Technological Options for Increased Food Production in West Africa

L.D. Swindale
Director General, ICRISAT

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ICRISAT
International Crops Research Institute for the Semi-Arid Tropics

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I.D. Swindale

Economic development in sub-Saharan Africa (SSA) since the era of independence in the early 1960s has barely kept pace with population growth. Our economists estimate that between 1950 and 1982 gross national product per capita increased at an annual rate of only 1.5%, compared with 3% for all low-income countries and 3.3% for industrial market economies. GNP per capita declined during the period for low-income, semi-arid countries. The economic decline started in the 1970s and accelerated in the 1980s. For example, the rate of growth of gross domestic product per capita was 1.3% per annum in the 1960s, dropped to 0.7% in the 70s, and has averaged -3.7% since 1980.

Although agriculture provides employment for two-thirds of the population and contributed 47% to GDP in 1960, it contributed only 33% to GDP in 1982. Its annual growth rate was about 2.1% in the 1970s, compared with 3% for GDP as a whole. In fact SSA is the only part of the developing world where the index of per capita food production has declined during the last two decades; yields per hectare for food commodities are the lowest in the world.

Among the subregions of SSA, West Africa has shown the slowest growth rate for total food production. The poor performance in food production is due mainly to the very low rate of growth (0.5% per year) for the major staples of sorghum and millet and the absolute decline in the cash crop, groundnut. The small increase in total food production has resulted almost exclusively from an increase in the area under cultivation, indicating that technological change is yet to make an impact on food production in West Africa. For example, sorghum over the 10 years to 1981 grew 22.7% in production, but only 4.7% in productivity.

West Africa, which was a net exporter of food in the early 1960s (1.2 million tonnes per annum), became a major food importer (1.3 million tonnes) by the mid-1970s. Total food-grain imports in Africa rose from 1.9 million tonnes in 1961-63 to 9.2 million tonnes in 1981, 25% of which is presently food aid.

These rather long-standing problems have been aggravated in the last few years by the impact of drought, bringing great hardship to many people—particularly in the countries immediately south of the Sahara—requiring an enormous increase in food aid, disrupting government development activities, creating serious concern about the advance of the desert, and producing a flood of world attention and concern. The governments of

the region and those who wish to assist them recognize that long-term solutions are needed. There is an increasing consensus about the nature of the problem and a growing determination to do something about it.

Sub-Saharan Africa is a large and diverse region. The generalization of declining food production per capita applies to much of the region, but the problem is particularly acute in the countries close to the Sahara. This paper, therefore, concentrates upon the problems that appear particularly important in this subregion and ICRISAT's possible role in the solutions that have been or will be suggested.

The Problems of Food Production in West Africa

Traditional villages in semi-arid West Africa have a strong sense of community and often an hierarchical system of control. Family units are large; they often contain several related adult males and 7 to 20 people. Although nuclear family units — comprising a single adult male and his dependents — are increasing, standards of living are low and food production has been declining. Population growth is high and the pressures on land are increasing.

Subsistence farming is much more common than elsewhere in the continent. Much of the land is owned communally, but worked by family units which have usufructory rights to as many as 16 separate small fields on soils of varying quality around the village. There is no permanent tenure. The range in size of holdings is narrow and the main cereal crops are sorghum and pearl millet. Fertilizers and improved seeds are hardly known and seldom used, but animal manure is used on the fields nearest the village. The use of animal traction is not common but is increasing. Donkeys are the usual source of animal power when it is used, except in Mali where oxen are fairly common.

Because the available power is low, soils are seldom plowed and all agricultural operations are time-consuming. Virtually all farm operations are labor intensive, and labor is currently in short supply. Fallowing and burning are used to return some fertility to the soil. Cropping intensity on commonly used lands seldom exceeds 75% except for the land closest to the village, which is used to grow the most important staple cereals. Land far from the village may be cropped only 1 year in 4. Intercropping is common, usually of cereals with cereals or cereals with cowpeas. Cash crops, such as groundnut, bambara nut, and sorrel, are grown on small fields as sole crops.

It is essential that agricultural production be increased, if only to feed the growing population, but resource and climatic conditions are difficult. Of the climatic elements important for crop production — rainfall, temperature, and solar radiation — rainfall is the most variable. Coefficients of

variation for annual rainfall exceed 20%. In the years when total rainfall is low, the coefficient of variation invariably increases. Distribution of the rain within a year is also highly variable and cannot be predicted with any reasonable degree of confidence. Furthermore, there appears to have been a steady decline in annual rainfall throughout the region in the last 30 years.

Because the coefficients of variation for temperature and solar radiation are small, the potential for evapotranspiration is more or less constant from year to year. Thus small negative deviations in rainfall from monthly, weekly, or annual norms are all that are required to initiate agricultural drought in these regions. In most years, however, the rainy season is 90 days are more, long enough for annual crops to grow. Indeed, there is usually excess water in the rainy season; some of it is stored in the soil but most of it is lost.

The soils of the region are sandy, low in fertility, with poor physical conditions and low water-holding capacities. They are generally low in organic matter, nitrogen, and phosphorus. Potassium, sulfur, and zinc deficiencies show up, if the soils are intensively used.

For all these difficulties, however, the soils are physically stable and they are not very susceptible to erosion. Surface structure and fertility may decline very rapidly when the natural vegetation is removed, but these are not difficult technical problems to solve, even within the constraints of traditional agriculture. The abundance of land encourages the use of shifting cultivation in spatially dispersed land holdings. Although this may be a relatively efficient use of the droughty, nutrition-deficient soils under conditions of low inputs, it encourages inefficient use of what inputs are available, of the short supply of labor, and of management skills.

Moderate increases in cropping intensity, or land productivity, are possible under existing conditions, particularly through more efficient cropping systems and the better use of intercropping. Integrated, improved animal crop tree systems hold promise for better use of land and for raising labor productivity through the increased use of animal-drawn equipment. There are only modest opportunities for increased irrigation. The Senegal and Niger are mighty rivers, but they have small command areas.

There is a great shortage of infrastructure and well-trained people to help the peasant people improve upon their agriculture. These are young countries. There is little industry. Exports are mainly primary commodities in low world demand. Policy formation and planning for development are not yet well developed. The wage and salary structure is still designed to fill governmental and service jobs required for administration.

Economic and institutional disincentives are also very important. Food aid can be one of them if the imported wheat, rice, or maize is sold to the people at prices substantially below those of locally produced sorghum

and millet. Farmers will then travel to the town to buy the cheaper food. Many problems are blamed on the government parastatal organizations. Set up as marketing organizations for exportable agricultural commodities, they now serve as marketing and distribution agencies for both inputs and products. Inefficiencies in these organizations—where they occur—tend to widen the transportation and marketing margins on crops at the expense of the farmer.

With so many problems, effective strategies for development and improvement are hard to find. "Agricultural development in Africa has been extremely elusive," Hogan and Johnson wrote in 1981. Carefully defined projects have not achieved success, probably because not enough attention has been paid to the problems of the smallholder. "The development of a new and reliable high-yielding millet can contribute as much to raising the living standards of millions of poor people as the changes in structure and policies that are also necessary," said the World Bank in its 1978 World Development Report.

Attempted Solutions

Most models of African agricultural development make the assumption that there is a surplus of land. Attempts are made to bring more land under cultivation. But only small increases in total agricultural output have occurred during the last two decades through the expansion of area cultivated, as pointed out by Pollineau in 1983. These increases have not been enough to meet the food needs of the region. Further, it is most unlikely that continuing expansion into new land areas can produce the desired results. The new lands available are of marginal suitability for agriculture. As IITA has shown in its long-term experiments in the derived savanna of West Africa, fertility decline in these poorly buffered soils is very difficult to stop. And the population growth rate is so high in Africa that suitable new lands will soon not be available for exploitation.

From time to time attempts have been made to transfer technologies to West Africa from other parts of the world. These have not been successful; the technologies have not proved to be adaptable to the ecological and socioeconomic conditions of the region. ICRISAT tried to transfer advanced breeding materials from India to West Africa in the mid-1970s. Like the attempts to transfer more complete technologies, these efforts did not succeed. The breeding materials, like the technologies, were simply not well enough adapted. The failure of many technical assistance and rural development projects, based explicitly or implicity upon this model, are testimony to the failure of this approach.

An attempt to circumvent the peasant farmer and develop large-scale, mechanized, capital-intensive land development schemes for food produc-

tion has also been made. But this has been no more successful than tranferring technology directly to the peasants.

Much agricultural research during colonial times was devoted to improving the productivity and production of exportable cash crops. Where successful, it has contributed to export incomes and to reducing the food costs of people in the industrialized countries.

There has been much debate about the value of the colonial emphasis on exportable cash crops. The World Bank in a report on sub-Saharan Africa in 1984 considered that this emphasis should continue because it exploits the comparative advantage of the African countries. On the other hand, the Organization of African States, in the Lagos Plan of Action (1980), clearly stated that they do not favor the continuation of this approach, and indeed blamed low commodity prices for most of the present problems in declining agriculture.

It would be wrong, however, to believe that all agricultural research in West Africa has been concentrated on export commodities during colonial times. There is a long history of research on sorghum, millet, and maize, on agronomy and on soil and water conservation practices in these countries. The work has been continued by international and national research agencies to the present. Many successes have been claimed and bright potential results have been predicted but, for whatever reason, the performance has been poor, and there are very few technologies of proven value at the farm level waiting for government to exploit through improved extension and policy incentives.

A host of microlevel socioeconomic studies in recent years, and the current fashionability of farming systems concepts, has led to many statements that the previous attempts failed because the technologies studied and produced were not designed with farmer constraints in mind, particularly those of the small farmer. Because the studies that have led to these conclusions are based on firm statistics—certainly better than is generally available in West African countries for agriculture as a whole—they merit careful consideration. The ideas, however, are a bit too new to have had adequate empirical testing, and it must be recognized that like all such studies of existing situations they tend to be conservative and conventional, to emphasize increased production more than increased productivity. What is almost certainly true is that most crop production and agronomic studies in the past did not adequately characterize either the soils or the climatic conditions under which they were conducted, did not measure enough variables to be able to specify accurately the domain of relevance, and, most of all, did not indicate the likelihood of success in wet years, dry years, and on the average over a long enough period to be able to allow either the farmers or government agencies to assess their true potential.

On a more optimistic note, there is evidence of a small but growing number of successes with conventional crop improvement research. Input-responsive and relatively stable cultivars of the major cereals (maize, sorghum, and millet), the main grain legume (cowpea), and the major root crop (cassava), have been produced by research institutes, released by governments, and are slowly reaching the hands of the farmers.

Several of these new cultivars have come from the International Agricultural Research Centers, particularly IITA and ICRISAT, but national research has contributed a significant number. Regional networks of trials of improved varieties of maize, sorghum, and millet are now being conducted in West Africa by the CILSS organization, in cooperation with the national agricultural research systems and the International Centers. The European Economic Community provides most of the support for national involvement in the trials.

The Growing Consensus

The governments of the West African countries recognize the need to grow more food. They are willing also to give a larger role to agriculture in their development strategies, and to consider a substantial transfer of domestic resources to the modernization of small-farmer agriculture. The devastating events of the recent droughts must not be repeated again and again. The people and the progress of development must be protected to the greatest possible extent from such catastrophes. Soils must be rehabilitated and the advance of the desert halted and even reversed.

One cannot avoid the conclusion that some inputs must be obtained and made available to farmers, perhaps as grants-in-aid initially but ultimately through commercial means. The obvious input is phosphorus. There are numerous research studies that have concluded that phosphorus is needed by West African soils and that it can be used profitably on several crops and in a variety of climatic situations. And phosphorus is the nutrient most available in the region.

Several countries have deposits of rock phosphate. Togo obtains a major portion of its foreign exchange by exporting raw rock phosphate. Deposits of similar quality exist in Niger and Senegal, and the latter country has now commenced producing commercial phosphate fertilizers. New markets outside the region are being found. This overall stimulus to the production of phosphate fertilizers in West Africa should increase the availability of partially or fully processed products within the region as well.

Nitrogen is the next most important nutrient. If it cannot be readily obtained as fertilizer, then an agriculture based on legumes must be the appropriate response within the region. Legumes in rotation, or inter-

cropped with cereals and root crops, can provide food, fodder, fuel, protection from the winds, and cash. They also provide nitrogen fixed from the atmosphere to be used by subsequent crops. If the staple cereals and root crops are to occupy less land, they must be higher-yielding and more input-responsive.

Michael Lipton, in a recent in-depth review of agricultural development strategies for sub-Saharan Africa, tried to summarize the long-term goals into one concise statement. He recommends food and water strategies with reliable and timely statistical information, backed by a massive transfer of domestic resources from other sectors into agriculture, to bring to smallholders field-tested, reasonably safe and hence water-controlled, fertilizer-supported, and, increasingly, intensively farmed, high-yielding varieties of major, currently grown cereals and root crops.

This is the long-term target. Short- and medium-term strategies are also needed, and they must be adapted to existing levels of natural, human, and financial resources. Initial strategies cannot afford to be too complicated; they must be based more on yield stability and sustainability than on highest yields per hectare, and must emphasize farmer-adapted means of conserving soil water and improving soil fertility. A limited range of input crop livestock combinations that seem suited to different climatic zones must be selected, and the limited resources of government applied only to those showing greatest promise. A groundnut cereal cowpea system utilizing applied, partially treated rock phosphate and fixed atmospheric nitrogen is a possibility worthy of thorough investigation for the southern Sahel. We will need, as Peter Matlon and Dunstan Spencer have pointed out, understanding of farmers' objectives and resources, and greater regional farm-type disaggregation and on-farm testing of the technological components, as an early and integral part of technology development.

The need for a large array of tested technological options requires an increase in the amount and sophistication of agricultural research. National governments have greatly increased their expenditures in agricultural research in recent years.

Problems that remain include:

a. Employment of insufficiently trained staff, without adequate incentives to improve research quality or long enough assignments to gain the necessary depth of experience.
b. Lack of operation and maintenance funds, aggravated by lack of foreign exchange to purchase equipment replacements, spare parts, and library materials.
c. Poorly developed, and poorly maintained research stations.
d. Lack of congruence between research strategies, farmers' problems, and development needs.

Suggestions for overcoming these deficiencies have been made and some of them are being heeded by governments. Setting of priorities is being improved, enabling greater focus on a smaller number of important areas and the bringing together of groups of scientists into fewer, better-supported research stations. A consequence of these changes is that national agricultural research systems in the region will improve and do more, but they cannot be expected to do all the research needed on all the commodities that are important. A sharing of responsibilities through internal, regional, and international efforts is necessary; and these responsibilities are being accepted and implemented.

The Role of ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972 by the Consultative Group on International Agricultural Research (CGIAR) to undertake research on improving rainfed farming in the semi-arid tropics, with particular reference to four crops, sorghum, pearl millet, pigeonpea, and chickpea. Groundnut was added as a fifth crop in 1974. From the Institute's inception, the need for it to have a role in sub-Saharan Africa was recognized. It commenced its research in Burkina Faso on sorghum improvement in 1974. The work was quickly expanded, mainly with UNDP support, to include millet, and was extended to several other countries in the region. ICRISAT's work has been expanded recently to eastern and southern Africa.

In 1978, work was begun on sorghum and millet in Sudan; in 1982 on groundnuts for the southern African countries, based in Malawi; in 1983 on sorghum and millet for East Africa, based in Kenya; and finally in 1984 on sorghum and millet for southern African countries, based in Zimbabwe.

These have largely been special projects of varying duration and limited range, based at national research stations and designed to introduce improved cultivars, evolve modern research methods, and strengthen national programs.

In the years since the program started in West Africa, progress has been made in adapting sorghum germplasm and some sorghum varieties from elsewhere to the region. Improved cultivars are being tested in regional trials, and several of them have been recommended for release to farmers. Sorghum varieties and hybrids resistant to drought, *Striga*, and midge have been successfully introduced, and they are being used as the bases for new varieties with agronomic and quality characteristics suited to local conditions and tastes.

Much less success was achieved in the early years with imported lines of pearl millet. Local disease and insect pressures were so great, and soil

conditions during crop establishment so harsh, that few of the imported lines reached maturity. Research on this crop concentrated, in consequence, on improving local varieties and regional germplasm with limited genetic range. Using this strategy, varieties have been developed for release to farmers in three countries of the Sahelian region. The large amount of improved germplasm available elsewhere, and particularly at ICRISAT Center, has largely been denied to the region by this approach, because of its focus on disease and pest susceptibilities and of soil and water problems peculiar to the region.

In eastern and southern Africa germplasm and breeding lines introduced by ICRISAT scientists have proved much more adaptable, and progress in crop improvement for these regions — on sorghum, millet, and groundnut — appears much better.

In Sudan, an ICRISAT sorghum hybrid and an ICRISAT-selected pearl millet variety have been released to farmers; they performed extremely well in drought conditions in 1984. In Ethiopia, a sorghum introduction from ICRISAT Center has been released, and in Zambia also sorghum and millet varieties from ICRISAT Center have been released for farmers' use. It is noteworthy that these latter two varieties have also been released to farmers in India.

The long-term solutions to agricultural production in sub-Saharan Africa, and the short- and medium-term strategies required to achieve them and overcome the socioeconomic constraints, involve much more than new varieties. From the beginning of its work in the semi-arid tropics, ICRISAT has realized that it must involve itself in research on cropping systems and farming systems, aimed at understanding and efficiently utilizing the human and natural resources available.

The duration of the research involved, its complexity, its combination of single-component and multicomponent studies, operational research needs, and the need for careful, thorough, and accurate soil and climatic characterization require that these activities be conducted at a location assigned to ICRISAT on a long-term basis and over which the Institute has control.

Such work on resource management by ICRISAT has progressed significantly only at ICRISAT Center in India. Improved technologies usable by small farmers have been developed to greatly increase the productivity of deep, black, heavy-clay soils (Vertisols). The true potential for increased production from these rather underutilized soils has been revealed and is starting to be exploited in India.

With the help of the Leverhulme Trust, ICRISAT commenced a research program on resource management and farming systems in Burkina Faso in 1979. The work was extended to Niger in 1981. Base-line studies in several sorghum- and millet-producing villages in the Southern Sahelian and Sudanian Zones have been made, and these are now being

analyzed. On-farm tests of improved varieties of sorghum and millet and improved agronomic practices have been conducted to determine the applicability of new practices, and to measure and understand farmers' reactions to change. Probably the most important finding of this work to date is that the research innovations currently available do not result in large enough improvements to persuade farmers to make significant changes in their traditional farming practices. Much more than small changes at the margin are required.

The ICRISAT Sahelian Center has been created with the support and assistance of the Government of Niger to enable ICRISAT to contribute more effectively to the search for these larger, more comprehensive solutions for the West African region. Its work will have relevance to the vast region of sub-Saharan Africa most affected by drought in recent years, where the advance of the desert has been most threatening to people and societies. The Center, which is an integral part of ICRISAT, has the following objectives:

1. To develop, for the West African region, improved millet-based cropping and farming systems adapted to the needs and possibilities of small farmers.
2. To bring together, evaluate, and utilize a wide range of genetically different cultivars of appropriate crops collected throughout the Sahelian region.
3. To develop other improved systems of crop and livestock production, including the fuller utilization of draft animals.
4. To train agricultural scientists and technicians and provide them with research information and methods.
5. To cooperate with national and regional crop improvement and farming systems networks, and in research projects with national scientists.

The pearl millet improvement program at the Sahelian Center is well established and can draw upon a background of 8 years' working experience in the region and the advice and counsel of a growing number of millet researchers in national programs. At a regional millet workshop in September 1984, there were 24 research workers present from 13 West African countries, besides the ICRISAT scientists. A comprehensive program of research has been developed, and it is being implemented through a regional network for cooperative research trials.

Groundnut is an important crop in the region, and it has been a major source of export income. A revival in groundnut production seems possible, and an increased program of research would be most timely. An international symposium on the climatology of groundnut held in Niamey in August this year was attended by approximately 80 researchers and meteorologists, including 30 from the Sahelian countries. Recommendations have been evolved for a cooperative program of research particularly relevant to West Africa. ICRISAT has been authorized by the CGIAR to

undertake a program of groundnut research at the Sahelian Center. The first scientist for this program will be appointed in 1986.

Cowpea is an important grain legume throughout West Africa, commonly grown in combination with sorghum and pearl millet. A cowpea agronomist from IITA has been stationed at the Sahelian Center, to incorporate results from that Institute's comprehensive cowpea improvement research into the improved cropping systems that are being developed.

The resource management and farming systems research team at the Sahelian Center contains scientists from several institutes. ICRISAT contributes the cropping systems agronomist, who is also the team leader, a tillage engineer, an agroclimatologist, and an economist. An animal nutritionist from ILCA has been participating in the village base-line studies in Niger. Phosphate and nitrogen studies are being undertaken by IFDC. Three universities — the Agricultural University of Wageningen, Texas A&M, and the University of Hohenheim — are also contributing directly to the work. It is hoped that funds will be sufficient to add a scientist from ICRAF to work on agroforestry in 1986.

Training will be an important part of the Sahelian Center's activities. The CGIAR has provided ICRISAT with excellent training facilities at ICRISAT Center, and this is where our main training activities are and will continue to be. ICRISAT scientists stationed within national programs in West Africa are also responsible for training and have contributed to the present strength of national programs in the region.

Because national programs of research on sorghum, millet, groundnut, and cowpea have expanded in recent years, there is a rising demand for training in research methodologies and statistical techniques. National research leaders have requested ICRISAT to provide training in field research to scientists and technicians at the ICRISAT Sahelian Center, and we expect to provide a limited program of in-service training in 1986. The national leaders agree that more sophisticated training and postgraduate studies should continue to be provided at ICRISAT Center. We can confidently expect, however, that when the ISC is fully constructed and functioning it will provide an enormous stimulus to national programs and scientists in the region. Training by example, on the basis of sound performance, is always more effective than training by exhortation. The training at the Sahelian Center will do much more for the region than training provided by individual scientists placed alone in national programs.

The research and training programs outlined will be presented in greater detail in subsequent papers at this meeting. They are in accord with the analyses of the problems of food production in West Africa, with the recommendations and suggestions of national scientists and administrators, and with the view of national governments. Given sufficient time and

resources—with fine tuning through further consultation and review as results emerge—they will lead to an array of proven and effective technological options that small farmers can adopt to make agricultural development in West Africa possible and to arrest the decline in production. But certain assumptions are necessary for the successful implementation of this program.

First, we must be assured of suitable research facilities. These comprise well-equipped laboratories and crop-work areas with assured electrical supplies, and a properly developed and managed research farm, with irrigation facilities where needed, so that short- and long-term, statistically sound, experimental work can be conducted. We must be able to attract and retain highly trained scientists with proven records and reliable, well-trained technical support staff. We must have an adequate library, conference room, and communication facilities. We must provide an adequate level of maintenance, including the proper care and maintenance of scientific equipment, and an administrative authority and procedures designed to facilitate and encourage creative, effective, productive scientific research. We must have the confidence and support of our donors, the support, advice, and cooperation of national research programs, and a long-term assurance of funding.

From this ICRISAT Sahelian Center we will be able to service national programs and to invite national scientists to participate in its work, make use of its services and facilities, and utilize its research and methods for their own research. We are completely committed to the emergence of strong national research programs, and we will do all we can to assist them to develop.

ICRISAT is deeply grateful to the Government of Niger for giving us permission to establish this international research and training center near its capital city of Niamey, for providing the land for the research farm, and for the many clear indications of its great interest in and commitment to the project. We are grateful to the CGIAR for its support of the research and training programs, and to the Governments of Italy, Switzerland, and Nigeria and the Arab Bank for African Development (BADEA) for the funds they have provided for the development and construction of the Center.

We do not have in hand all the funds that are needed to proceed with the construction of the ICRISAT Sahelian Center, and the Government of Niger needs substantial support at this time when drought has caused so much economic strain in the country to be able to provide the roads, telephones, and electricity supplies that will be needed by the Center.

We are creating here in Niamey an important research and training resource for the region and for all sub-Saharan Africa. There is no doubt that it is needed. We request your help, support, and assistance.