89-504 were also observed resistant to virus and bacterial blight.

In Sudan, the emphasis of research has been on the development of an integrated *Striga*-control management package (i.e., breeding, chemical control, and agronomic practices). Cameroon served as Lead Center for WECASORN to screen sorghum cultivars for resistance to *Striga*. Several resistant genotypes have been identified. Results of the West African Sorghum *Striga* Resistance Trials have indicated IS 9830 and ICSV 1007 BF as promising *Striga* resistant lines.

Evaluation of sorghum for nutritional quality and for industrial uses, such as brewing, has been a project priority for both the EARSAM Network and WECASORN. Cultivars with higher ratings for food quality have been identified. For example, in Nigeria the local variety, Farafara, and in Kenya, Kat 369, were found suitable for wheat-sorghum composite bread and confectionery.

With regard to insect pests of sorghum, stalk borer (*Chiloa partellus*) is one of the important pest problems in Eastern Africa. In cooperation with the Ministry of Agriculture of Somalia and with the technical support of ICRISAT, the EARSAM Network has established facilities to screen sorghum cultivars for resistance to the stalk borer.

On the Western side of the continent, sorghum head bug (*Eurystylus marginatus*) is an important economic pest. Mali, as the Lead Center, has reported results that interested other members of WECASORN. With Sudano-Sahelian climatic conditions, the insect was more abundant toward the end of September and early October; thus, early planting of sorghum is a possible control measure. In addition, about 25 lines were reported to be resistant to the head bug.

The EARSAM Network initiated a project to control blast disease on finger millet in 1990. The program was based largely on collections and accessions obtained from Katumani genetic resources unit of KARI. Over 250 lines of finger millet were screened for resistance to the disease. A regional blast nursery has already been established.

West and Central Africa Cowpea Research Network (RENACO). The West and Central Africa Cowpea Network (RENACO) has facilitated the development and diffusion of cowpea varieties suitable for adaptation in three main ecological zones in West and Central Africa (i.e. the northern Guinea, Sahel savanna zones, and Sudan). The Cowpea Network has collaborative research projects in six relatively strong national programs that serve as Lead NARS Centers. A number of cowpea varieties resistant to *Striga*, drought, and aphids have been identified (Table 15). The drought-resistant cowpea cultivars developed by Lead Centers include SUVITA-2, 58-57, Kvx 30-309-6 G, TN 88-63, Kvx-396-4, and IS86-275. The aphid-resistant varieties developed and contributed by IITA include IT82E-2S, IT835-742-2, and IT856-3755, while some of the bruchid-resistant cultivars developed by Burkina Faso and IITA are IT845–275-9, Kvx 30-6467-6-10K, and IT845-22461.

Affordable technologies to control storage insect pests were developed by Cameroon and Ghana as Lead Centers. These studies showed that local plant products (i.e., neem seed oil, groundnut oil, black pepper powder, and ash) could be used to control cowpea storage pests. In Nigeria, dual-purpose cowpeas, producing both grain and fodder and adapted to northern Guinea savanna zones, were developed. Agronomic research at Samaru, Nigeria also established that the application of phosphorus up to 60 kg P_2O_5/ha increased cowpea yields. In Senegal, three cowpea lines with combined resistance to thrips, bacterial blight and virus diseases were identified. In Nigeria, the IAR in Samaru and the IITA Kano Substation collaborated to elucidate the genetics of inheritance to *Striga* and *Alectra* in the cowpea line, B301. This has facilitated the incorporation of resistance to the two parasites into agronomically acceptable cowpea cultivars.

The West and Central Africa Maize Research Network (WECAMAN). The cultivation of maize has substantially expanded in the semi-arid zones (Sudan and northern Guinea savannas) during the last decade. Maize production has good potential in this ecology in which large increases could be attained through innovative agricultural-development policies that enhance the application of improved production technologies.

The SAFGRAD Maize Network has taken a pragmatic approach in expanding maize cultivation in the semi-arid ecology, primarily to fill food gaps resulting from low yields and a lengthy growing season of traditional crops, such as sorghum and millet.

Maize-research priorities encompassed development of short-season maturity varieties with resistance to *Striga*, drought, insect pests, and diseases. Problems associated with low soil fertility and related agronomic practices have also received attention (Tables 15 and 16).

The Network promoted maize improvement within and among NARS through collaborative research project activities (Table 15). Six major collaborative projects were developed at Lead Centers. These research activities coordinated by the Network have enabled NARS to identify suitable germplasm for their own climatic conditions. Capability in maize streak-resistance-conversion technology has been strengthened in Togo and Ghana NARS. In Côte d'Ivoire, network-supported research on the identification of sources of stem-borer resistance in maize of different periods was begun. The extent of damage on the maize crop by three species of borers was assessed and several accessions of maize were screened. In Cameroon, the development of drought-tolerant and *Striga*-resistant maize was given priority. In Nigeria and Cameroon, improved agronomic packages for early and extra-early maize varieties were developed.

In Burkina Faso, where the Network Headquarters is situated, several extra-early-maturing maize cultivars were developed and have been included in the regional trials. Streak resistance has been incorporated into early maize cultivars such as TZEE-W, CSP and TZEE-Y. The Ghana national maize program has developed maize of different maturity periods, including maize cultivars that mature within 120, 105 and 95 days.

Table 16. Research Output of NARS Lead Centers of the Maize Network in West and Central Africa.

Collaborative Projects	Lead Center Country	Number of Researchers	Research Output
Breeding maize for different maturity groups, drought resistance, and *Striga* tolerance.	Cameroon	12	Developed drought-tolerant synthetics from Pool 16 DR and from IITA and SAFGRAD sources. Agronomic-management practices for early and extra-early maize cultivars were developed. CMS 8806 and Pool 16 DR were released.
Development of early and extra-early maize with drought resistance	Burkina Faso	5	In collaboration with Burkinabe National Program, developed several drought-tolerant cultivars being utilized in the regional trials. Several extra-early-maturing maize cultivars (less than 82 days to maturity) were developed. Streak resistance was incorporated into TZEE-W, TZEE-Y, and CSP Early.
Screening maize cultivars to stem borer resistance	Côte d'Ivoire	5	Network provided assistance to develop research facilities. Identified three species of stem borers in Northern Côte d'Ivoire. Screened several accessions of maize.
Screening for streak resistance in maize cultivars	Togo	4	Improved facilities for screening streak resistance. Two maize populations are being improved for streak resistance. Varieties EV 8443-SR and Ikenne 81495R were released.
Development of maize of different maturities and with streak resistance	Ghana	10	Various populations of maize for different purposes, with white dent, yellow/flint dent, and different maturity groups (120, 105, and 95 days) developed. Incorporated streak resistance to standard maize cultivars. Varieties SAFITA-2, Dorke SR, and Abeleehe, Okomasa were released.
Fertilizer requirements for maize and cowpea mixture	Nigeria	8	At Samaru, Northern Nigeria-maize grain yield increased with the application of up to 75 kg N/ha and 40 kg P_2O_5/ha. For cowpea, N application depressed grain yield while responding to P, up to 80 kg P_2O_5/ha.

Diffusion of Elite Germplasm via Regional Trials. An important mechanism for direct exchange and evaluation of elite germplasm has been the regional trials conducted among member countries of various networks. The importance accorded to regional testing of improved technologies as one of the key activities of the networks is not only because of the need to popularize germplasm and related technologies available in various NARS and IARCs but also because of the necessity to accelerate verification and validation of the performance of technologies under different environmental and socio-economic conditions.

West and Central Africa Sorghum Research Network. Among the various elite varieties evaluated, the Naga white variety from Ghana gave the highest yield among the early-maturing sorghum varieties in 1987, 1988, and 1989; its grain yields varied from 2.8-3.5 t/ha. ICSV 1063 yielded highest among the medium-maturing varieties, producing between 2.6 t/ha and 3.3 t/ha. Among the hybrids, ICSH 567 ranked first in 1988 and 1989, with mean yields of 3.3 and 3.7 t/ha, respectively.

In 1988, the West Africa Sorghum *Striga* Trial consisted of 11 entries which had been evaluated in fields with high *Striga* infestations in Cameroon, Ghana, Mali, Niger, Nigeria, and Togo. The results of two years of evaluation showed IS 9830 and ICSV 1007 BF as promising *Striga* resistant lines.

During the past few years, WECASORN has made some modest impact in the overall effort for sorghum improvement in West and Central Africa. A number of improved sorghum varieties have been released. For example, S-35, an improved sorghum cultivar, has been released in the Far-North Province of Cameroon and in Chad. The Framida variety, introduced in 1980s for its *Striga*-resistant trait, is being cultivated in Burkina Faso (Manga region), the northern regions of Ghana, and Togo.

In Mali, ICSV 1063 BF and ICSV 1079 BF were tested on farmers' fields; ICSV 1063 BF produced superior grain yields over the local variety. This variety was tested in several villages during the 1990 crop season. ICSV 11 IN and M 66118 have received greater attention in Ghana; ICSV 1063 BF and Mali Sor 84-1 were included in on-farm tests by extension agencies in Côte d'Ivoire. Promising sources of resistance to the prevalent leaf diseases and to *Striga* have been identified through disease-observation nurseries and *Striga* trials.

Eastern Africa Regional Sorghum and Millet Network. The low-land and intermediate-altitude regional yield trials included 25 and 16 entries, respectively, while the elite finger-millet trials consisted of 16 entries (for more data, see the Appendix). The participation of NARS in the regional trials appeared to have been influenced by the importance of the crop in particular ecological zones. Thus, the low-land trials, intermediate-altitude trial and the finger-millet trials were conducted by 8, 5 and 4 NARS, respectively.

Among low-dryland elite sorghum varieties, Seredo produced the highest mean yield (3.37 t/ha) across locations, followed by ICSV 112, CR 35-5 and KAT/83369 which averaged 3.42, 3.39 and 3.31 t/ha, respectively. The promising sorghum cultivars at the intermediate altitude zone were IS9302 (from Ethiopia) and Nyirakkabuye and Amasugi (both from Rwanda) which yielded 3.33, 2.61, and 2.54 t/ha, respectively, across locations. Of the entries in the elite finger millet Trials, the variety, Gulu, (from Uganda) was the highest yielder across locations (with an average of 2.6 t/ha).

Of the sorghum varieties grown by farmers in Eastern Africa, the variety Seredo has been released in Ethiopia, Kenya, and Uganda. Other varieties, such as Lulu, Serena, and Tegemeo, are largely cultivated in Tanzania. The varieties Dinkmash, Gambella 1107, and Melkamash are the major improved cultivars grown by farmers in Ethiopia.

In the Sudan, a number of improved varieties have been released. In the early 1980s, the development and release of the sorghum hybrid, the Hageen Dura-1, through the collaborative effort of ICRISAT and the National Research Program of Sudan, brought new hope for substantial increase in sorghum production in the country. On-farm verification trials of sorghum variety SRN-39 (since 1986), in collaboration with the Sudanese-Canadian project, expanded the production of this cultivar by farmers in the Sim and Gedaref regions.

West and Central Africa Maize Research Network. Regional trials of the Maize Network have enhanced the broad evaluation of elite cultivars in different national programs. Between 1987 and 1990, the Network coordinated three types of regional trials. The SAFGRAD trials concentrated on the early and extra-early maize. The trials of late and intermediate varieties were coordinated by IITA. The Regional Uniform Variety Trials (RUVT) consisted of:

RUVT-1: Drought resistant, early maturing (90-95 days)
RUVT-2: Intermediate and late maturing (105-110 days)
RUVT-3: Extra early maturing (less than 82 days)

Almost 350 sets of trials, including 192 of RUVT-1, 135 RUVIT-3, and 630 of RUVT-2, were evaluated in 12 to 15 locations in network-member countries. Participation in these regional trials has enabled national programs to identify 21 varieties from RUVT series suitable for semi-arid climatic and soil conditions. The availability of short-cycle maize cultivars has allowed the expansion of maize into new frontiers, specifically the Sudano-Sahelian zones.

The short-cycle varieties that have been developed by the Network are targeted to short growing seasons in which the crop could be harvested as green maize two months after planting, thereby filling the food-gap shortage before the harvest of sorghum and millet. Agronomic research in Cameroon indicated that the extra-early varieties could also fit into the farming system of hydromorphic soils (vertisols) where yields up to 5-7 t/ha have been reported at recommended plant density and soil management levels.

Some of the maize germplasm exchanged through the Network was incorporated into the national maize-improvement programs of participating countries particularly to develop early and extra-early cultivars. Each country participating in the Network has its own established maize-improvement program basically funded from national and other resources. With its limited resources, WECAMAN played a catalytic role in intensifying scientific interaction and exchange of germplasm between NARS and IARCs and among NARS. This effort has paid off since maize germplasm and improved agronomic packages were made available to all participating countries.

APPENDIX

Table 1-A.

TOTAL SCORES BY COUNTRY, FOR ALL CRITERIA AND BY NETWORKS

COUNTRY	NETWORKS (all criteria)				TOTAL	RANK
	WECAMAN	EARSAM	RENACO	WECASORN		
1. BURKINA FASO	10		10	10	30	1
2. MALI	8		9	9	26	2
3. CAMEROON	9			9	18	3
4. GHANA	9				9	5
5. TOGO	6			6	12	4
6. BENIN	5				5	13
7. ETHIOPIA		9			9	6
8. KENYA		8			8	7
9. SUDAN		7			7	10
10. BURUNDI		6			6	11
11. NIGER			8		8	8
12. GUINEA-BISSAU			4		4	14
13. GUINEA-CONAKRY			4		4	15
14. CHAD				6	6	12
15. NIGERIA				7	7	9
16. UGANDA		4			4	16

Table 2-A. SAFGRAD Program Assessment: Criteria for Selecting Countries for In-Depth Study.

NETWORK/CROP, REGION, AND COUNTRY	SCORES BY NETWORK	CONSTRAINTS/ECOLOGY					MAJOR SAFGRAD ZONES			PERFORMANCE/RESOURCES			AVAILABILITY OF BASIC ECONOMIC DATA
				PESTS & DISEASES									
		DROUGHT/ WEATHER	INFERTILITY/ SOILS	STRIGA	OTHER	AGRONOMIC PRACTICES	SAHEL	SUDAN SAVANNA	N. GUINEA SAVANNA	ABOVE PAR	AT PAR	BELOW PAR	
WECAMAN — WEST & CENTRAL AFRICA (MAIZE)													
MALI	8		X		X	X	X	X	X			X	X
BURKINA FASO	10	X	X	X	X	X	X	X	X		X		X
GHANA	9	X	X	X	X	X		X	X	X			X
TOGO	6		X	X	X			X	X		X		
BENIN	5		X			X		X	X		X		
CAMEROON	9	X	X	X	X	X		X	X	X			X
EARSAM — EAST AFRICA (SORGHUM & MILLET)													
SUDAN	7	X		X	X	X	LE*			X			X
ETHIOPIA	9	X	X	X	X	X	LE*	IE*	HE*	X			
UGANDA	4		X		X			IE*				X	
KENYA	8	X	X		X	X	X	X					X
BURUNDI	6		X		X	X		X	X			X	
RENACO — WEST & CENTRAL AFRICA (COWPEA)													
MALI	9	X	X	X	X		X	X	X		X		X
BURKINA FASO	10	X	X	X	X	X	X	X	X	X			X
NIGER	8	X	X	X	X	X	X	X			X		
GUINEA-BISSAU	4	X			X			X				X	
GUINEA-CONAKRY	4		X		X				X			X	
WESCASORN — WEST & CENTRAL AFRICA (SORGHUM)													
MALI	9	X	X		X	X	X	X	X	X			X
BURKINA FASO	10	X	X	X	X	X	X	X	X	X			X
CHAD	6	X		X		X	X	X				X	
TOGO	6		X	X	X	X			X			X	
NIGERIA	7	X	X	X		X		X	X		X		
CAMEROON	9	X	X	X		X	X	X	X	X			X

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* — Ecological zones in Eastern Africa: LE = Low Elevation (below 1,000 M); IE = Intermediate Elevation (1,000 - 1,500 M); HE = High Elevation (above 1,800 M).
Source: SAFGRAD/SCO and maize and cowpea network coordinators.

Table 3-A. Research Manpower (by Discipline) for Sorghum Improvement in the Eight Case-Study Countries.

	1982-84	1985-87	1988-90	1991-92	SAFGRAD Input
BURKINA FASO	5	6	8	10	Supported training of a sorghum breeder at Ph.D. level during SAFGRAD I[a]
Breeding	1	1	1	2	Supported training of a soil scientist at Ph.D. level[b]
Agronomy	2(PT)	2(PT)	3(PT)	3	Strengthened plant pathology research in identification of sources of resistance to leaf anthracnose[c]
Pathology	1(PT)	1(PT)	2(PT)	2	Supported training of three economists, 1 at Ph.D. level and 2 at M.Sc. level[d]
Entomology	1	1	1	1	On-the-job training for several technicians by the ICRISAT/SAFGRAD program[e]
Agricultural Economics	-	-	1(PT)	1	
Processing Technology	-	-	-	1	
Technicians	5	5	6	9	
CAMEROON	6	6	8	7	Extension agronomist was assigned to North and Far-North Provinces through the ACPO program (1982-87)[a]
Breeding	1	1+			An extension agronomist was trained at M.Sc. level[b]
Agronomy	2	2	1	1	Provided some financial support for screening sorghum genotypes resistant to *Striga*[c]
Pathology	1(PT)	1(PT)	2	2	
Entomology	1(PT)	1(PT)	1(PT)	1(PT)	
Agricultural Economics	1(PT)	1(PT)	1(PT)	1(PT)	
Processing Technology	-	-	1(PT)	1(PT)	
Technicians	6	6	1	1	
			8	8	
ETHIOPIA	14	12	10	12	Provided some research support to improve research capabilities in the identification of resistant cultivars to *Striga* and anthracnose[a]
Breeding	3	6(PT)			
Agronomy	6(PT)	8(PT)	6(PT)	8(PT)	
Pathology	2	2	6(PT)	8(PT)	Carried out seed production and entomology short training courses[b]
Entomology	2	2(PT)	2		
Agricultural Economics	-	-	1(PT)	1	
Processing Technology	1	1	1(PT)	1(PT)	
Technicians	8	12	1	2	
			12	10	
GHANA	3	4	4	4	Some technicians benefitted from short-term training in *Striga* control and on-farm agronomic research[a]
Breeding	1	1+			Provided limited funds for research support[b]
Agronomy	1	1	1	1	Provided germplasm from regional trials; consequently released varieties such as Framida[c]
Pathology	1(PT)	1(PT)	1	2	
Entomology	-	1(PT)	1(PT)	1(PT)	
Agricultural Economics	-	1(PT)			
Processing Technology			1(PT)	1(PT)	
Technicians	-	-			
	2	2	NA	NA	
			3	3	

Table 3-A (cont.)

KENYA	9	10	12	10	15 trainees benefitted from short-course training in seed production, insect, and disease control[a] Received financial support to screen sorghum genotypes for resistance to long smut, covered smut, and drought[b] Benefitted from the exchange of germplasm, consequently released varieties for farmers' use. New variety KAT 369 released and seed being increased for use in composite flour for bread[c]
Breeding	3	3			
Agronomy	3	4	4	4	
Pathology	1	1	6(PT)	6(PT)	
Entomology	1	1	3(PT)	1	
Agricultural Economics	-	-	0	1	
Processing Technology			1	-	
Technicians	1(PT)	1			
	8	9	3(PT)	1	
			12	18	
MALI	6	9	13	15	2 agronomists and 2 breeders of sorghum were trained at M.Sc. level through the Accelerated Crop Production Program (ACPO)[a] An expatriate agronomist was based in Mali (1979-85) through the SAFGRAD project to strengthen the technology-transfer efforts and to improve linkages between research and extension[b] 10 technicians were trained to assist in sorghum on-farm research. Financial support provided to screen cultivars resistant to headbug[c]
Breeding	2	2			
Agronomy	2.5(PT)	3(PT)	2	3	
Pathology	-	-	3(PT)	3(PT)	
Entomology	1	1	1	1	
Agricultural Economics	1(PT)	2(PT)	1	2	
Processing Technology	1	1	2(PT)	2(PT)	
Technicians	3	2	2	3	
	15	13	3	3	
			12	14	
NIGER	5	7	8	8	Facilitated pathology research for screening sorghum cultivars for resistance to long smut disease[a] Three trainees participated in monitoring tours and two other trainees benefited from short-term training[b]
Breeding	1	1			
Agronomy	3	4	2	2	
Pathology	-	1(PT)	4	3	
Entomology	1	1(PT)	1(PT)	1(PT)	
Agricultural Economics			1(PT)	2(PT)	
Processing Technology	-	-			
Technicians	6	10	1	1	
			11	12	
NIGERIA	8	9	10	10	The network provided financial support to broaden the use of sorghum for industrial purposes[a] Financial support was provided for on-station and on-farm verification trials to screen sorghum cultivars suitable for different cropping systems[b]
Breeding	2	2			
Agronomy	2	3	2	1	
Pathology	1.3	1	4	4	
Entomology	1.3	1	1	1	
Agricultural Economics	1	1	1.3	1.0	
Processing Technology	1	1	1	1	
Technicians	5	6	1	1	
			8	9	

PT: Part-time (33% to 60% of research time).

Sources:
[a] Ethiopian Sorghum Improvement Progress Reports 1982-1991, IAR, Ethiopia.
[b] SAFGRAD Phase I (1986) and Phase II 1991 Reports.
[c] Presentation de l'INERA, 1992.
[d] INERA Rapport au Conseil de Gestion, Gestion des Ressources Humaines, Etat du Personnel au 31/12/90.
[e] Unpublished data collected in the eight study countries 1992/93, OAU/STRC-SAFGRAD.
[f] Network Coordinator Synthesis Reports, 1992, ICRISAT/SAFGRAD.

Table 4-A. Research Manpower (by Disciplines) for Cowpea Improvement in Six Study Countries of West and Central Africa.

Country/Disciplines	1982-84	1986-87	1988-90	1991-92	SAFGRAD Input
BURKINA FASO:	3	3	4	4	Trained several technicians and some researchers to enhance cowpea improvement. Assisted in supervising thesis research for the degree of "Ingenieur Agronome" from the University of Ouagadougou. Facilitated long-term training at M.Sc. and Ph.D. levels. Strengthened INERA capabilities to generate technology by integrating regional and national cowpea research efforts.
Breeding	1	1	1		
Agronomy	-	1(PT)	1(PT)	2	
Pathology	1(PT)	1(PT)	1(PT)	1(PT)	
Entomology	1(PT)	1(PT)	1	1(PT)	
Agricultural Economics	-	1(PT)	1(PT)	1	
Processing Technology	-	-	-	1(PT)	
				-	
CAMEROON	3				Trained some technicians and one extension agronomist at M.Sc. level who currently conducts on-farm research on all cereals including cowpea. Facilitated visit to other national cowpea programs. Contributed cowpea germplasm.
Breeding	-	1	1		
Agronomy	1	1	1	1	
Pathology	-	-	1(PT)	1	
Entomology	1(PT)	1(PT)	1(PT)	1(PT)	
Agricultural Economics	1(PT)	1(PT)	1(PT)	1	
Processing Technology	-	1(PT)	1(PT)	1(PT)	
				1(PT)	
GHANA					Facilitated the exchange of information through seminars and monitoring tours. Contributed germplasm relevant to Northern and Coastal regions of the country.
Breeding	1	1	3		
Agronomy	1(PT)	1(PT)	1	4	
Pathology	1	1		2	
Entomology	1	1	2	1	
Agricultural Economics	-	1(PT)	1(PT)	3	
Processing Technology.				1(PT)	
	-	1(PT)	1(PT)		
				1(PT)	
MALI					Trained some technicians in cowpea breeding and agronomy. Trained one extension agronomist at M.Sc. level who managed on-farm research. Supported expatriate staff (1979-89) to promote transfer and adoption of technology.
Breeding	1	1	2		
Agronomy	1(PT)	1(PT)	1	3	
Pathology	1(PT)	1(PT)	1(PT)	1	
Entomology	1(PT)	1(PT)	1(PT)	1(PT)	
Agricultural Economics	-	1(PT)	1(PT)	1(PT)	
Processing Technology	1(PT)	1(PT)	1(PT)	1(PT	
				1(PT)	

Table 4-A (cont.)

Country/Disciplines	1982-84	1986-87	1988-90	1991-92	SAFGRAD Input
NIGER					Some researchers participated in analysis and review of cowpea research and appropriate technology development. Some researchers participated in scientific-monitoring tours which facilitated joint monitoring and evaluation of the performance of elite germplasm included in the regional trials.
Breeding	1	1	2	3	
Agronomy	1(PT)	1(PT)	1	1	
Pathology	1(PT)	1(PT)	1	1	
Entomology	1(PT)	1	2	2	
Agricultural Economics	-	1(PT)	1(PT)	1(PT)	
Processing Technology	-	1(PT)	1(PT)	1(PT)	
NIGERIA					
Breeding	1				
Agronomy	2				
Pathology	1				
Entomology	1(PT)				
Agricultural Economics	1(PT)				
Processing Technology	1(PT)				

PT = Part Time; 33 to 60% of research time.

Sources:
SAFGRAD Phase II Report 1987-1991.
Synthesis Report of RENACO Activities in Strengthening National Programs 1992, IITA/SAFGRAD Report.

Table 5-A. Research Manpower (by Disciplines) for Maize Improvement in Five Study Countries of West and Central Africa.

Country/Disciplines	1982-84	1985-87	1988-90	1991-92	SAFGRAD Input
BURKINA FASO					Facilitated release of varieties, such as SAFITA-2, EV8322-SR, Pool-16DR. Supported research in the development of early and extra-early maize cultivars, 1986-92). Trained technicians in field-plot techniques, variety maintenance, seed multiplication, etc. Made available several maize germplasm, 1990-91. Supported on-farm research and adoption of maize cultivars through the Accelerated Crop Production Programs.
Breeding	1	2	2	2	
Agronomy	1	-	3(PT)	6(PT)	
Pathology	1(PT)	1(PT)	1(PT)	1(PT)	
Entomology	1(PT)	0	2(PT)	3(PT)	
Agricultural Economics	1(PT)	-	2(PT)	3(PT)	
Processing Technology	0	-	1(PT)	1(PT)	
Technicians	7(PT)	5	5	6	
CAMEROON					Trained technicians, 1980. Supported on-farm trials for the adoption of early and extra-early maize cultivars in the North and (1990-92) Far North Provinces of Cameroon (1987-91). Provided technical assistance through three-man FSR team in in north Cameroon, 1986-89 . Promoted on-farm research and technology transfer through the Accelerated Crop Production Program, 1980-85).
Breeding	1	8	8	7	
Agronomy		9	4	4	
Pathology	-	-	2	2	
Entomology					
Agricultural Economics		6(PT)	6(PT)	6(PT)	
Processing Technology					
Technicians	2	4	6	6	
GHANA					Trained technicians Supported the development of facilities to undertake screening of maize cultivars resistant to streak virus. Provided early-maturing maize varieties of which SAFITA-2 is adopted in Northern Ghana. In Northern Ghana, supported on-farm verification trials for the adaptation of maize cultivars in association with other foodgrains.
Breeding	2	3	3	3	
Agronomy	6(PT)	12(PT)	16(PT)	16(PT)	
Pathology		1(PT)	1(PT)	1(PT)	
Entomology	1(PT)	1(PT)	1(PT)	1(PT)	
Agricultural Economics		3(PT)	5(PT)	5(PT)	
Seed Technology	1(PT)	2	2	2	
Biometrics					
Processing Technology					
Technicians	1	1(PT)	1(PT)	1(PT)	

Table 5-A (cont.)

Country/Disciplines	1982-84	1985-87	1988-90	1991-92	SAFGRAD Input
NIGERIA					In Northern Nigeria, supported on-station and on-farm verification trials for adaptation of maize cultivars in association with other crops.
Breeding		3	3	3	
Agronomy		4	10	10	Provided funds for agronomic research in the early and extra-early maize varieties.
Pathology		3	1	1	
Entomology		4	2	2	
Agricultural Economics	1	3	3	3	
Processing Technology					
Seed Technology		2	2	2	
Technicians		10	24	24	
MALI					Supported training of one agronomist at M.Sc. level.[a]
Breeding		NA	NA	NA	
Agronomy		1	1	1	Trained several technicians to carry out on-farm research.[b]
Pathology		1(PT)	1(PT)	1(PT)	
Entomology		1(PT)	1(PT)	1(PT)	Provided agronomist, 1979-1984.[c]
Agricultural Economics		1(PT)	1(PT)	1(PT)	
Processing Technology		1(PT)	1(PT)	1(PT)	Supported on-farm research for adoption of foodgrain technologies through the Accelerated Crop Production Program of SAFGRAD, 1979-1987.[d]
Technicians		1(PT)	1(PT)	1(PT)	
					Provided funds for an agronomic evaluation on the adaptability of early and extra-early maize cultivars. Some varieties were released (SAFITA-2, DMR-ESRY).[e]

NA = Not Available
PT = Part Time; 30 to 60% of research time.

Sources:
[a] Human resources division of INERA 1992 (Burkina Faso)
[b] IRA/NCRE Reports 1986/90 and 1981/91
[c] Ghana Grains Development Project Annual Reports for 1987-90
[d] Strategic Plan of SAFGRAD Networks
[e] SAFGRAD Phase II Final Report, Maize and Cowpea Collaborative Research Networks for West and Central Africa, June 30, 1991

Table 6-A. Indicators of the Oversight Committee Management Performance, 1987-91.

Main Issues Deliberated	Recommendation/Decision	Output
OAU financial contribution, 1987	Recommended to OAU to increase its financial contribution	OAU contribution was raised about 300%
Urged SCO to solicit funds from other donors, 1987	Recommended development of proposal to submit to donors	African Development Bank became new donor to SAFGRAD
Publication and diffusion of network technology, 1988	Decided that the activities of the four commodity networks be published through the SAFGRAD Newsletter	Several articles on network research results, training, and workshops activities were being published
Appointment of full-time Coordinator for the West and Central Africa Sorghum Research Network	Recommended ICRISAT to take action in 1987	ICRISAT appointed Coordinator in 1989
Harmonization of SAFGRAD and CORAF Networks	Recommended the merger of the two networks in response to the resolution of the National Agricultural Research Directors	Difficulties encountered to merge the two maize networks due to delicate political ramifications and recommended that the OAU Secretary General approach the French Minister of Cooperation to draw the latter's attention to apparent duplication of efforts in Africa
Internal appraisal of network performance, 1990	In 1990 made decision to undertake appraisal of networks. The Committee fielded a six-man team that evaluated network activities in Burkina Faso, Mali, Niger, and Nigeria in West and Central Africa; and Ethiopia, Kenya, and Sudan in Eastern Africa.	In general, it was observed that Networks had influenced NARS' research agenda and priorities, foodgrain production technologies had reached farmers, recommended improvement of linkages between NARS and IARCs and SCO, proposed gradual transfer of network leadership and management to NARS
Retrieval of research data and financial expenditure receipts	National Agricultural Research Directors' decision was implemented, 1988	Improvement in percentage of data returns from regional trials
Institutionalization of SAFGRAD, 1987, 1988, 1989	Recommended to OAU to institutionalize SAFGRAD as permanent research institution of OAU	OAU meeting on SAFGRAD approved in principle for the institutional transformation. Increased contribution to fully assume funding of the Coordination Office, Sept. 1991.
Improving financial management in NARS, 1989	SCO financial management assistance to those NARS receiving funds from SAFGRAD, 1989	Financial Controller visited NARS to streamline accounting procedures. Improved disbursement and accounting for funds received, 1990.
Strategic Plan of SAFGRAD Networks	Directed its completion, 1990	Long-term plan of SAFGRAD activities was completed
OAU and NARS contributions to Networks	Recommended the quantification of NARS and OAU contributions to Networks, 1991	Estimated contribution of OAU and of certain lead centers of $3.5 million, 1987-91
Publication of a scientific journal, 1990	Recommended joint publication of scientific journal	Four volumes of FSR journal published. Improved dissemination of scientific information.
Strengthening the East Africa regional research program	Recommended the recruitment of a liaison officer for East Africa, 1991	Liaison officer not yet recruited due to lack of funds

Table 6-A (cont.)

Main Issues Deliberated	Recommendation/Decision	Output
Impact assessment of Networks, 1991	Stressed that the network impact assessment should be based on the expected output stipulated in the project document	The study covered issues beyond expected project output
Coordination of network activities with other programs of SAFGRAD	Stressed harmonization between FSR and on-farm verification trials. Network technologies should need to be promoted.	ADB-supported on-station and on-farm technology verification trials in eight countries also promoted the adoption of technology
Renewal of membership in Steering Committees, 1991	Stipulated procedures be followed in membership renewal to ensure multidisciplinary participation	Composition of Network Steering Committee included various disciplines and areas of research activities
SAFGRAD donors' meeting, 1991	Directed SCO to coordinate donors meeting on SAFGRAD	Donors' meeting not held because of schedule conflict
Inter-network task force, 1991	Recommended integration of network programs in certain areas, such as seminars, workshops	Inter-network conference held in Niamey, Niger, 1991. Joint training in agronomy organized, 1991.
Training course in scientific writing	Recommended series of training on this subject	Two courses on scientific writing were organized in West and Central Africa. Similar course also planned for Eastern Africa.

Table 7-A. Ecological Mandates of CORAF and SAFGRAD Maize Networks and Their Respetive Maize Production Constraints.

	CORAF	SAFGRAD
MANDATE	Humid, sub-humid and irrigated colonies (forest, forest/savanna transition zone and Southern Guinea savanna). Irrigated areas (rainfall < 400 mm)	Semi-arid (Northern Guinea savanna, Sudan savanna, and Sahel (rainfall not less than 400 mm)
CONSTRAINTS	**BIOLOGICAL**	**BIOLOGICAL**
	Diseases:	**Diseases:**
	Streak	Streak
	Rust	Blight
	Curvularia	Stalk and Ear Rots
	Stalk and Ear Rots	
	Pests:	**Pests:**
	Borers	Termites
	Storage Pests	Storage Pests
	Rodents	Locusts
	Termites	Rodents
	Striga	***Striga***
	Weeds	**Weeds**
	Physical:	**Physical:**
	Soil Erosion	Soil Erosion (wind)
	Low Solar Radiation	Soil Compaction
	Soil Fertility:	Poor Water Filtration
	Acid Soil	Drought
	N, P, S, Zn, Mg deficiencies	N, P, S, Zn, Mg deficiencies
	Sandy Soil	Low Organic Matter
	Socio-Economic:	**Socio-Economic:**
	Consumer Preference	Consumer Preference
	Labor	Labor
	Capital	Capital
	Inputs	Inputs
	Post-Harvest Technology	Post-Harvest Technology
	Cropping System	Cropping System

Conclusions and Policy Implications

Research Results, NARS, and IARCs

One notable success of the '80s in Sub-Saharan Africa has been the introduction of new maize cultivars, especially in the moist savannas as in northern Ghana. Improved production practices have generally included improved cultivars and increased chemical fertilizers. New cultivars have been developed or adapted by the NARS from improved material obtained from IITA, CIMMYT, and the NARS. The networks have played an important role in distributing this material among countries.

There has also been successful introduction of improved shorter-season cowpea cultivars, principally those introduced without higher input levels. This has been maintenance research to maintain yield levels since cowpeas are attacked by a large number of insects and diseases. Also for cowpeas, increased chemical fertilizer and insecticides are being introduced into the moist savanna, as in northern Ghana. Increased P fertilization is now being used in one region of the cowpea/millet system of the sandy dune soils of Niger.

There have been fewer successes with sorghum and millet but S-35 was successful in northern Cameroon and Chad. There is an important contrast between maize successes that included higher chemical inputs and were concentrated in the moist savanna and those cases where there was failure to introduce new cultivars of sorghum or to introduce chemical inputs in the dry savanna where rainfall risk is higher. Other studies indicate that gains are possible for sorghum and millet, especially if future research concentrates more on adapting agronomic technologies to simultaneously increase water availability and improve soil fertility (Sanders et al., 1990; Shapiro et al., 1993). If water availability and soil fertility are improved, much higher returns to breeding of sorghum, millet, and other improved cultivars are possible. Putting agronomic improvements first is probably the only way to be successful with breeding activities. Breeding is unlikely to be successful as the lead activity since the agronomic environment is too harsh.

Since almost all applied agricultural research is the adaptation from other regions to the NARS' own site-specific requirements of either materials (such as cultivars), processes (such as the screening techniques to a specific disease), or ideas, there is a very high return to regional networks and to international networks and scientific contacts. The interchange between the IARCs and the NARS and among NARS has been successful in producing and adapting new maize cultivars. Moreover, the regional NARS networks also facilitated the adaptation and diffusion of new material.

Now that the NARS have evolved in human-capital capacity and ability to set up multidisciplinary research units to investigate applied research problems, the research system in Africa needs to be improved by delegating more authority to the NARS and making sure that they are adequately funded to do good research and to adequately reward and support their highly trained human capital. The increasing regional specialization, networking, and sharing of information among the NARS are all very important developments and need to be encouraged with sufficient financial support. International funders have become disillusioned with the performance of many national research organizations in managing funds. Successful performance in producing outputs needs to be combined with improved financial management.

Adequate financing for increased regional and international scientific collaboration has a very high return and will be critical to continuing success of the NARS. Many NARS research systems have become highly dependent upon external financing. Their own political systems need to recognize the high economic returns to research and to increase their domestic support. This has been extremely difficult in the past decade of structural reform and extraction of debt repayments. Donors and national governments need to return to the development of the institutions (the NARS) and the product (applied agricultural research) that will be essential to drive the agricultural and development processes in these countries. More evidence from impact studies needs to be presented to government policymakers and to the general public. National economists doing impact studies and setting up monitoring systems for future impact analysis are an urgent need now for the NARS so that these research systems can obtain more domestic resources and thereby help convince donors that the national governments are serious about improving the efficiency and output of their research systems.

Networks, NARS, and Future Research Funding

Some implications from the review of the impact of the networks:

1. In determining size or the existence of a network, important considerations are:

- Economic importance of the crop as a staple food or for its export value.
- Commonality of biotic, climatic, and socio-economic constraints (in network countries) that could influence the production, marketing, and use of the commodity.
- The NARS research base, i.e., number of researchers/multidisciplinary groups engaged in the improvement of the crop.
- Effective use of the ecoregional approach to network research.

2. There is conflict between reducing crop networks to manageable size and excluding the weak and small NARS. For example, maize, sorghum, millet, and cowpeas are not cultivated on large areas in Cape Verde, Gambia, Guinea Bissau, and Mauritania. However, these crops are staples in these countries and these small countries need to have access to these networks for their genetic material and their scientific training.

3. The network scheme has greatly facilitated the evaluation of germplasm. The NARS have concentrated their efforts on adaptive and applied research. The regional trials have served as a focal point for the evaluation and release of germplasm.

4. The "lead NARS" concept has been effective in optimizing comparative research advantages that existed in a few strong national programs. The mechanism enabled the relatively more developed national centers to assume regional research responsibilities.

5. Impact assessment indicated that networks not only have substantially increased the availability of new technology but also facilitated direct involvement of NARS in the development and evaluation of technologies.

6. Analysis of research management of networks also revealed the following weaknesses that require special attention in future network support:

   a. There has been no systematic follow-up and technical direction for networks to address some of the identified research priorities, including socio-economic constraints, that could have enhanced technology transfer and adoption.

   b. Research grants were provided largely to lead NARS since they had assumed regional responsibilities. Such grants should have been provided on a competitive basis.

   c. Specific criteria for disbursement of funds retrieving expenditure receipts were not fully developed or uniformly applied.

   d. An efficient reporting system to retrieve technical data from NARS has been one of the problems of networks. The impact assessment has generated methods and technical formats for data collection. Initially, these formats could be revised in order to install efficient data-reporting systems.

In the last ten years, the development of crop networks has been narrow in scope and biased toward crop improvement through breeding. Agronomic research was emphasized by the SAFGRAD networks during the last five years. Very little attempt was made to integrate allied disciplines, such as socio-economics, soil-fertility improvement, and studies on renewable resources (i.e., crop residues, nitrogen fixation) into the regular network program.

The future crop-commodity networks should incorporate into their design the sustainability of production systems (cropping) and their contribution to improve the quality of the environment. Sustainability is referred to as "the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources" (CGIAR, TAC, 1988).

This broader scientific emphasis for the networks will require long-term planning and commitment of financial resources and the development of scientific manpower by national governments with donor assistance. The sustainability of networks will also depend on the extent to which network programs have been responsive to research and development needs of member countries, as well as the extent to which network activities are entrenched in the national research systems.

In general, NARS are starved for resources not only for recurrent costs but also for improving research infrastructure. Budget allocations of research of NARS governments should triple in the 1990s to effectively support agricultural development. The national governments will increasingly have to support their NARS at higher levels. In recent years, many NARS have become even more dependent on donor funding, often for more than two-thirds of their funding,. This is not a sustainable system.

Improving the Research Environment

In general, modernization of the research environment needs to include:

- Establishment of conducive research policies, including research statutes with adequate allocation of funds and competitive salary-scale benefits to attract scientists so that they can make research their long-term careers.

- Recognition of innovative and highly productive researchers at national level through periodic evaluation of research output and technology diffusion. Special prizes, merit awards, promotion, and salary increases could be provided to more deserving scientists.

- Encouragement of technical publications in professional and national journals, technical bulletins, and leaflets for extension and farmers' use. Such scientific tradition, i.e., building the knowledge base through publications, is virtually lacking in most of Sub-Saharan Africa.

- Promotion of multidisciplinary research and pooling of scientific talents and resources to alleviate specific constraints to agricultural production.

- Introduction of the system of competitive research grants which could motivate NARS researchers not only to increase research output but also to be creative, with major concern to transfer results to end users (i.e., farmers, private agencies, industry).

Funding

The allocation of funds for research by governments in various countries did not accompany the substantial increase in research manpower and program expansion. The implementation of research projects and capital development was expanded primarily through increases in donor funds or loans.

Large proportions of the national research budgets contributed by governments were used to cover salary costs. In general, there has been a significant decline in operating funds for research in the past ten years. The possible options to NARS for responding to these financial pressures include:

- Streamline their research programs, within the limits of their own resources. This calls for NARS institutions to undertake fundamental policy reforms, including merging or phasing out of programs and scaling down the size of research operations.

- Allocation of more national resources in support of agricultural research. National governments need to take research more seriously as the main driving force to agricultural development. NARS should face up to actual realities and avoid depending on donors to strengthen research and agricultural development. Donors, however, could continue to help in certain fields of research and human-resource development where NARS may have a weaker comparative advantage.

Small NARS Have Benefitted From Networks

National programs vary in size and level of research and development. Small NARS constitute nearly 45% of the countries in the current maize, cowpea, and sorghum networks in West and Central Africa. The SAFGRAD network scheme has evolved with both lead and small (weak) NARS. The advantages to the small NARS of the network scheme have been:

- Access to Elite Germplasm. The menu of regional trials is made available to small NARS by the respective networks. The regional trials deliver elite germplasm targeted to different agroecological zones and maturity groups. As a result, these groups of countries concentrated their efforts on adaptive research.

- Spillover of Technology. There has been increased spillover of technology from lead to weak NARS. This has reduced costs for technology generation by nearly 50% for the collaborating countries of each SAFGRAD network, particularly in West and Central Africa, as well as in Eastern Africa.

- Training. Within SAFGRAD, networks emphasized more the needs of the weak NARS to receive training in research.

- Assistance. Network coordinators and relatively senior NARS researchers have provided technical assistance and consulting services to improve the research capabilities of small NARS.

- Self-Help. If excluded from networks, small NARS would disperse their meager manpower and financial resources by getting involved in numerous nurseries and trials coming from various sources since they would be cut off from obtaining elite germplasm through direct participation in the different networks.

It is necessary for small NARS to participate in networking since their resources cannot fully support the development of their research capacities to solve the entire range of their agricultural production problems. Most of these countries also lack the educational institutions that offer first degrees in agriculture. In West and Central Africa, the research needs and requirements of small NARS may be met by establishing "lead center" satellites. Each satellite unit could have three to five countries, including small NARS, which could be neighboring countries to the lead NARS. Membership in the Steering and NARS Directors' executive committees could be limited to lead countries that are regular members of the network. Small NARS would participate in workshops, training activities, and regional trials.

Final Observations

In the tripartite institutional partnership of SAFGRAD (i.e., NARS, OAU, and IARCs), while NARS (as beneficiaries of the project) fully participated in network management, the IARCs provided technical support for the development of networks. The OAU, through its Coordination Office, not only mobilized available research resources in the sub-region but also carried out network activities that transcended political boundaries as well as linguistic and cultural barriers. Indigenous regional institutions were established by the countries themselves as a mechanism to mobilize and bring together their national efforts. The regional-management mechanism not only accelerated the transfer of network scientific leadership and management to NARS but also facilitated the pursuit of a concerted policy for food self-sufficiency and research self-reliance.

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Impact Assessment of the SAFGRAD Commodity Networks

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