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The Agricultural Research Support Project in Mali:

Technical Analysis for the Project Identification Document

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Above all, I would like to thank the staff of IER for a spirited reaction to this report. My sincere hope is that it will not only contribute to completion of the PID but also, perhaps more important, contribute to the development of a national agricultural research strategy for Mali, now under way.

The views, opinions, and recommendations contained in this report are mine and should in no way be construed as those of USAID/Mali.

Jack deMooy

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INTRODUCTION

The technical portion of the project identification document (PID) deals with the structure of the proposed research scheme to be supported by the U.S. Agency for International Development in relation to the Malian government's existing national agricultural research system (NARS). The national system employs a regional approach to describe the research structure, whereas the PID is presented in terms of the commodities involved. The centers of activity of the major commodities are geographically separated and fit fairly well into the regional subdivision. Classification in terms of commodities has the advantage of easy reference and should facilitate donor support which usually follows commodity lines.

The purpose of the Agricultural Research Support Project (ARSP) is to support and guide the excellent research expertise in Mali into operating in well-defined, production-oriented activities by means of:

- Integrating commodity, farming systems, livestock, and agricultural engineering research into the most efficient network to attain sustainable, adequate agricultural production;

- Strengthening certain important sections of the NARS and thereby provide the farmer with the basic means and advice to increase food production and receive greater returns from his labor and other inputs;

- Supporting development of cultural practices that maximize the use of all available natural resources and low-cost inputs, reduce soil erosion, and improve soil fertility conditions in a concerted effort to make farming more sustainable through intensification;

- Strengthening on-farm testing of new technology through involvement of both on-station and farming systems researchers in two types of activity: first, short-duration, researcher-designed, farmer-operated trials conducted at a large number of locations to provide on-station researchers with feedback on many different conditions; and, second, long-term, on-farm testing as conducted by farming systems research (FSR) teams; and

- Placing proper emphasis on crop commodities and agroecological conditions to support research according to national significance and regional potential.

The rainfall-dependent agricultural potential of the country increases from North to South and roughly follows the division into five agroecological zones:

1. The North Sahelian zone
   Little arable agriculture
   Rainfall-long term: less than 400 mm
   in recent years: less than 320 mm

2. The South Sahelian zone

Early- and mid-season millet often intercropped with cowpeas and Bambara groundnuts

Rainfall-long term:	400 to 600 mm
in recent years:	320 to 480 mm

3. The North Sudanian zone

Principal zone for early- and mid-season millet and fonio (*Digitalis exilis)* in pure culture or intercropped with grain legumes.

Mid-season and late sorghum

Groundnuts in the western portion

Rainfall-long term:	600 to 800 mm
in recent years:	480 to 640 mm

4. The South Sudanian zone

Main production area for sorghum, maize, and cotton

Rainfall-long term:	800 to 1000 mm
in recent years:	640 to 800 mm

5. The Guinean zone

Maize, long-season sorghum, and very late millet varieties

Rainfall-long term:	1000 to 1200 mm
in recent years:	800 to 960 mm

BALANCE BETWEEN ON-STATION AND FARMING SYSTEMS RESEARCH

There are two broad approaches to agricultural research in Mali:

- High technology, on-station commodity research that produces high-yielding crop varieties resistant to drought stress, insect pests, and disease, following the example of research models in developed nations; and

- FSR, which is based on locally existing environmental conditions and resources, and proceeds step by step to achieve grain yield increments by integrating all available resources into the most advantageous crop production system.

An impressive amount of new technology, including high-yielding varieties available for application, has been generated under the on-station system over the years, with significant technical support from international organizations. The research infrastructure for the most important two staple crops in Mali is well established at Sotuba for sorghum and at Cinzana for millet. Although insufficient experimental land is available to the sorghum group close to the main station at Sotuba, additional land is available within a radius of 20 kilometers.

The FSR approach has the advantage of being able to study all aspects of local farming in detail, including animal production with its utilization of crop residues and forages and returns of manure to the cropping cycle. Intercropping combinations and relay systems can be compared with and without application of compost, manure, fertilizers, and any other recommended practices and varieties. The effectiveness of erosion-control measures, such as grass strips and live hedges, can be determined with full utilization of benefits for crop and animal production while accounting for disadvantages, such as spreading weed stands and birds' nests over time. With major modern improvements out of reach because of their high cost, evaluation of the interaction of numerous small factors becomes important. Economic analysis interprets the sum total of costs and benefits of the entire production system. It is followed by recommendations for acceptance or rejection by the farmers with immediate feedback from the farmers involved.

The farming systems approach is used to form a bridge between on-station research and on-farm extension by adaptation of research results to practical agricultural application. Special constraints operating in Mali have enlarged the function of FSR considerably. Socioeconomic constraints, especially the unfavorable price structure of agricultural inputs and produce, render new technological packages, involving expensive chemical fertilizers and the application of modern chemical products, uneconomical. Without such inputs, newly developed crop varieties often do not produce higher yields than traditional varieties, and sometimes produce varieties less. New technology with high potential, therefore, must be put temporarily on the shelf, until such time as prices and policies change in favor of investment in improved cultural practices. Such change may occur at any time. Under such conditions, high-technology research results will become immediately applicable and quickly accepted by the farmers.

For example, with newly introduced, short-season, grain-type cowpea varieties in villages, high yields and market prices permitted the use of seed treatment with fungicide, chemical fertilizers, field-crop insecticides, and storage insect control by means of phostoxin. Other improved practices, such as pure culture and high population density, were also accepted. When the value of yield responses obtained exceeds the cost of necessary inputs, advanced agricultural research can lead to intensification and can change traditional cultural practices into modern agriculture. Similarly, under falling prices, intensive cultural practices can revert to extensive production methods. The degree of intensification will vary with time and location. Such differences occur also among those fields close to the farmer's house; the in-fields; and those further away; the outlying fields.

Assuming that the economic conditions will remain as they are for a considerable period of time, high-technology production methods and varieties will not be directly applicable. Farming systems with low-cost inputs starting from the grass-roots level, integrating animal production, forage, and grain cropping practices, become the only effective path available. For this reason, farming systems are assigned the highest research priority in the ARSP budget proposed for the next 10 years. At low initial production levels, many constraints do not require sophisticated research inputs for their solution. Rather, it is a matter of making use of all available resources and opportunities offered by the local environment. During this phase of development, on-station commodity research may have to focus on providing solutions for problems identified and conditions specified by FSR groups.

For example, if new varieties are needed for sorghum/cowpea intercropping at low population levels on degraded soils, evaluation of breeding lines in pure culture at high population and adequate fertility may not be the most appropriate form of research. Close cooperation between on-station researchers and on-farm FSR personnel must be achieved and projects clearly defined in short, effective research protocols. Annual meetings are now held between FSR and on-station researchers to discuss mutual needs and research topics. Actual involvement of staff from both institutions in mutual programs should be the next step toward optimum design, review, approval, and evaluation of on-station as well as FSR activities. When this has been accomplished and well-defined procedures are being followed, contributions from the two groups will flow in both directions and strengthen each other's performance.

As progress is made toward the intensification of agricultural production, higher yields are obtained and the farmer's prosperity is raised. Gradually, increasing intensification will call for progressively more sophisticated agricultural inputs and crop varieties from on-station research. Ultimately, under continued favorable agricultural development, the high-technology packages produced by on-station research will find direct application. This stage will be reached faster in areas where high-value cash crops, such as cotton, are a part of the cropping system because farmers can then pay for chemical inputs. Other crops, such as maize, groundnuts, or rice, can provide similar opportunities for raising production levels when producer prices rise above a certain threshold level.

Market gardening around small towns may take the place of a cash crop in the production system outside the cotton producing area. Elsewhere, no high-value cash crops are available. Farmers primarily concern themselves with food crops to secure a sufficient food supply for the family, and plant additional areas to sorghum or groundnuts for various purchases, schooling of children, and payment of taxes. Inflexible, traditional customs may determine which crops will be grown, in what proportion, and by which member of the family. Therefore, recommended cropping systems and cultural practices must vary from one area to the next. Agronomists will play an important role in this type of research, closely tied to the needs of the farming community.

Valuable results have been obtained to date by farming systems teams presently operating in the country. Yet, the high priority assigned to FSR in general does not pre-empt the need for re-evaluation of the quality of certain activities, more efficient programming, and more careful reporting of research findings, thereby maintaining satisfactory records of experimental findings collected as part of the national research program. It is proposed that an editorial board be set up to define and enforce acceptable standards for description of experimental methods that will include pertinent environmental conditions, statistical analysis, and interpretation of data obtained.

THE IMPORTANCE OF RESEARCH IN SOIL FERTILITY AND SOIL AND WATER MANAGEMENT FOR EROSION CONTROL

Building up of soil fertility by means other than chemical fertilizers and prevention of further soil erosion are currently recognized as high-priority research topics in Mali. They are important because both are hard to accomplish but essential factors in achieving higher agricultural production. Erosion-control measures, such as contour planting and cultivation, terracing, and alley cropping with live hedges, are described as highly effective in reducing runoff and loss of soil. Live hedges of leguminous tree species, such as *Leucaena leucocephala*, fix atmospheric nitrogen in the root system that is later released into the soil and utilized by crops planted in the alleys between hedges. Highly protenaceous tree trimmings can be utilized for livestock fodder or for the provision of green manure to raise the fertility of the soil in the alleys further. The practice leads to increased water infiltration and higher crop yields under certain conditions.

Higher yields may be obtained on sloping lands with medium-textured soils in the subhumid Guinea and Sudan regions, but the same effectiveness would not apply to millet growing on the sandy soils in the semi-arid, Sahelian zone. These soils readily absorb the precipitation received. There, little benefit can be expected from prevention of water erosion in terms of higher grain yields. Farmers generally appreciate the danger of erosion in connection with future downward trends in crop yield, but the practical need to provide food for their families means that only increased yields can motivate them to invest in labor and materials for erosion control. Recommendations for control of soil erosion should always be associated with procedures resulting in increased crop yields.

Building soil fertility is a slow process. Favorable effects on production reported after one or two years are usually due to moisture conservation resulting from combined soil-erosion/fertility-building treatments. These effects are weather dependent and variable from year to year. Obviously, such research must be continued for several years to give reliable results. Some FSR trials in Mali have been continued for 10 years already, providing useful information.

Large amounts of animal manure or compost must be incorporated into the soil to produce a measurable, permanent effect on soil fertility. Amounts under 10 tons per hectare are unlikely to do more than just prevent further decline but may produce yield responses during the decomposition period. Application of organic improvements alone can only increase productivity by small increments at a time. Introduction of agroforestry can assist in raising soil fertility when leguminous trees are utilized, the trimmings of which can be used as green manure while nitrogen fixation underground adds nitrogen to the soil. FSR is eminently suited for delineating the best procedures under different sets of conditions and including modest quantities of fertilizer where economically justifiable.

THE IMPORTANCE OF FERTILIZER RESEARCH

Chemical fertilizers can raise soil fertility and crop yields faster than any organic amendments. Their combined use is recommended for future research. The major element, nitrogen, is generally the most needed in subtropical regions. Its application is likely to give the highest returns in crop yield of any single element. However, it is also the element that is most readily lost from the soil when not utilized by the plant during an unfavorable first season. Residual effects are usually small. This is likely to affect millet farmers in the semi-arid region with sandy soils where droughts occur frequently.

Phosphates are more residual in nature and more likely to be effective during a subsequent season if no responses occurred in the year of application. Furthermore, fertilizer application rates, if aimed at being economically justifiable, need to be so small that the sporadic yield responses may become noticeable only after a number of years of accumulation. This problem will be felt most severely in the region where millet is grown. The cost of chemical fertilizers generally is not covered by the monetary value of millet grain yield response. Therefore, research on the subject is not applicable in practice at this time and has low priority.

Fertilizer experiments must be continued over a number of years and be conducted in combination with other production practices offered by the environment. The FSR approach is the most appropriate for identification of practices leading to profitable yield increases.

Micronutrients are most likely to be lacking in the impoverished, ancient soils of Mali, which are characterized by lateritic substrata and heavy leaching of nutrients. Deficiencies of this nature will be identified over time in the various regions and research undertaken to remedy the situation, because application of the major nutrients cannot yield returns when micronutrients are absent.

THE IMPORTANCE OF IMPROVED CROP VARIETIES

High-yielding varieties are part of modern technology and dependent on high-cost inputs which are mostly uneconomical at current yield response levels and produce prices. New varieties produced by on-station researchers are readily accepted by the farmers sometimes even before they have been properly released, but they often produce at the level of traditional varieties or slightly below that without additional inputs. Improved features such as increased grain/straw ratio and resistance to pests, diseases, and drought are very useful characteristics for incorporation into FSR programs in the various regions. Shorter stalks, where those of the traditional varieties were very long, can greatly increase the productivity of the companion crop and land equivalence ratios (LERs) of intercropping systems. However, some sorghum varieties released with shorter stems are not appreciated by the farmer. New varieties with denser heads can produce higher yields but also are more subject to infestation by head insects. Sources of resistance are available and breeding efforts are continuing.

Seed quality is an important characteristic in breeding. Quality, usually referred to as taste, is one factor evaluated in newly developed lines because unsatisfactory taste makes a variety unacceptable. Breeding for special purposes in food technology is receiving attention. An example is quality *to*, the staple made from sorghum grain; "quality" refers to its suitability in terms of a certain consistency and absence of stickiness.

THE ROLE OF LIVESTOCK RESEARCH

The primary role of livestock research in the national agricultural research program is to contribute to the integration of forage crop and small ruminant production in the cropping system. The value of certain leguminous crops, such as *Stylosanthes* and cowpeas and several other species, has been proven. Screening of legume species and varieties for various environmental conditions, optimum population density, and management practices for adaptation to various needs are topics for investigation. The rate of acceptance of forage crops by the farmer will presumably be greatest when proposed as improved fallow in the rotation. This serves the dual purpose of restoring soil fertility, after depletion by several years of exhaustive cropping, and simultaneous production of quality fodder for livestock. Leguminous forage species build up the nitrogen and organic matter content of the soil faster than voluntary fallow vegetation. Furthermore, forage crops do not add to the farmer's burden of hand weeding his grain crop and thereby permit him to expand his farming operation without increased demand for labor during critical periods.

Part of the role of legumes in the farming system is to provide a fodder supply for maintaining livestock during the off-season, especially during the last two months before the next growing season. Screening of cowpea and groundnut germplasm for lines which retain a larger percentage of their foliage until late in the season, and even after grain harvest, would serve this purpose. A great need exists for storage of dry-crop residues, with as much of the leaves as possible still attached, for feeding of draft animals prior to the beginning of soil tillage for the next season. Similarly, cutting and drying of green shrubbery and natural grasses for hay early during the season before aging and deterioration, instead of burning at the end of the season, would help improve the fodder supply during early spring.

Small ruminants are efficient for utilization of crop residues, and their manure can form an essential component of soil fertility maintenance if means can be found for its collection, proper storage, and preservation. The required level of cooperation between crop and livestock departments will be best served by assignment of animal science specialists to FSR teams. While the contemplated merger of the Institut d'Economie Rurale (IER) and Institut Nationale de Recherche Zootechnique, Forestiere et Hydrobiologique (INRZFH) may take place in the foreseeable future, the highly desirable collaboration of scientists from the two institutions should not be affected by the ultimate outcome of such considerations. Close cooperation in conducting commonly designed projects under USAID/ARSP funding will demonstrate the need for an integrated national research strategy and may assist in accomplishing the desired objective.

THE NEED FOR MECHANIZATION

Although manual labor is the basis of the typical farm in Mali, the level of mechanization can be divided into three categories:

- Farms with no animal traction;
- Farms with some animal traction; and
- Farms with adequate resources for animal-traction-based operations.

As a result of long-term livestock and FSR, significant progress has been made in preparing farmers, in areas relying on manual labor, for mechanization using animal traction. Incorporation of forages into the cropping system, feeding trials, development of holding pens, utilization of animal manure, design of suitable harnesses, and experimentation with animal-drawn equipment have made mechanization a more acceptable concept. Mechanization facilitates deeper cultivation, cleaner seedbed preparation, and timely sowing of crops. It can greatly reduce the time spent on weeding. One problem is the limited capacity, due to lack of fodder, for work by oxen during tillage operations early in the season. Fodder conservation for strengthening draft animals prior to the start of the new season is obviously necessary for further progress.

Manual labor tends to be replaced by animal traction during the process of agricultural development, since farmers will no longer have sufficient time to perform manual tasks such as hand weeding. Women farmers engaged in rice growing accept herbicides before fertilizers as the most important agricultural input. Dryland farmers have expanded cereal crop plantings to the extent that hand weeding has become the most serious production constraint. Animal traction is available to a greater extent than previously expected and suitable animal-drawn implements need to be developed. Improved cultural practices place emphasis on intensive rather than extensive land use. The Agricultural Engineering Department (DMA) of IER, located in Bamako, is ready to cooperate in the adaptation of agricultural implements to the environmental and soil conditions in the various regions.

PROPOSED NEW FARMING SYSTEMS CENTER

The three FSR groups in the country are all located in the Sudan/Guinea region. The remaining, larger, Sahelian portion of the country is not covered. This area includes the millet-growing region with coarse-textured soils, low soil fertility, and low yields. Drought stress aggravated by below normal rainfall, wind erosion, and insect pest damage present an extremely difficult situation for improvement. This is presumably the reason why no FSR group has been established in the region. In addition, different development problems occur in the inland delta area along the course of the Niger River. Also, the water-harvesting techniques practiced in certain areas could be improved. It is proposed that a fourth farming systems team be located at Mopti to accomplish the following tasks.

- Develop solutions for millet growers spread over a wide area by combining resources for arable crop culture with those from the cattle and small ruminant industry. Crop varieties released as a result of on-station research provide the necessary resistance to drought and insect pests. An asset of the area is the occurrence of *Acacia albida*, which has the combined advantage of a visibly favorable effect on crop growth within a certain radius from the tree, as well as the fact that it sheds its leaves at the beginning of the cropping season, thus minimizing competition for soil moisture with the growing crop. Neither the quantity of atmospheric nitrogen fixed by its roots nor the areal extent of the beneficial effect has been accurately determined. There is no evidence of any attempts made by farmers to plant additional *Acacia* trees in their fields. This topic by itself would be suitable for on-station research and subsequent application of the results by FSR groups working in the region.

- Attend to problems that have arisen with the cultivation of floating and deep-water rice over the last decade. Land that is no longer subject to flooding due to lower maximum water levels of the river during the growing season is now available for dry-land grain production, but is characterized by extremely fine-textured soils that will require special attention due to difficult soil/water relationships. The typical millet-growing area away from the river is dominated by coarse-textured soils.

- Consider the possibility of land reclamation in perimeter areas of high flood level in the Niger River delta for production of irrigated rice with small lift of water by means of pumping. Production of rice per hectare may be tripled by changing from floating rice to irrigated rice and two crops per year harvested, compared with only one with floating rice. Local rice production would be increased six-fold -- of some importance since the government imports rice to make up for shortages in local rice production. Food grains imported in aid of the country's food shortage could become the greatest disincentive for local rice growers by lowering the market price at the time of harvest.

Potentially very large areas are involved, an unknown fraction of which may offer economically suitable conditions. Topographic conditions determine feasibility and cost of construction of water inlet structure, design of water courses, and land leveling. Areas suitable for small-scale development need to be selected by means of surveys evaluating topographic, as well as socioeconomic, conditions. Socioeconomic factors involving labor availability for planting, weeding, and harvesting, as well as transportation in isolated areas, play an important role in such development.

THE PROPOSED RESEARCH NETWORK

The rational for research support is that very little research would be undertaken in Mali without it. The government pays the salaries of the research staff but is unable to contribute much to the funding of operational costs. Not all disciplines and activities of the national research institutes are represented in the proposed research support scheme and budget (Table 1). Only the most important

TABLE 1

AGRICULTURAL RESEARCH SUPPORT PROJECT
RESEARCH STRUCTURE AND DRAFT BUDGET ($000s)

Category	Commodity	Priority	Main Station	Substations	Personnel (Ph.D/MS)	Main/ sub	Support per annum Yr 1	2	3	4	5	6	7	8	9	10	Total 5 yrs	Support 10 yrs
Research support	Sorghum	5	Sotuba	Cinzana Be'na Same	2 breeders 3 agros 1 physio 1 entomo 1 patholo 1 seed quality	Main Sub	350 30	371 32	393 34	417 36	442 38	468 40	496 43	526 45	558 48	591 51	1,973 170	4,612 397
	Millet/ fonio	6	Cinzana	Koporo Sotuba Katibougou Bougouni Mopti	1 breeder 1 agro 1 physio 1 entomo 1 patholo	Main Sub	250 50	265 53	281 56	298 60	316 63	335 67	355 71	376 75	398 80	422 84	1,410 282	3,296 659
	Rice/irri (dutch support)	9	Kogoni	-	1 breeder 1 agro 1 livestock 1 drainage		0**	0	0	0	0	0	0	0	0	0	0	0
	Rice/floating & deep water	7	Mopti	Dire Gao Longorola	1 breeder 1 agro (WID) 1 entomo 1 weed sci	Main Sub	250 20	265 21	281 22	298 24	316 25	335 27	355 28	376 30	398 32	422 34	1,410 112	3,296 263
	Maize	8	Bougouni	N'Tarla Samanko Kita	1 breeder 2 agros	Main Sub	150 30	159 32	169 34	179 36	189 38	201 40	213 43	226 45	239 48	253 51	846 170	1,978 397
	Cowpea/groundnut	10	Same	-	1 breeder		50	53	56	60	63	67	71	75	80	84	282	659
	Fruit/vegetable	11	Bamako	-	1 breeder		50	53	56	60	63	67	71	75	80	84	282	659
	Multilocational testing	12	-	4	1 Ph.D. 4 agros		50 100	52 106	56 112	60 119	63 126	67 134	71 142	75 150	75 159	75 169	282 563	659 1,317
	On-Farm testing	13	-	15	15 agros*		150	159	168	179	189	201	213	225	239	253	845	1,976

* MS, BS, or qualified technicians
** supported by other international donor

TABLE 1 -- Continued

Category	Commodity	Priority	Main Station	Personnel (Ph.D/MS)	Support per annum Yr 1	2	3	4	5	6	7	8	9	10	Total 5 yrs	Support 10 yrs
Research Support	Food Technology	14	Sotuba	1 Ph.D. 2 food tech	50	53	56	60	63	67	71	75	84	84	282	659
	FSR/E I/OHV	1	Sotuba	1 team lead 2 agros 1 ag econ 1 an sci 1 socio 1 WID spec	0***	0	0	0	0	0	0	0	0	0	0	0
	FSR/E II/Mali-Sud (Dutch support)	2	Sikasso	1 team lead 2 agros 1 an sci 1 ag econ 1 WID spec 1 plant prot	0***	0	0	0	0	0	0	0	0	0	0	0
	FSR/E III/Mali-Sud	3	Bougouni	1 team lead 1 agro 1 an sci 1 econ 1 socio	350	371	393	417	442	468	496	526	558	591	1,973	4,612
	FSR/E IV/Reg. 5	4	Mopti	1 team lead 1 agro 1 an sci 1 ag econ	0***	0	0	0	0	0	0	0	0	0	0	0
			Total Research Support		1,930	2,046	2,167	2,303	2,436	2,584	2,739	2,900	3,077	3,257	10,882	25,439
Postgraduate Training	- Degree Total number of national scientists proposed less (existing staff + number of students abroad + those supported elsewhere) 20 x 3 years x 2 for each post x $30,000 per student				420	859	1,348	929	492	0	0	0	0	0	4,048	4,048
	- Non-degree Short-term in food technology, soil erosion, etc.				50	53	56	60	63	67	71	75	80	84	282	659
			Total Postgraduate Training		470	912	1,404	989	555	67	71	75	80	84	4,330	4,707

*** supported by separate AID contract

TABLE 1 -- Continued

Category	Commodity	Personnel		Support per annum Yr 1	2	3	4	5	6	7	8	9	10	Total 5 yrs	Support 10 yrs
Technical Assistance	- Long Term	Team Leader/agronomist	Years: 1 to 4	150	159	169	179							657	657
		Research Administrator	Years: 1 to 3	150	159	169	0							478	478
		Financial/Accounting spec	Years: 2 to 4	0	159	169	179							507	507
		Breeder	Years: 1 to 4	150	159	169	179							657	657
		Soil Scientist	Years: 1 to 3	150	159	169	0							478	478
		Ag Economist	Years: 2 to 4	0	159	169	179							507	507
	- Short Term	CRSP consultants INTSORMIL BEAN/COWPEA TROPSOILS		25	27	28	30	32	33	35	38	40	42	142	330
	One-week visits, two each per year														
	Other short-term consultants			50	53	56	60	63	67	71	75	80	84	282	659
		Total Technical Assistance		675	1,034	1,098	806	95	100	106	113	120	126	3,708	4,273
Miscellaneous Expenses	International Travel by Malian Scientists			100	106	112	119	126	134	142	150	159	169	563	1,317
	Commodity Group Planning Meetings			5	5	6	6	6	7	7	8	8	8	28	66
	Purchase of computers for DAF and DDI			25	25	50								100	100
	Support to DDI for production and distribution of IER reports and publications			10	15	20	22	23	25	30	30	35	50	90	260
		Total Miscellaneous Expenses		140	151	188	147	155	166	179	188	202	227	781	1,743
		Subtotal		3,215	4,143	4,857	4,245	3,241	2,917	3,095	3,276	3,479	3,629	19,701	36,162
		Project Evaluation (2%)		64	83	97	85	65	58	62	66	70	74	394	729
		Total Budget		3,279	4,226	4,954	4,330	3,306	2,975	3,157	3,342	3,549	3,768	20,095	36,886

commodity programs and specific research programs were selected for funding, to form the nucleus of an integrated agricultural research program most likely to maintain a sustainable food production system for the country.

Sorghum and millet undoubtedly are the most important crops for national food production, followed by rice. Maize, cowpeas, groundnuts, fruit, and vegetables are important as food, cash crops, or leguminous components of the cropping system, but relatively minor in areal extent compared with the major staple food crops.

The proposed network of main stations and substations for the various commodities fits the existing IER network rather well. The sorghum and millet centers at Sotuba and Cinzana have a sufficiently large concentration of scientists to stimulate team work. Close cooperation with FSR personnel is highly desirable and development of joint research programs will further broaden the range of disciplines involved with each center. The rice research at Kogoni is supported with funding and technical assistance by the Dutch. The entire district is affected by a very serious drainage problem. At Bougouni, the maize research team of three scientists will form a viable group or "critical mass" with the team of five FSR people. Also, millet researchers will use Bougouni as a substation.

Similarly, at Mopti, the proposed rice research team of four will be reinforced by a FSR team of four, a group of adequate size to promote interdisciplinary discussion. In addition, millet researchers will use Mopti as a substation.

The level of financial support required for research operations varies with the nature of activities and needs for instrumentation. These will be further specified during Phase Two of the ARSP and the support level adjusted accordingly. As a first approximation for the purpose of the PID, an average amount of $50,000 per annum has been allocated per commodity scientist with certain modifications augmenting or reducing the total amount in various instances.

A similar reasoning has been followed for support of operations at substations, setting the amount at $10,000 per substation per annum. These values will need to be reconsidered after more detailed planning during Phase Two. Support for agronomists in multilocational and on-farm testing was based on anticipated program expenses and traveling. The cost of postgraduate training of Malian scientists was estimated at $30,000 per annum. The cost of maintaining and supporting the research operations of expatriate scientists under technical assistance was estimated at $150,000 per annum.

Multilocational testing is presented as a separate activity in the budget because the number of personnel assigned to the activity is smaller than the number of commodities served and because the staff should not be widely dispersed. However, it should be realized that the activity is to be conducted in close cooperation with the various commodity groups, sharing plans of action and results, and serving the interests of all parties.

On-farm testing, proposed as a separate activity, differs from multilocational trials in that it follows the former and is researcher designed but farmer operated. It is also designed to provide the researcher with feedback from the farmer. It is the lowest level of research involvement, important for testing the applicability of research results at the farm level. This on-farm testing differs from the kind

conducted by FSR teams, which includes a much wider scope of work, integrated with forage and livestock activities. The latter includes input from all available local resources and amounts to long-term research, whereas the former does not.

Food technology is assigned the lowest priority in the scheme, not because it is the least important, but because it cannot precede actual production of adequate quantities of agricultural produce. Financial support projected for the first year is based on the assumed cost of the as yet unspecified equipment needed.

STAFFING OF THE VARIOUS RESEARCH STATIONS

The numbers and disciplines of proposed personnel includes only MS and Ph.D. staff and reflect the minimum deemed necessary to maintain a viable national program in each commodity and activity selected for financial support by USAID. Staff appointed to conduct experimentation at substations is assumed to be at the BS level, and, therefore, is not shown under personnel but is provided with a certain amount of funding. The staff concerned should be capable and authorized to make the necessary changes in research protocols in case of isolation from main station personnel or under pressure from an unforeseen change in circumstances.

The personnel positions listed in Table 1 represent estimated needs. The staffing indicated for some stations represents an already existing situation -- for example, FSR/E II in Sikasso. At other locations, the proposed staff consists of existing positions augmented by reasonable needs expressed by existing staff -- for example, millet at Cinzana -- or is based entirely on evaluations by the PID team.

RESEARCH PRIORITIES

The research priorities shown in Table 1 give highest priority to the four FSR activities. This reflects the special position in which agricultural development is placed in Mali. The on-station research is in capable hands and should continue unabated. This is clearly indicated by allocation of a total of approximately $20 million to on-station research in the proposed budget. The research topics, however, must change in favor of the fastest way to fulfill the prime national interest--increased food production. FSR, on the basis of results already obtained and of on-going experimentation, appears to be the most likely -- and perhaps the only approach -- capable of bringing all available resources together in suitable cropping systems, properly adapted to specific sets of conditions under which farmers must operate. Without modification through a joint effort with FSR, on-station research might not be effective during the next developmental stage which could take five to ten years.

On-station commodity research has been assigned priority in the order of sorghum, millet, floating and deep-water rice, maize, irrigated rice, cowpeas, groundnuts, and fruit/vegetables. Under normal conditions, irrigated rice would probably rank next after millet but several decades of poor irrigation water management have resulted in severely reduced potential of the entire irrigated rice area in the Office de Niger. Drainage provisions on farmers' land are grossly

inadequate. The groundwater level has risen from more than 40 meters below the surface of the soil to less than two meters below the surface. Under shallow water table conditions, water evaporating at the surface of the land is replaced by groundwater brought up by capillary rise. Soluble salts are left behind and accumulate at the surface as the water evaporates.

Associated with salinization are alkali and cation imbalance problems, all of which usually appear first in patches and later spread over larger areas. Such salt-affected patches have been observed already by researchers and are indicative of more extensive problems which follow. The priority ranking of research on irrigated rice -- which should be quite high -- is therefore well below that of floating and deep-water rice and of a relatively minor crop such as maize. This is no reflection on the quality and methodology of the rice research conducted at Kogoni, but rather a consequence of the limited potential for application of new technology under the prevailing conditions.

In terms of priorities, multilocational testing (Number 12), on-farm testing (Number 13), and food technology (Number 14) logically follow after that of the actual research.

Reduction of the scope of research support proposed in the PID can be based on the priorities shown, if deemed necessary during the next phase of PP development. Each of the lower-ranking commodities proposed for research support play an important role in the development of new cropping systems, either as leguminous components (cowpea, groundnuts) or income-generating cash crops (groundnut, maize, fruit, vegetables). Yet, sacrifices would have to begin with deletion of support for fruit and vegetables (Number 11), followed by cowpeas and groundnuts (Number 10), and maize (Number 9) in that order. Support for multilocational, on-farm testing, and food technology would be reduced in proportion. Elimination of research support for each one of these crops would affect the development of innovative cropping systems to some extent. Elimination of maize research would affect its role as a cash crops and weaken Bougouni as a FSR center. Also, the number of researchers would fall below the concept of "critical mass" and perhaps be sufficient reason for abandonment of Bougouni as a FSR enterprize. Similarly, elimination of research funding for floating and deep-water rice would severely affect the viability of a FSR center at Mopti.

EVALUATION OF USAID-FUNDED RESEARCH

Scientists developing research programs commit themselves to an integrated approach for each commodity. The programs proposed by individual scientists or research teams should have clear economic potential if the results are to find a place in sustainable agricultural development. The annual budget of the commodity groups is mainly decided through negotiation with various funding agencies. In the case of the ARSP, the main agency will be USAID. Research fund allocation by USAID will have to be made on a firm, factual basis. In addition to the general discussions held by the Technical Committee, there is a need for thorough evaluation of the results obtained by each individual research project over the previous three- to five-year period, depending on its nature and longevity and the project's economic potential. This must be followed by ranking according to priority in view of sustainability of

the integrated approach of which it is a portion. This function could be performed fairly and free from bias by a small committee made up of representatives from USAID, perhaps AID/Washington, a budget manager, IER, INRZFH, and two national researchers who are unaffected by conflict of interest.

Funding levels of individual projects should be decided, and periodically adjusted, based on the quality of the completed work and promise for the future. Assuming limited resources, certain projects will receive more funds than other projects. This will establish considerable motivation in research circles to design highly useful projects and work effectively at obtaining results. Without a direct linkage between evaluation and budget funding, USAID will have no control over the nature or quality of research carried out under its auspices. Satisfactory budgeting within a commodity is done on a project-by-project basis.

IMPROVEMENT OF THE DESIGN, REVIEW, APPROVAL, AND EVALUATION OF ON-STATION RESEARCH

The main improvement in the design of on-station research lies in choice of research topics. The quality of research is not being questioned. The point is to have on-station researchers focus on direct applicability of their programs. The criterion should be a measurable increase in food production resulting from the research. Research programs designed at this stage should be utterly practical and have a high probability of solving one of the farmers' production constraints. The FSR approach is closest to the farmers' problems and practices, and examines many factors for possibilities of progress in development of new cultural practices as long as they are within reach of the farmer. It is for this reason that emphasis is placed on the role of FSR throughout this PID (see section on balance between on-station and FSR). Under the ARSP program, on-station research needs to apply itself to the needs expressed by the FSR groups and the latter must learn to define and express these needs more clearly to on-station scientists.

Annual meetings now held between the two parties are the first step in the direction of strengthening the design of on-station research. The process of review, approval, and evaluation forms the next step. This process has already been initiated during the customary annual sessions of the Commissions Techniques. However, the process is not yet sufficiently selective to identify and encourage the research which is most likely to lead to increased production. It may be appropriate to include agricultural economists in the peer review to evaluate the applicability of on-station research to practical farming in economic terms.

Further, the evaluation and approval of research accomplishments need to be accompanied by the force exerted by selective funding of research projects as was suggested in the section on evaluation for USAID-funded research. This should apply to on-station as well as on-farm research. Farming systems researchers are likely to come up with a large number of suggested research topics. All of those may be valid but they also need to be evaluated and prioritized for financial support.

STRENGTHENING OF ON-FARM TESTING TECHNOLOGY

Strengthening of on-farm technology developed by on-station researchers is proposed in the budget under the heading of on-farm testing to a total of $2 million over the 10-year period covered by the ARSP. This on-farm testing is proposed as a separate activity from multilocational testing and designed as the lowest level of involvement by the on-station researcher (see section on proposed research network). As explained earlier, the on-farm testing program also differs from that conducted by FSR teams.

REGIONALIZATION

The quality of research performed would be well served by a change in policy whereby research scientists responsible for experimentation at outlying substations are required to reside at or near their place of work. Such a policy could be successful only if accompanied by two essential factors:

- Adequate financial resources to conduct the research assigned; and
- Provision of essential services to the families of scientists living at isolated locations.

The latter would include satisfactory housing, transportation to and from work, and school and medical facilities within reach, such as could be reasonably expected in compensation for voluntary abandonment of the comfortable living conditions enjoyed by the majority of the nation's research scientists now established in the capital city.

POSTGRADUATE TRAINING

Postgraduate degree training is necessary to fill the positions listed in the various disciplines of the proposed ARSP, in so far as not already provided for by the existing research staff structure, and by students presently studying abroad. It is envisaged that a relatively large demand for agronomists and agricultural economists may result from greater emphasis on FSR during the first phase of this ten-year project. A need exists also for statisticians with computer ability to assist scientists from all research centers in the proper design and analysis of experiments. Short, in-service training courses organized at a central location, in addition to individual consultations, would be desirable in upgrading research staff competence.

Short-term, non-degree training programs of up to three months in the United States or elsewhere are provided to quickly familiarize scientists with state-of-the-art knowledge in certain specialty fields.

TECHNICAL ASSISTANCE

The technical assistance team proposed in the budget for a four-year period consists of four people: a team leader who is also the agronomist, one plant breeder, one soil scientist, and an agricultural economist. Technical assistance from a team of scientists with extensive experience in work on dry-land crop production problems, including utilization of crop residues under severe semi-arid climatic conditions in the United States, could make an excellent contribution to the development of research programs with the major grain crops, especially at FSR centers such as Bougouni and Mopti. The team members would divide their working time between the two stations. The agronomist would be responsible for planning the appropriate experimental treatments for building new cropping systems. He would bring expertise on crop management, soil fertility issues, and experimental design.

The plant breeder would assist with screening of introduced crop and forage varieties, and help define the crop breeding requirements of the FSR teams in contact with on-station researchers. The soil scientist would be the resource person for soil management and moisture conservation, proper treatment for soil erosion control, and adaptation of management practices to different soil types. Advice in the area of agricultural economics is widely needed for planning and interpretation of experiments not only by the two FSR teams but also by several commodity research groups who have no economist on the team (see Table 1). It is recommended that a certain degree of diversity be maintained among those institutions providing such assistance to individual centers to encourage cross-fertilization of ideas. Assistance during the first four years of the ARSP would be the most effective.

INTERNATIONAL NETWORK TRAVEL

Malian scientists engaged in USAID-funded research projects would profit greatly from visits to other scientists working on similar programs in the same discipline or commodity elsewhere in the international network. A suitable schedule needs to be designed to distribute travel opportunities over all facets of the research covered under the program and expand international contacts as efficiently as possible.

CONSULTANCIES FROM COLLABORATIVE RESEARCH SUPPORT PROJECTS

Collaborative Research Support Project (CRSP) consultants from, for example, International Sorghum and Millet (INTSORMIL), Bean/Cowpea, and Tropical Soils (TROPSOILS), can provide new insights during short visits. INTSORMIL has been involved with sorghum and millet research problems in Mali for many years. The Bean/Cowpea CRSP could provide helpful guidance in establishing the cowpea research at Same by using lines, breeding programs, and improved cultural practices, including intercropping, it has developed in neighboring countries. TROPSOILS could

advise on suitable alley cropping methods with *Leucaena leucocephala*, *Glyricidia sepium*, and other species as well as other erosion control practices not yet widely known in Mali.

Week-long visits, twice a year, would be helpful, once during the growing season for observations and again during the off-season for discussion of results and planning for next year. The consultants could plan their visits as part of their regular programs in West Africa.