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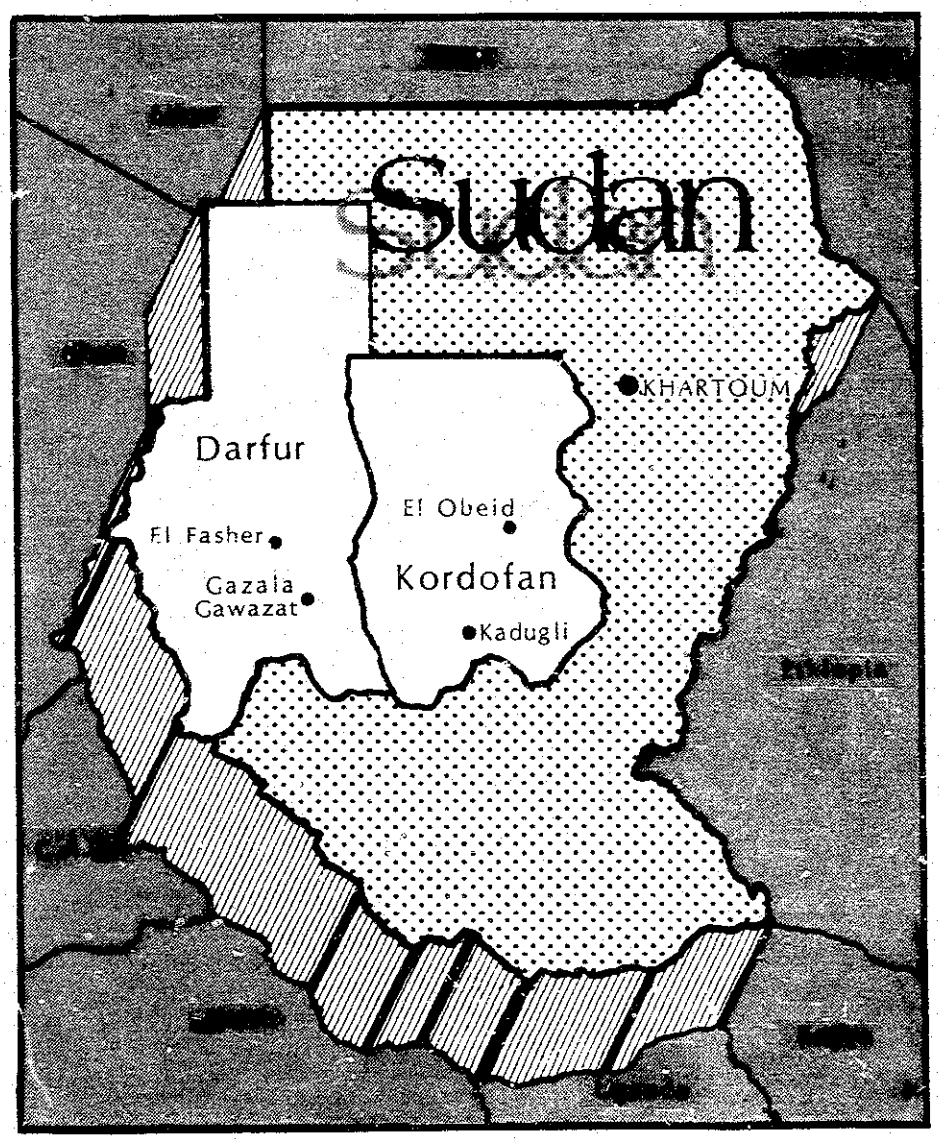
Western Sudan Agricultural Research Project

- A sixth-year evaluation
- Recommendations for continuance
- An analysis of mechanized rainfed agriculture research



WINROCK INTERNATIONAL

WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

AN EVALUATION WITH RECOMMENDATIONS

Prepared for:

U.S. Agency for International Development
Sudan

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Washington State University was most helpful through provision of copies of most reports originating under their management of the Project. These were most valuable to the team in assessing the progress of Project activities.

The team also wants to make special recognition to Barbara Friston and Fey Santos for their invaluable assistance in putting our lengthy and somewhat unorganized documents into the word processor. We were most appreciative of their pleasant and helpful attitude in spite of what must have seemed to be unreasonable demands for secretarial output.

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WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT
AN EVALUATION WITH RECOMMENDATIONS

INTRODUCTION

The Western Sudan Agricultural Research Project (WSARP) was designed to improve the research potential of the Sudanese Agricultural Research Corporation (ARC). The end objective was to improve the standard of living of subsistence farmers and pastoralists in the arid and semiarid areas of West Sudan.

Background

The history of agricultural research in Sudan started in 1902 in response to needs of Britain's cotton industry. In 1967 responsibility for agricultural research was vested in the semi-autonomous ARC.

The WSARP has its roots in a study by the Ford Foundation which was requested and authorized by the Ministry of Agriculture and Natural Resources (MANR) in 1975. The study undertook to assess Sudan's agricultural research and related services and recommend ways to strengthen the research capabilities.

The series of studies emphasized the potential of rainfed agriculture in West Sudan and recommended the development of a research network for the region. It was considered that the traditional production systems for groundnuts, sesame, gum arabic, sorghum, millet, and livestock held the greatest promise for near-term solution to Sudan's economic problems. A research program would assist the agricultural sector of that region to take advantage of this potential. Subsequently, in 1978, agreements were signed between the Government of Sudan (GOS), the World Bank, and USAID for assistance in developing an agricultural research program for Western Sudan. The project was developed as an integral component of the ARC.

Activities and responsibilities for the various participants in the Project were defined in the basic Project documents. The World Bank financed a major portion of the construction program and the purchase and operation of the aircraft. USAID's component supported architectural and engineering/construction management, a portion of the construction costs, technical assistance, and institutional development activities, such as, personnel training, equipment and commodity purchase, and administrative support. There were also USAID provisions for purchase of research supplies and operational costs including 70% of the WSARP Sudanese salaries.

USAID entered into a contract with the Consortium for International Development (CID) of Tucson, Arizona, in August 1979. This was done under Title XII of the Foreign Assistance Act, Collaborative Mode. The contract was primarily to implement the technical assistance, training, and procurement portions of the WSARP. Washington State University (WSU) was designated as the lead university within CID to implement the program.

USAID support was withdrawn from the Darfur stations in mid-1985. As a consequence to this development in project operations, the World Bank has agreed to support the two Darfur stations by provision of loans for technical assistance, long-term training, and other operation costs. It will continue to provide for operation and maintenance of the WSARP aircraft over a five-year period.

The World Bank technical assistance includes four expatriate scientists for three years each. Two ARC scientists are to be trained to Ph.D. level. There is to be continued support of the aircraft for the Kordofan stations as well as Darfur locations and all recurrent expenditures associated with operating the research stations at Ghazala Gawazat and El Fasher.

The WSU/CID contract was originally scheduled to be completed on 14 August 1985. The contract was extended to 31 December 1985 to permit the livestock and economist technical assistants to remain through the majority of the cropping season. Project activities will continue to 1987 under direction of ARC-WSARP personnel, with technical and financial assistance from USAID.

The technical assistance to be provided by USAID until project completion is to include four expatriate scientists with specialties in Agronomy, Livestock Production, Soil and Water Management, and Agricultural Economics.

USAID organized this formal review of the Project at the end of year six to assess ongoing Project activities and to make recommendations for last-minute refinements of these activities as the Project approaches its completion date in 1987. The review took place from January 14 to March 14, 1986.

Scope of Work for the Evaluation Team (from document of USAID, Khartoum)

1. "Identify types and levels of administrative support required (journal subscriptions, library materials, printing facilities, etc.) for the ARC to take full advantage of the investment USAID is making in dryland agricultural research in Western Sudan.

2. Evaluate the existing relationship between WSARP and the ARC. Recommend means to reduce the parallelism of the institutions and bring WSARP into ARC as an integral component.

3. Review the African Bureau's guidance--"Plan for Strengthening Agricultural Research and Faculties of Agriculture in Africa." This new project and any follow-on work under WSARP will be structured around the commodity focus suggested in the Bureau's guidance. Though USAID's resources and support will be focused almost exclusively on Western Sudan, the GOS and ARC's requirement to look at the development of a nationwide research strategy for all the rainfed areas in the country is recognized. Therefore, the team should consider the national resources, needs, and policy in order to put USAID's assistance to Western Sudan into a national context and ensure that our strategy for the west is consistent with national priorities.

4. Review ISNAR's and INTSORMIL's papers on the ARC and after evaluating any subsequent changes, recommend management/ administrative and research support changes which the Project should address in order to enhance the effectiveness of its investment in agricultural research in Western Sudan. This must be viewed under the assumption of the GOS's limited resources to devote to institutional support for the ARC's general development.

5. Identify means of strengthening the ties between the ARC and IARCs which will reduce the ARC's requirement for expensive basic research which is redundant of that already evaluated by IARCs. Particular emphasis should be placed on linking research activities in Western Sudan to international efforts.

6. (a) Determine the extent to which WSARP's goals and objectives have been or are being achieved. To make this assessment the team will review and evaluate annual research plans and research reports to identify the operational research scope of the project and outputs of research actually achieved to date and will specify any additional requirements necessary to finish incomplete, potentially high payoff research activities.

   (b) Determine if minor adjustments or refinement of the project research scope, inputs or objectives are required between now and the PACD.

7. Assess the commitment of the ARC to support research within the rainfed sector under existing budgetary limitations; determine the additional budget resource requirements that would be necessary to adequately support agricultural research at two research stations in Western Sudan. (This assessment will take into account ARC budget allocation to the irrigated sector and rainfed research stations throughout Sudan.) Evaluate the Ministry of Finance and Economic

Planning's latitude to and interest in increasing financial support to agricultural research. In answering these questions, (a) evaluate the current research administrative structure and its effectiveness; (b) evaluate current and projected budgetary support levels which would be required to realize the recommended research agenda; (c) determine the current technical staff available relative to the proposed research agenda; (d) prepare projections for the budgetary requirements (foreign and local currency) to implement the proposed research program; and (e) prepare starting projections (Sudanese, expatriate, participant training) required to implement recommended research activities.

8. After evaluating the cost constraints (donor and GOS) and the Mission's biases detailed in the background section, specify an appropriate research agenda for each "recommended" research station for the next 5-10 years. Include the level of effort required to achieve the recommended research objectives. Indicate the nature of the commodity-oriented research focus; specify the current production constraints that are to be addressed by the team's proposed research agenda including how long it is expected to take for research to generate outputs which will address these constraints. Specify the magnitude/nature of the costs involved with the proposed research and provide rough estimates of the expected rates of return for recommended research activities. Estimate recurrent costs and include these in the cost/benefit analysis.

9. (a) Identify how agricultural research can be effectively linked to farmers, extension, and credit personnel, area merchants, and the larger private sector community in Sudan. This is to ensure that research generates profitable outputs within the technical, financial, and managerial capacity of target farmers as well as technologies and services that can be effectively and profitably disseminated by the Sudanese private sector. Identify an appropriate feedback mechanism for relating farmer's and merchant's demands back to researchers.

(b) The same assessment should be made to determine the extent to which research findings have sat on the shelf and the constraints that have been encountered in moving research findings and recommendations into commercial channels."

The Evaluation Team

USAID contracted with Winrock International Institute for Agricultural Development (WIIAD) for completion of the evaluation. Members of the evaluation team included:

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Dr. Robert Temple
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Dr. Gordon McLean
Soil Scientist and Agronomist
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Mr. Winton Fuglie, M.Sc.
Agricultural Economist
Audubon, Minnesota

The Evaluation Plan

Members of the evaluating team were provided with a broad array of reports and documents which provided background for the evaluation. These documents, in addition to those acquired throughout the period, were reviewed to provide information on project goals, planning, activity implementation, administration, and effectiveness.

Briefing and background meetings were arranged with former Washington State University team members in Washington, D.C., and with USAID and GOS staff in Khartoum. Meetings with the Project Director and a previous Deputy Director of ARC, Dr. Musa, and with the Director General of ARC at Wad Medani provided useful background for the team.

A previous mid-term evaluation of the WSARP by Collinson, Vercoe, Idris, and Turk served as a most helpful foundation upon which to base the approach to the evaluation.

Research sites at Kadugli, El Obeid, Ghazala Gawazat, and El Fasher were visited prior to completion of the year six review. A draft of the report is to be submitted prior to the team's departure on March 13, 1986. After review and comments in Sudan and Washington, D.C., a final draft will be prepared in the U.S.A. and submitted to appropriate USAID authorities in May.

PROJECT GOALS AND OUTPUT

Project Goal: An improved standard of living for subsistence farmers and pastoralists in Western Sudan.

Project Purpose: Develop and institutionalize an efficient system for agricultural research operations in West Sudan.

Outputs: Anticipated outputs for the Project included:

1. Ongoing research projects in:

   a. Livestock and Crop Production
   b. Water and Land Use Management
   c. Range and Livestock Management

2. Physical infrastructure of research facilities.

3. Strengthened management capability for agricultural research in Western Sudan.

4. Expanded and improved human resource base of Sudanese staff.

5. A viable logistic/communication system for support of complementary agricultural research organizations in Sudan as well as ARC's.

The logical framework developed for the project states that the following circumstances would indicate that project outputs had been achieved:

1. Five research programs would be completed.

2. Four research stations would be completed.

3. The office building for management in Khartoum would be completed.

4. Thirty Sudanese would have been trained externally. Eighty Sudanese trained on short-term basis within the country.

5. Five radio stations established,
   four mobile radio stations operational,
   the aircraft would be operational.

6. A planning and evaluation committee would be formed.

7. Conferences would be held.

Within this report the outputs have been evaluated and presented in two parts: (1) institutional building and development and (2) research programs.

Institution Building and Development

A. Construction

There have been many reports and many meetings relative to construction activities of the WSARP. The team visited all of the construction

sites. Construction at El Obeid is about 90% complete. Most of the material is on hand to permit completion of the headquarters. Although the contractor and GOS now predict an April 1986 completion date, past experience of the review team suggested that September 1986 would be a more realistic prediction.

Efforts at El Fasher and Ghazala Gawazat are close to an 85% completion level. Materials are at hand at Ghazala Gawazat for completion of both sites. The expected completion date is September 1986. This also seems optimistic considering past performance of the contractor.

The team was impressed with the functional utility in the design of the research facilities at all locations. Construction quality was considered by the review team to be adequate at all locations.

The contractor's procurement and transportation of construction materials seem to have been the major constraints to timely completion of the contract. Considering the magnitude of the construction program and the logistical problems associated with transport to remote locations, the original completion date was totally unrealistic. It would have seemed logical if the first five years of the project had been restricted to construction and personnel training with only diagnostic research activities undertaken to identify constraints and provide a basis for establishing research priorities.

B. The Training Component

Advanced Degree Training. The plan for training to improve research capability by sending staff to earn graduate degrees in U.S. institutions was modest in scope. The Project Paper of July 26, 1978, called for training of 11 staff members (6 to Ph.D. degrees and 5 to M.Sc. degrees). Actually, 6 Ph.D. and 8 M.Sc. degrees will have been awarded to ARC-WSARP staff at the end of the current training program in 1986. Two of the scientists received both M.Sc. and Ph.D. degree training. The evaluation committee considered it counter productive for a trainee to have the privilege to earn more than one advanced degree within the time-frame of the Project.

The concept of having the research for thesis and dissertation preparation planned and conducted in Sudan is to be commended. It is somewhat more expensive because of the extra transport involved for the student and his major professor. It can be justified in terms of allowing the student to receive his research training under conditions in which he will develop his future research activity. Likewise, the U.S. university experiences growth in international understanding, in that more of its staff are introduced to the constraints under which research must be accomplished in the developing world.

Needs for training four more staff members to the Ph.D. level and three more to the M.Sc. level have been identified by the Director of WSARP. The review team considers this to be a realistic training objective. There are always some back-door losses of personnel from government agencies to more attractively salaried positions in private industry and other countries. It is improbable that added training would correct this.

Students were trained at five different universities. Seven of the 14 degrees were awarded by WSU. As is often the case, low TOEFL scores and an inadequate proficiency in the English language were handicaps to admission at many alternative universities. WSU was able to provide provisional admittance status until language competence was achieved or other academic deficiencies were corrected.

Early selection of students by the Government of Sudan would have expedited the training process. Careful screening of candidates should be accomplished before they depart for training. Two of the students' programs were delayed because of academic inadequacies and one trainee was terminated because of lack of motivation. Perhaps a training program to acquaint the student with the American system as opposed to the European system of advanced education would be helpful.

Non-degree Training. Goals for non-degree training were established for 17 staff members to be trained out of country. Records indicate that 20 persons spent a total of 50 man-months in external non-degree training. Internal training activities were satisfactory.

There are many special training courses that should be considered. These are offered on a continuing education basis at the international research centers, at land-grant universities and by USDA/OICD.

For the remaining period, it is suggested that WSARP should take advantage of every opportunity to provide additional training for selected mid-level staff as well as for scientific staff. The following list of short courses, although incomplete, is suggestive of type of training which would be of benefit to the WSARP staff:

.Database systems for agricultural research stations

.The use of statistics in agricultural research

.Integrated pest control, for various cropping systems

.Soil conservation techniques in cropping systems

.Minimum tillage practices for erosion control and labor utilization

.Organizing and implementing farmer diagnostic surveys

.Sorghum and millet production systems and intercropping techniques

.Vegetable production systems and drip irrigation

.Planning and managing agricultural experiment stations

.Techniques and procedures in farmer managed research trials

.USDA/APHIS research on control of Striga hermonthica

.Improvement of small farmer harvesting and storage

.The use of leguminous trees as nitrogen source and conservation

.The use of animal traction and small farm implements

.Broadbed and furrow systems for soil and water conservation

.Range rehabilitation

.Techniques in water harvesting and conservation

The USAID training office should have access to more complete listings. It is suggested that project personnel interact with USAID training officers to identify some of the needs for non-degree specialized training. WSARP should then nominate appropriate participants and seek training opportunities.

Use of IBM Portable Computers and Programs. Quarterly and annual reports from the WSU team indicate that it had provided training to the research staff at Kadugli Research Station in the use of microcomputers and programs. It is understood that a consultant to do this training of personnel was refused because of limitations imposed by the State Department for security reasons.

The socioeconomist at Kadugli has indicated that the staff is unfamiliar with the use of the recently acquired IBM portable computers and the Wordstar, MStat, and Lotus programs. There are simpler and more user-friendly programs which could substitute for the MStat and Lotus programs. A combination of DBase II and ABSTAT would satisfy this requirement. All research results might be permanently recorded on DBase II for all the stations in the Project. A two-week "hands on" training program with the scientists at each research station would be sufficient to train them in the use of the system. At least a two-month consultancy might be arranged for the dual purpose of establishing each research station's database system and conducting training for the scientists.

C. Research Support Activities

Linkages. The Senior Advisor made very commendable progress for

integrating activities of international agricultural research centers (IARC), into the program of ARC and WSARP. The type of relationship developed with CIMMYT, ILCA, ICARDA, IDRC, INTSORMIL, AND ISNAR needs very much to be continued. The WSARP Director indicates that this is being done but with less effectiveness than when the Senior Advisor concentrated on this issue. The above organizations are sources of short-term training, technical assistance, and even grant assistance to both ARC and the WSARP. They have been, and will continue to be, of great potential assistance to WSARP. Intensity in continuing linkages with them will continue to be limited until a Sudanese Deputy Director is nominated for WSARP. This person should have full responsibility for staff training and outreach activities of WSARP.

The integration of WSARP into ARC remains a critical issue of concern to USAID personnel. The evaluation team concluded that the integration of the two agencies was as complete as it could possibly be, given the organizational structure developed for the assistance project. The two institutions will never be completely integrated, nor will parallelism be eliminated as long as WSARP remains a semi-autonomous unit of ARC.

Budgeting processes, research planning, and Project review and evaluation are integrated activities for the two organizations. Yet, to procure staff for WSARP it is necessary for scientists to be seconded from ARC. The use of this term implies moving of personnel from one organization to another organization that is outside the administrative jurisdiction of the first. It would seem that the extent of integration will only be discernable when the Project is completed and donor support for recurrent budgets had ceased.

ARC presently holds responsibility for publication of reports and their distribution. This aspect of the Project, together with development of library facilities, has been neglected. It is appropriate to state at this point that support in this critical phase of the Project was planned by WSU but was not authorized by Project Management and USAID until final stages of the Project. This authorization was negated by State Department travel advisories late in the Project which prevented consultant visits to Sudan. Many purchases of books and periodicals were completed by WSU. These documents are on hand awaiting completion of the library at El Obeid. A librarian has been trained to process and catalog library acquisitions as well as other aspects of library management. It is recommended that short-term technical assistance be provided to assist the WSARP librarian develop a functional library at El Obeid. This technical assistant would also be helpful in improving the documentation and agricultural information services at ARC headquarters in Wad Medani.

A proposal for improving management of agricultural information in Sudan was prepared by Dr. Riley in 1982. A grant for improving information services was provided to ARC by IDRC. The status of this development is unknown except for a printing press that was non-functional at the time the evaluation team visited ARC headquarters. The team assessment is

that there is need for the development of a research/ outreach support system unit at ARC headquarters. This unit should have a circulation network connecting it to all stations. It would have responsibility for (1) editing, printing, and distributing periodic research journals, (2) printing and distributing research reports, (3) preparing and distributing pamphlets and brochures for technology packages used for extension activities, (4) maintaining the national agricultural library and developing a retrieval and distribution system for all agricultural research stations.

It would seem appropriate for WSARP and ARC, with some leadership and support from USAID, to explore either continuation of or expansion of the input of IDRC in development of such a system. IDRC does not have a representative in Sudan. The closest office is in Cairo. The contact at that location is Gordon Potts.

THE RESEARCH PROGRAM

A. Overview.

The orientation of the research program of WSARP is directed toward agricultural production systems that are prevalent in Western Sudan. The approach taken is a modification of farming systems research and is termed "production systems research" to reflect its encompassment of pastoral as well as farming activities. The approach is rational in that traditional rainfed agricultural production systems in Western Sudan contain cropping systems integrated with livestock production. The systems can be sedentary, transhumant, or nomadic. The families or tribes engaged in the latter two systems are not limited to a farm or a single geographic location. Sedentary farmers in the region raise agricultural crops as well as maintain some animals.

B. Research Planning.

1. Planning strategy of the project focused on getting an early start with research activities. This included the defining of research needs and approaches, defining the research role that each of four outstations were to perform, as well as determining the needed infrastructure. The four stations were as follows:

   a. El Obeid. Nyala was originally planned to be the ARC headquarters for Western Sudan. It was later determined that El Obeid would be a more effective site, due to the existing communication links with the capital city of Khartoum. This decision necessitated the construction of a complete research and administration facility having the central analytic laboratories, main computer facilities, and containing the central library and regional information services. Its research thrust would be in millet improvement and millet-based cropping systems, market

analysis, water conservation, horticulture, environmental preservation, and agro-forestry. It would also maintain a collaborative program to link with the regional Ministry of Agriculture extension services.

b. Kadugli. Although facilities were already in place for this station, renovation and construction of additional facilities were necessary. Kadugli Station was to conduct integrated research on crops and livestock; sorghum based cropping systems and sorghum varietal improvement, range and forage improvement and preservation, and to conduct investigations into burning and bush control.

c. El Fasher: A new station was built here to conduct research on range and forestry interventions, improvement of production practices associated with camels, sheep, and goats. There were plans to strengthen the regional veterinary services of the Darfur region Ministry of Agriculture.

d. Ghazala Ghawazat: This was an outstation for the Livestock Department of the Ministry of Agriculture. While a few facilities were available, they were extremely limited and in poor condition. New facilities had to be constructed. It was to focus its activities into the improvement of genetic qualities of livestock, conduct studies on rangelands, animal nutrition and husbandry practices. It was also to determine the role of acacia trees in agro-pastoral production systems.

C. The Research Approach

The WSARP staff, after discussions with various consultants, agreed that an integrated production systems approach was most valid. The systems were described and constraints to increasing production in the various systems were defined. It was evident, however, that this diagnostic stage of the research program would take a considerable amount of time to develop. Consequently, some research on obvious constraints was initiated early.

To implement this phase, surveys were made in the three types of systems. The various disciplines (agronomy, soils, animal production, anthropology/sociology, and economics) were evidently included in the field teams either full or part-time, although this is not clear in the WSARP Publication 15, Work Plan, Vol. III. WSARP staff were in continual contact with farmers and pastoralists surveying and assessing their needs and constraints, testing promising ideas or germplasm in their fields or pastures, developing new technology suitable to their limited resources, and conveying methods judged improved by the producers themselves to extension personnel for widespread application. After having reviewed the research reports (WSARP Publication Series)

and discussing the research program with WSARP, USAID, and World Bank personnel, there is agreement within the evaluation team that the approach has been correct and WSARP should be commended. However. two phases of the approach appear to have received less in-depth investigation than would have been desired.

1. Survey and assessment of farmer and pastoralist needs and constraints These appear to have lacked a sufficient economic and social appraisal of the needs and constraints relative to each other as well as to regional and national needs and constraints.

   Admittedly, these relative socioeconomic values of problems and constraints are difficult and tedious to obtain but are of absolute necessity in knowing whether one is embarking on research on the constraints which (1) have a relatively good chance of a solution, (2) will be socially and economically acceptable to the farmer, and (3) are high on a priority list to the farmer, region or nation. Without this evaluation scarce resources could be spent on research and non-important, unsolvable problems. In addition, during this evaluation some solutions came to light which required little research. Perhaps this type of evaluation was carried out in the systems surveys and studies by the economist and social/anthropologist, but if so, they are not explained in detail in the reports.

   This step is of extreme importance in systems methodology. It is explained in general terms in the Work Plan Volume III, WSARP Publication No. 15 pp 9-10, but in reviewing the reports of research results, one does not find such a socioeconomic appraisal.

2. Conveying methods judged improved by the producers themselves to extension personnel for widespread application. It is not clear in the WSARP reports what role farmers and extension personnel played in the surveys, in the planning of research, or the steps used leading up to the "widespread application." It is stated in the Work Plan that, "It is this dynamic interaction with producers and their environment that differentiates production systems research from the more traditional approaches." Little is reported on this interaction; however, it may be too early in the project for the real interaction to take place. It is doubtful whether the present extension activities are strong enough to be of such benefit in systems research, but it may be the opportunity to strengthen extension. The three-way exchange among research, extension, and the farmer is the end result of good research. Systems research is not complete until innovations have been accepted and practiced in the field.

Some reviews and evaluations of WSARP and some of the WSARP publications give the impression that there is not a good understanding of the total production systems research approach. There is an impression that one

does commodity research, systems research, or disciplinary research. Systems research is only a vehicle to look at more than one discipline or one commodity at a time and to put these commodities in their proper perspectives in the defined system. Systems research encompasses both disciplinary and commodity research and is not complete, or at least it is less than optimal, if it does not utilize the knowledge gained in more detached or "breakdown" (disciplinary and commodity) research. A total systems approach must depend on the knowledge gained from investigating the "parts" of the system.

The phrase "systems research", regardless of in what context it is used, Farming Systems, Livestock Production Systems, Irrigated Systems, Dryland Agricultural Systems, etc, it is only an invention of words to express the thought that there are several, many, or a few, factors or forces having an influence on a given object of production all at the same time or over a span of time in a production cycle. These forces often times do not exert themselves independently of one another, but rather interact so as to change the magnitude of their independent influence. Systems research is only a tool to look at these forces in combination with one another and to determine which are most important in the total system and which ones can be beneficially changed so as to increase the end-product of the total system which is usually some measure of production or income.

In Western Sudan, it appears that a production systems research approach has a great deal of merit since constraints are not well defined and potential solutions need testing at the farmer level. Sudan does not have adequate research resources to conduct "trial and error" research without a good overall plan of research. The risk associated with the exclusive use of disciplinary or commodity research is that it can, but obviously does not always, lead to research with little practicality to the farmer. Systems research can provide the vehicle for a good organization plan but can also be overdone, and one risk is that the systems methodology may become more important to "systems researchers" than the end product.

D. Socioeconomic Research

There were a number of reports prepared by WSARP which gave results of the socioeconomic research which was conducted. But, as stated previously, they lacked sufficient economic and social appraisal of needs and constraints relative to each other, which would have served to better target the research work which was initiated in the Project. However, the overall output of the reports was commendable and gives a good understanding of the production systems which exist in the project area. While there was an attempt to provide critical data needed, the researchers cited certain difficulties. Among these were: (1) the basic units of production were not individual households (Nuba), (2) producers were evasive in giving information concerning their production and sales, (3) rate of illiteracy was high (90 to 98 per cent) and quantitative data was extremely difficult to obtain, and (4) the

necessary support staffing to conduct the essential surveys was inadequate.

Another constraint was the turnover of sociologists assigned to the project by the contractor. The first sociologist came on a one-year contract. The second arrived in time to assist with planning the research program, but apparently had difficulty keeping his activities directed at project objectives. The review committee was told that because of personality conflicts, he was returned to the Pullman campus prematurely to complete his research reports. There was no further appointment to the sociologist position. Ms. B. Michael served two years as a research associate sociologist. Although her reports were not available to the evaluating committee, it was understood that her research was most useful and well conducted.

The first agricultural economist conducted a diagnostic survey which was summarized into both a report giving major constraints, and another which furnished more detailed economic data. The second economist was heavily involved in working with the technical researchers in the economic evaluation of station and on-farm trials, as well as conducting a study on farm gate and market prices. There was a considerable use of committee meetings with the WSARP staff to draw up research priorities.

The source of data was frequently secondary information, as well as drawing upon the previous professional experience and training of the researchers themselves. A summary of the research conducted is as follows:

1. Systems of Agricultural Production Among the Nuba (WSARP Publication No. 11) was completed in September 1981. The report describes the organization for production among this tribe and gives insights into ways by which researchers can work effectively in on-farm research. It is interesting to note that working with individual farmers would be ineffective due to jealousy and suspicion of their neighbors. The men are reluctant to share information concerning their crop yields and worry about neighbors using witchcraft to spoil their crops. It was also found in this study that women must be recruited to conduct on-farm research for the Project. The social unit that affects production is the work party (men or women) called the nafir which cooperates to carry out tasks of agricultural labor. The nafir operates as a cooperative among households.

2. A study of 15 villages was done in Southern Kordofan in 1983. It was intended to (1) define the sedentary system, (2) develop necessary production data relevant to sedentary agriculture, and (3) verify constraints to agricultural production. A summary of the production constraints was included in a report prepared by the agricultural economist. It contained useful information as to the degree of magnitude that the farmers attached to many of the constraints that ended up as research priorities. A later

study appears to have been incomplete, as it did not provide quantification and summary of production data for individual farms and households.

3. A sociological study conducted in 1983 was concerned with the problems encountered with the establishment and maintenance of on-farm research trials. This study had particular relevance as it pointed out the necessity of a careful selection of farmers (so as to secure good cooperation) and the necessity of a clear understanding of the resources to be provided by both the researcher and the farmer. There also needed to be continual contact with the farmer and plot monitoring on a day-to-day basis.

4. Social science studies were summarized in WSARP Publication No. 25, August 1984, and provided information concerning the transhumant production systems, identification of recommendation domains, and the selection of farmers for WSARP on-farm trials. It cited 210 references in the bibliography which were collated for WSARP by the sociologists in the project. While there was no economic data presented to support the recommendations, it proposed a major strategy of more frequent cropping of land and use of crop rotation. Higher yields would reduce land requirement and decrease the unit area under production. It also proposed a "production package" of improved sorghum varieties and a package of practices relying on a minimum of imported materials. Once yields were increased, farmers would be more prepared to adopt other techniques including rotation and the use of leguminous crops for food or forage.

5. Research program results from the Kadugli Research Station in September 1985 gave indications of a major input by agricultural economists. While no source of information was provided for the economic interpretations which were made, there were inputs as to: (1) net benefits from the mulching of sorghum, (2) use of phosphate on local and improved varieties, (3) potential labor savings associated with adoption of ox-cart transportation, (4) household labor allocation for crop production on household gardens as opposed to distant fields, and (5) seasonal price changes for sorghum and sesame at the Kadugli market. According to the Sudanese sociologist now present at the Kadugli station, 1985 was a "good year" as it reflected a team approach to research by the technical and socioeconomic staff working on the project.

6. A particularly valuable study done in the Project area is entitled, "Socioeconomic Constraints to the Production, Distribution and Consumption of Sorghum, Millet and Cash Crops in North Kordofan." While it was done by INTSORMIL rather than CID/WSU, WSARP provided the logistical support. In its survey of 40 farm households, the study provided a wealth of economic

information concerning yields of crops, rates of return by individual crops, labor expenditures and distribution, seeding rates, market prices, types of intercrop systems, time of cropping activities, chemical inputs, economic losses to predators, and the economic potentials of research to be conducted with small holders.

E. Range and Livestock Research

Considering the time involved, the output of range and livestock research has been commendable. A general criticism is that it is not evident whether there was a thorough socioeconomic evaluation of the constraints to be considered in the range and livestock research program. At the time the research was initiated the constraints to be investigated were apparently evident to the researchers, but whether these constraints were of the highest priority is not clear.

Evaluation of range condition and establishment and classification of rangeland communities. This aspect of range research can be considered part of the diagnostic phase of systems research. Although it is obvious to even the untrained eye that overgrazing and denuding of the ranges have occurred, it is important to establish both a quality and quantity appraisal of the existing range conditions. A preliminary classification of central South Kordofan based on botanical compositions, physiognomy, topographic characteristics, and climate was begun early in the project. In general, vegetation communities are heterogeneous and complex, but strongly associated with land-form and soil type.

Most rangelands in South Kordofan are in only fair condition due to a dominance in the herb layer of tall, coarse, fast-maturing annuals of low-nutritional value. This is largely the result of inadequate grazing pressures during the growing season and the high incidence of burning during the early dry season. In terms of grazing, the existing livestock biomass in this area only consumed about 6 - 10% of the net primary production average for wet and dry years. This inefficient utilization of forage resources was due to the poor spatial and temporal distribution of livestock which was partly related to traditional out-migration of livestock during the rainy season by unfavorable disease, pest, and environmental (mud) conditions.

Woody vegetation on most rangelands is declining in abundance and diversity in response to existing pressures from selective browsing, frequent burning, and a rising demand for farming land and wood.

Fires consume annually an estimated 25 - 30% of the net primary production. Prevention of these fires would supply a 43% increase in livestock biomass which would have no adverse impact on the range during

the dry season. During this season, approximately 30% of the rangelands are under-utilized by livestock due to a total deficiency of water.

Monitoring Studies with Sentinel Herds. Sentinel herds (researchers observing selected traditional herds) have been established. These studies have shown that cattle can be maintained on a year-round basis on southern rangelands at levels of productivity equal to or greater than that found under migratory practices, provided that (1) animals are given one year to adapt to the climate, (2) year-round sources of water and natural forage are available, and (3) the strategic control of ectoparasites is practiced.

Nutritional Studies. In-herd studies of the seasonal nutrition status of transhumant cattle and sheep have shown that for cattle: (1) adult animals are in a negative energy/nitrogen balance and 95% of the lactating animals are clinically deficient in phosphorous during the dry season; (2) adult animals are in a positive energy/nitrogen balance during the rainy season, while the majority of lactating animals are clinically deficient in phosphorous.

In the case of sheep, results have shown that: (1) energy and phosphorous appear to be the most limiting nutrients for pregnant ewes during the rainy season; (2) energy, crude protein, and phosphorous were limiting for lactating ewes during the mid dry season; and (3) energy was apparently the most limiting nutrient for adult ewes during the late dry season.

Having identified the above constraints, dry season supplementation (sesame cake at maintenance levels) was practiced in researcher-managed herds of cattle. Feeding trials with adult female transhumant cattle showed that: (1) supplemented cattle gained significantly more weight, produced significantly more milk, the calves had higher birth weights, and maintained significantly higher blood plasma phosphorous levels than did unsupplemented cows; (2) during the subsequent rainy season, previously unsupplemented cows gained more weight than the previously supplemented cows and there was no difference in milk production between groups; (3) lactating cows showed the lowest phosphorous levels in the rainy season; and (4) the marginal benefit/cost ratio for the dry season supplementation of lactating cows was -0.18%, due to the high purchase and transport costs of sesame cake.

Researcher-managed, in-flock supplementation (sesame cake at 1/2 of the maintenance levels plus a phosphorous supplement) of breeding ewes during the dry season, showed that the level of supplementation was not sufficient to demonstrate any signficant improvement in productivity for treated groups. This, apparently, was primarily because of very poor grazing in the study areas as a result of the 1984 drought. Sixteen per cent of all lambs less than three months old died of respiratory infections and the ewe losses ranged from 12-20%, being highest in the unsupplemented, control animals.

Livestock Marketing Studies. Livestock marketing studies indicated that the producer strategy was quite complex, depending on rainfall patterns, commodity prices, demand for liquidity, and scale of anticipated purchases. The rapid increase in the price of sorghum, resulting in a price ratio of male cattle/sack-sorghum of 1:1 by May 1985, made the usual practice of selling small ruminants for most staple food purchases impossible to follow during the 1985 dry season.

Introduction of Draft Power and Improvement of Nutrition. Economic analyses of animal draft trials demonstrated benefit/cost ratios ranging from 1.15 to 3.45 over a five-year period when only rental benefits were considered, and 4.92 to 11.24 over a similar period with the addition of welfare benefits. Supplemental feeding trials have shown that quite high levels of good quality forage are required to make a significant impact on production, and such forage is scarce and expensive in the area. The conservation of native grass as hay is presently not feasible because of the poor quality product resulting from problems in harvesting, curing, and storage.

Evaluation of WSARP Research in Range and Livestock Subsector. Two shortcomings in the research to-date of the WSARP research in range and livestock have already been identified: (1) lack of adequate socio-economic analysis of constraints to increasing production; and (2) inadequate organization implementation of researcher-extension farmer/producer contacts incorporating extension/farmer contacts into research planning. These are mentioned again to emphasize their importance in production systems research.

Regarding the first of these two shortcomings, "paper and pencil-pushing research" would have probably revealed that phosphorous and sesame cake supplementation would not have been economic to the transhumant producers because of the cost of transport of the cake and unavailability of phosphorous supplements. The data that the study revealed during the subsequent rainy season were interesting, but these data only confirmed information already in the literature from trials in Texas, Arizona, New Mexico, and Botswana. Whether the research was important enough to repeat in Sudan is questionable. "Paper research" at the beginning may have (but not necessarily) revealed the same answer. This is an easy criticism to make, but the researchers should have written a better justification for the experiment which included a preliminary economic analysis.

The evaluation of range condition and classification of rangeland communities is an absolute necessity in range-livestock production systems research, and WSARP is to be congratulated for the detail with which this was conducted. The establishment of a herbarium was also an important contribution, not only for the present but for future research. There is a question, however, as to whether there are plans to continue periodic range surveys in the same areas to be able to

determine range trends. Although this is not clear in the WSARP reports, we recommend that this be a continuing feature of WSARP research plans.

"Sentinel" herds and flocks are a vital part of the production systems research approach. The information gathered is important and continues to point out problems and constraints, as well as success or failure of interventions into the system. Again, it is not clear from the WSARP reports as to whether it is intended to keep collecting data on a yearly basis from these herds and flocks. These herds, and this approach, should be a permanent aspect of the livestock research.

Like the range condition and "sentinel" herd studies, the livestock marketing studies should be a continuing source of valuable data and information. WSARP economic studies should include repeated visits to the same markets to establish trends. There can also be "spot" studies to determine particular local parameters.

The draft power study appears to have had some weaknesses: (1) number of hours the animals worked per day, (2) type and quantity of rations fed during working period and during "off" period, (3) the actual working of draft animals for crop cultivation and collecting related economic data, (4) variations in the types of equipment used and development of alternate types of equipment and, (5) inclusion of opportunity costs of manual labor involved in use of draft animals. It is understood that the work was done in cooperation with another organization, but a more complete explanation of the study would have been useful.

Initial contacts with ILCA have been made. Dr. John Trail has visited the Project as a consultant. Attempts should be made to secure continuing inputs from ILCA into the efforts of animal scientists working within WSARP. This international organization could be of great value in overcoming misunderstandings and inertia in the livestock research programs that have resulted from the division of responsibility for its accomplishment among different sections of the ministry.

It is equally necessary to include continuing contact with ILRAD as the project activity. Since barriers to land tenure preclude effective use of growing management technologies, the major research input into range livestock will center about nutrition and health parameters associated with livestock production in mixed farming operations.

G. Crop and Soils Research

The scope and size of crop and soils research at the Kadugli Research Station had greatly changed with the advent of the WSU research staff input. The crop research component tended to concentrate on the introduction and performance of new varieties of sorghum, legumes,

groundnuts, sesame, and millets. The varietal testing of cotton was excluded from the crop testing program because a cotton improvement program already existed.

The genetic materials in these tests were limited to varieties supplied by either ARC in Wad Medani or from the International Agricultural Research Centers (IARCs). These tests were not planned with environmental factors or local farmer preferences as specific criteria, but varieties were probably selected on the basis of seed availability .

The introduced varieties, in general, performed remarkably well in comparison to the local varieties. This appears to be either good luck or that the local selections had a low yield potential. Yield increases of 40 to 100% over the local checks were obtained with crops as varied as legumes, cereals, and oil seeds.

Recently, the breadth of genetic variation in locally produced seed was demonstrated with a collection of over 100 different sorghum varieties from farmers' fields in the vicinity of Kadugli. It is expected that the diverse populations of crops other than sorghum might be equally rich in genetic diversity. An effort to collect and sustain the traditional varieties would be worthwhile because of their inherent features of insect and disease resistance, their drought resistance, and their grain quality which could be incorporated into future breeding programs.

Scientists of ARC must increase their emphasis on development of varieties for the rainfed agricultural sector. This work must be accomplished at Abu Naama with varietal testing at the WSARP locations, as well as at field testing locations of the Mechanized Farming Corporation.

The quick "fix" obtained with the introduction of exotic varieties seldom persists and there is often a breakdown in the performance of introduced varieties selected solely because of yield. Consequently, crop improvement programs should not rely solely on plant introductions, but should concentrate on incorporating the desirable features into locally adapted cultivars. This means ultimately a breeding and extensive selection program which was not introduced to the Kadugli Research Station. This does not mean that performance testing of exotic introductions is wrong. It is a first step in identification of genetic factors associated with yield components and disease and insect resistance or tolerance. The Sudan has already had a report of a complete lack of striga tolerance in the Hageen Dura hybrid. This may make its further diffusion more difficult or even questionable. In any event, it will restrict areas in which Hageen Dura I has an advantage.

There should be expanded effort to utilize technical assistance and research capabilities of INTSORMIL and ICRISAT to accomplish the basic

research needed for support of the applied research effort of WSARP scientists.

The introduction of crop varieties is an ill-advised concept if the expectations are that a simple introduction of exotic seed will consistently result in major increases in production. Granted, there are well publicized results where an introduction has produced a quantum advance in regional or national production; but every plant breeder will support the conclusion that such successes are rare, and more frequently success is the result of multitudes of crosses and many years of field selection. As such, the plant introductions might be impressive in one or two years' trials, but environmental conditions will more frequently result in a breakdown in yields of the exotic variety.

Research on soils was basic enough to measure the distribution of soil moisture throughout the dry season as a function of depth. Soils research was also sufficiently simple and adaptive to measure yield response to fertilizers. Soil moisture studies were a first step in understanding both soil moisture storage and replenishment in the soil profile.

The use of the neutron probe was a major introduction of a new technology that will permit rapid recording of soil moisture changes in different soils, for different crop rotations, and for a variety of mulches used in soil moisture conservation research. Soils researchers should recognize this technique as a valuable tool to repeatedly measure soil moisture under a wide variety of conditions. However, the measurement in itself is not research. There needs to be a scientific application of the collected data and a program for extending these applications as farmer practices. Such research, by nature, is time consuming and repetitive. Conclusive results will take four to seven years.

The research on fertilizers is more simple and uses yield response as the phytometer. Rates, ratios, and times and methods of application are the variables. The danger is in extrapolating the results over too wide an area. Fertilizer recommendations tend to be site specific and need to be replicated and confirmed over many locations. Fortunately, the Western Sudan reportedly has vast areas of relatively uniform soils. Consequently, once a set of fertilizer recommendations is developed, it should suffice for rather extensive areas on these broad plains where soils have developed in place. Another advantage for the researcher but disadvantage for the farmer is that the inherent fertility status of these soils is so low that the addition of most plant nutrients will create some response.

The one exception to this rule is that applications of nitrogen might stimulate the growth of plants excessively and exhaust the existing soil moisture before flowering and seed set. In the higher and more uniform rainfall belts (600 mm) this might not be necessarily true; but in

those conditions where rainfall ceases early or is less than 450 mm, the heavy applications of nitrogen might be expected to reduce yield.

The agronomy research is perhaps the most rapid in producing results suitable for extending to the farmer. The problems of seed placement, seed rates, seed depth, plant populations, and weed control are relatively straightforward, and after three or four years of trials there should be a suitable package of practices ready for extension. Crop production cannot be divorced from either soils or plant breeding. Changes in varieties, fertilizer, and available soil moisture will, of course, require constant changes in the approved and recommended package of agronomic practices for any specific crop.

All in all, the WSU team did an excellent job in the introduction of crop and soils research technology to their Sudanese counterparts. Time was not sufficient to establish a complete cycle of long-term research. The agronomists, because of their simpler mandate, were perhaps the most effective in obtaining results. The soil scientist had a more difficult chore and attacked it at two levels, namely, soil moisture and fertility. It is hoped that Sudanese counterparts collecting soil profile moisture data were trained in how to use the collected data in the improvement of crop production under limited soil moisture conditions. The collection of vast amounts of data is not to be the end result of good research. Such data is needed to develop practical applications.

FACTORS AFFECTING PROJECT ACHIEVEMENT

Project Management

It appears to the Project evaluators that the stated purpose of the Project has been only partially fulfilled. Not only have there been constraints in implementation of research activities as a result of construction and training delays, the Project has deviated somewhat from its original intent. There have been changes in implementation activities. Although not well documented, it is assumed that these changes occurred as an outgrowth of strategy planning at the coordinating committee level. Change often occurs when reality and idealism come face to face. Examples of change include the decision not to move either the ARC headquarters or the ARC administration headquarters to Khartoum.

The decision was made not to organize a Planning and Evaluation Unit (PEU). This was paralleled by changes in the terms of reference for the Senior Advisor position. It is unfortunate that the Senior Advisor to the Director General of ARC was never able to function under the original terms of reference for his position. The evaluation team was not certain why this failed to happen. Apparently, the Director General of ARC did not desire the services of an advisor or did not know how to best utilize the services of an advisor.

It was an error not to post the Senior Advisor at ARC headquarters. Advising requires daily contact. Also, an effective advisor is a "behind the scenes" person. His only function is to make things happen through his influence on the person he is advising. It appeared that the Senior Advisor became too administratively involved and took independent action rather than taking the necessary indirect route. This may have been accentuated by the fact that there were two Director Generals of ARC with the period of time covering the Senior Advisors tenure in Sudan.

The input of the Senior Advisor shifted subsequently to the WSARP. Although lines of authority of WSU project administration were less than clear, his effort had a very positive effect on the achievement of goals by the WSU-WSARP staff.

It should be noted that there also has been a variation in the continuity and intensity of supervision of the WSARP by both USAID and WSU. USAID apparently became aware of this inadequacy and the input of their supervision subsequently intensified. Sometimes without adequate communication or documentation, a change in position will create misunderstanding and uncertainty. Regardless of how justified administrative decisions may have been, they resulted in considerable decline in morale for both contractor employees and WSARP staff.

Contributing to this problem is the fact that there have been three USAID Mission Directors, four USAID Project Officers, four WSU Chiefs of Party, two Project Directors, and three Director Generals of ARC.

The early termination of selected technical assistance personnel, the failures to extend the contract with CID/WSU, and the decision by USAID/Khartoum to withdraw support for the Darfur region all appear to have contributed to uncertainty on the part of the contractor and to misunderstanding and, therefore, justifiable concern by the host country. The USAID withdrawal from Ghazala Gawazat and El Fasher appears to have been a unilateral decision for a program which was intended to function through a coordinating committee that was comprised of donors and host country personnel.

The evaluation team observed that none of the previous evaluations or reviews recommended such an approach to future project management. The team has been told that the decision was made as an attempt to close audit recommendations relative to recurrent cost problems. This is somewhat unusual since the Project agreement does not call for GOS to assume recurrent costs before Project completion date. In any event, the Project momentum has been seriously interrupted. It will be difficult for the proposed technical assistants, who are to be provided by USAID through personal service contracts, to restore that momentum and provide the focus needed for effective future research activities. This is particularly true in terms of providing guidance to the embryonic researchers returning to the project with graduate training and degrees but limited experience in planning and implementing research programs.

Sudanese Inputs to WSARP Management have negated attempts to reorganize ARC and move the headquarters to Khartoum. Although there is substance to the arguments supporting such a move, the reality of the situation is that, unless housing or subsidies are provided, the administrative unit of ARC cannot and will not move to Khartoum. Actually, it may be prudent to not disturb the unit through such reorganization, but to use the scarce financial resources for increased support of ongoing programs.

WSARP administrators were responsive to management inputs from WSU. This is evidenced by the research planning and reporting activities of WSARP following the departure of the WSU team. There seems to be some delay by the Project Director in responding to the needs expressed by directors of field stations and by field personnel for equipment, support services, training opportunities, and other project inputs to planned research.

The lack of understanding by the Ministry of Agriculture and Natural Resources for the urgent need of adequate research inputs is reflected in the fact that, although staff salaries for ARC have increased, there has been no increase for Chapter Two (Operational Budgets) since the beginning of the Project. The end result of this is that about 88% of the available budget is restricted to salary and only 12% is available for research operation support. This may also account for the fact that the most recent annual report available from ARC headquarters is for the 1977-1978 research year.

Researchers are often hampered by inadequate funds to implement, supervise, and complete their research. On the basis of present understanding of the evaluation team, it will be almost impossible for ARC to assume the required budget obligations for the staffing and operations of the WSARP after the Project is completed.

Research scientists must have support money to initiate, conduct, and publish research. They also must have opportunity for travel to professional meetings or to International Agricultural Research Centers. Provision must be made for professional growth and opportunity for creative research. Otherwise, staff losses to other countries will continue at a rate somewhat equivalent to the rate of training staff to advanced degrees.

Future project planning must involve some basis for assuring that GOS support for the recurrent operational costs of research will be increased stepwise on a regular basis each year so that, by the Project completion date, the GOS can continue Project initiated research activities without a loss of momentum.

WSU Staffing for WSARP involved 68 person-years for the Project. Of this amount, almost one quarter (16 years) were utilized at the home campus for administrative support of the resident field staff. The campus activities included identification and fielding of TDY and long-term field staff, administering participant training, commodity procurement and shipping, editing, and publication of reports.

Of the approximate 52 person-years of resident staff, 50% were involved in research activities. The remainder served either in an administrative or advisory role. This seemed to the evaluation committee to be an imbalance of administration relative to research input. The evaluation team considered this to be an imbalance of administrative input relative to the research emphasis. USAID obviously recognized this, because technical assistance cuts were made from the non-scientific staff late in the project period. There was some variation from intended staffing patterns (Table 1), but this apparently did not detract from project achievement.

TABLE 1

PLANNED AND ACTUAL STAFFING OF TECHNICAL ASSISTANCE SUPPORT TO WSARP

Planned Staffing			Actual Staffing	
Title	Location	Person Years	Location	Person Years
Senior Research Adviser to Director General	Khartoum	6	Kartoum	5.2
Planning and Evaluation	Khartoum	6	-	-
Project Engineer	Khartoum	6	Khartoum	5.2
Deputy Project Director	Nyala	6	Khartoum/Kadugli	6.0
Land Water Use Spec.	Khartoum	6	El Obeid	2.0
Agro Climatologist	Nyala	4	-	-
Sociologist	Nyala	5	Kadugli	3.0
F.M. Economist	Kadugli	5	Kadugli	3.0
Agr. Engineer	Kadugli	4	-	-
Lvstock/Crop Production Systems Spec.	Nyala	6	-	-
Range Scientist	-	-	Kadugli	4.7
Anim. Prod. Spec.	-	-	Kadugli	3.1
Agronomist	-	-	Kadugli	3.2
Vehicle Main. Eng.	-	-	Khartoum	2.9
Dep. Admin. Off.	-	-	Khartoum	3.6
Senior Secretary	-	-	Khartoum	1.7
Research Assoc.	-	-	Kadugli	1.9
Chief Admin. Off.	-	-	Khartoum	5.8
TOTAL		54		31.3

Due to complexity of the Project, there would have been much to gain from increased continuity in the Chief of Party position. Four persons were assigned this responsibility during the life of the WSU Contract. The Chief of Party was in an unenviable position of having little responsibility for decisions made but much responsibility for success or failure of the Project. In the opinion of the evaluators, WSU/CID extended too much administrative influence from Pullman, Washington. The Chief of Party should not have been given an administrative title and role of Deputy Director of WSARP. This made him directly responsible to the Project Director, when indeed he should have had the privilege of over-ruling decisions of the Project Director when such decisions interfered with fulfillment of established project objectives.

There was a conspicuous lack of continuity and timeliness in appointing the socioeconomic staff. This resulted in a disjointed effort in this discipline and contributed to inadequacies discussed in the research planning section of this report. The review team was told that this was because the Project Director refused to allow the sociologist position to be refilled.

The need for, or the role of, the Project Engineer was not clear. The person in this position was obviously over-qualified and over-paid for the work required. (Building fences and service roads do not require a Ph.D. engineer.) As a result of USAID's termination of this consultant, these responsibilities are now being fulfilled by a Sudanese engineer at a much lower cost to the Project without any sacrifice of engineering input.

Sudanese Staffing for WSARP. This has been a continuing problem. GOS has had some difficulty meeting staff requirements for the Sudanese component of WSARP. Staffing difficulties were exacerbated by the number of researchers who were nominated for training activities. This is another factor that enhances the argument for long-term support of research oriented projects.

1. The staffing at WSARP Headquarters is inadequate. No permanent Deputy Director has been appointed and staffing of the support unit is incomplete. A Deputy Director would be of importance to the Project in providing follow-through on staff training needs and opportunities. It would also permit increased activity in development of linkages with the International Agricultural Research Center.

2. Kadugli Station has always been understaffed. Several of the staff are still in training out of the country. There is a need for an additional Animal Production Specialist because the current specialist also serves as Station Director. Technical Assistance is being sought by USAID for three positions: Livestock Specialist, Agricultural Economist, and Agronomist. The lack of skilled English language secretarial assistance is obvious. This delays

communication and reporting. Improvement of scientist typing skills through added training in word processing on the personal computers is recommended.

3. At El Obeid there is a fine complement of young scientists. Delays in administrative staffing are to be expected until construction is complete. Technical assistance is being solicited by USAID for a soil and water management specialist. There is need for a biometrician to assist in planning research and analysis of data. A Farm Systems Research specialist is needed to organize the special Farm Systems research unit recommended for the headquarters.

4. Staffing at El Fasher and Ghazala Gawazat will be delayed until construction is completed. Four Sudanese scientists have been appointed and are presently resident at other WSARP stations. These positions will be complemented by the four technical assistants to be provided through added World Bank funding.

External Factors Affecting Project Achievement. Sometimes developments or happenings occur which are beyond the control of anyone associated with the Project. Ramifications of such events may have direct or long-term indirect influence on the goals of programs or projects underway. Such a decision appears to have been made by the Government of Sudan. A recent recommendation to the Council of Ministers to form a separate "Ministry of Animal Resources" creates a dilemma for WSARP and ARC. It is proposed to include all research activities in livestock production and animal health, as well as pasture and range management, wildlife, and fisheries. It is anticipated that the new ministry would ask for the responsibility of the Ghazala Gawazat and El Fasher Stations and the livestock related research at Kadugli and El Obeid.

It seems futile to create yet another organization to be responsible for research in Sudan. This adds to higher administrative costs and considerable parallelism in facilities and effort. Obviously, the new organization was proposed because those now responsible for agricultural research in Sudan were not putting any priority on livestock aspects of agricultural production.

If adequate liaison and cooperative effort is demonstrated by the two organizations, duplication of research activities and facilities can be minimized. Under these circumstances an extremely productive agricultural research program could develop.

To achieve the necessary cooperative effort will represent a challenge to the GOS, as well as to the community of international donors who fund agricultural research and extension activities.

Periodic Evaluations (according to the USAID P.P.). "Periodic evaluations will be undertaken by IDA during the construction of facilities, Phase I, in which AID will be invited to participate. The prime contractor for scientific personnel, CID, will be required to perform periodic evaluation and to report on the progress of activities being undertaken by or under the direct supervision of individual scientists and representatives of IDA, GOS, and AID, to review the detailed research program proposals for years four through six and to assess the timing of the transfer of research facilities, as outlined under the Six-Year Development Plan, to ARC. The evaluation of these plans must be approved by all of the participating donors. A second project evaluation would be performed in year six, as outlined above, when the results of the research efforts would be forthcoming and at which time the stage would have been set for the future orientation of agriculture research in the West."

The formal mid-term evaluation was conducted in year three of the Project as planned. A detailed report dated January 24, 1983, was prepared. The report included 24 recommendations. The report, and especially the recommendations, were reviewed by the Director of WSARP and the CID/WSU team. All of the recommendations were taken into account and acted upon with the exception of those outside the control of the Project. In general, the mid-term reviewers found the Project behind schedule in both construction and staffing, but felt that the research objectives were well founded and made no recommendations for changing of direction, or for omission of any of the four research stations.

In July 1984, a two-man USAID mission to the Sudan was requested to focus on "USAID's upcoming decision regarding the extension of the technical assistance position of the WSARP." They strongly recommended that: (1) the Project should be continued and that the technology base should be not left uncovered; (2) the Project team members are competent and motivated, that the contractor has done a good job of staffing the project with the expatriate personnel needed, and that changes would be undesirable; (3) a long-term commitment to the Project is the logical route for USAID to follow; and (4) that in regard to the question as to whether or not to support the stations at El Fasher and Ghazala Gawazat in a future extension, in their judgment, funds should be provided for research at all four western stations.

The reasons for the above recommendations are well documented. They further indicated that criticism has been directed at the construction program at El Obeid, but that the construction was now a "sunk" cost and that the construction was planned jointly by the World Bank, USAID, and the Government of Sudan. The intention was to attract Sudanese staff. "Commitments made and implemented in the past should be treated as constants and not variables."

The CID/WSU team has written an evaluation dated February 25, 1985, which points out many of their concerns over the future of the Project. They recommended continued expatriate technical assistance at all four stations and refer to change in direction on the part of the USAID Mission in Sudan which led to rumors and disgruntled staff members and a lowering of morale. In this regard, the WSARP Director has verified that lack of verbal support from the USAID mission has been disappointing and that the decision to drop the USAID commitment to Ghazala Gawazat and El Fasher is, essentially, a breach of promise.

An "issues paper" for the evaluation of the Project was written by Robert E. Evenson in September 1985. The report indicates that "the project appears to be quite disappointing at this stage ... in terms of the number of Sudanese scientists in place and in terms of the international staff. This disappointment is unrelated to the individual scientists involved, all of whom were working in a dedicated fashion." It further states that "Scientists have been given too many shifts in direction and support to get their work done effectively."

The USAID Project Paper calls for a final evaluation of the Project of which the present paper is the object. The final report of this team is intended as: "1) an evaluation of the research done under WSARP and the basis for any changes which may be recommended for the final two years of the project, and 2) the substance from which the Mission will prepare either an amendment to WSARP or a PID/PP, if required, for a new project."

CONSIDERATIONS FOR FUTURE ACTIVITIES OF USAID IN WEST SUDAN

RECOMMENDATION 1.

It is recommended that USAID continue its research support in West Sudan through October 1991 by strengthening of research projects concerned with:

a. Livestock and crop production systems at El Obeid and Kadugli, with supporting activities at Ghazala Gawazat.

b. Water and land use management programs at El Obeid with supporting activities at El Fasher.

c. Livestock production and range management programs at El Fasher and Ghazala Gawazat for nomadic and transhumant production systems.

Support for research into the nomadic and transhumant produciton systems at El Fasher and Ghazala Gawazat should be planned into activities of El Obeid and Kadugli.

Justification. The positive attitude of research staff and momentum of research activities developed in the initial phases of WSARP should not be lost, but rather should be supported and strengthened. The withdrawal of USAID support from Ghazala Gawazat and El Fasher leaves the research programs at those stations vulnerable to mis-direction and laxity. The World Bank has assumed some responsibility for supporting research activities at these stations. They have budgeted for technical assistance (four positions and external training), as well as a limited amount for recurrent operational expenses for the next five years.

The housing and laboratories at the Darfur locations will be ready for occupancy by September or October 1986. ARC/WSARP has indicated that the stations will be staffed as originally planned. Four of the staff have already been identified, others are to return from training.

A water and land use management research program is planned for the El Obeid research center. This program is to support the multidisciplinary research teams working on various commodities within the Project area. The support includes survey, monitoring, and classification of available land and water resources and their rational use in crop or livestock production.

A proposal prepared by the Soil Management Support Services (SMSS) of the AID in March 1986 is entitled, "Soil Resource Inventory, Land Evaluation and a Land use Database for the Democratic Republic of Sudan." The elements of this proposal would provide an excellent baseline for work of the water and land use research at El Obeid. See Annex 4 of the proposed amendment to the Project Paper for details of this proposal by SMSS.

With appropriate cooperation between USAID, ARC, WSARP, and the Soil Survey Administration (SSA), the objectives of both programs could be reached and the outputs of both enhanced. Ways to effect such a collaborative effort must be explored by GOS and USAID.

Livestock represents one of the major contributions to the agricultural export market for GOS. To sustain and to improve this important potential for foreign exchange will require research programs which emphasize animal production and range management. The fragile ecosystems of northern Kordofan and Darfur have been destroyed by inappropriate land use. In these areas of low precipitation, cropping with millet and sorghum have destroyed millions of feddans of grazing land. This has resulted in concentration of increasing animal populations on decreasing areas of range land. Desertification continues to move southward into the arable lands.

RECOMMENDATION 2.

Identification, training, and fielding of a Field Systems Research Unit at El Obeid to function throughout the various production systems of West Sudan. See Attachment 1 of this document for the basic components of this research unit.

Justification. One of the obvious successes of the WSU input into WSARP research has been the initiation of the Production Systems Research approach. Although there were some inadequacies in the planning stages of the research, the initiation of the philosophy and use of the approach has been commendable. Not only has this approach had a positive effect on the WSARP scientists, it has also had an impact on research planning and evaluation at ARC headquarters. Director General Gameel of ARC indicated that ARC scientists were now planning to complement station research activities with "on farm" research trials and eventually put successful interventions into farmer-managed tests.

The Field Systems Research Unit would provide a continuing source of information from all production systems for the research scientists. Though based at El Obeid, they would function throughout West Sudan. They would monitor specific systems and collect baseline data so that the effects of imposing an improved intervention could be economically and socially interpreted. The unit would also be the linkage between farmers and researchers in identifying constraints and establishing priorities for research to solve the problem.

RECOMMENDATION 3.

Field systems research units should be developed at each research station to test technology interventions for various production systems on the farmers' fields and to implement and monitor farmer managed tests of the improved technology packages (Attachment 2).

Justification. If station proven technology is to undergo further testing in the farmers' fields, someone has to have specific responsibility for the off-station program. Success of field testing demands confidence and cooperation of the intended user. A production research unit would be expected to develop appropriate relationships within the communities they serve. They would select the cooperators for such tests, as well as implement and monitor the intervention from beginning to end.

This will free the research scientist at the station from many off-station obligations. It will result in more effective use of his time for developing and testing technologies under carefully controlled circumstances before they are taken to the field.

RECOMMENDATION 4.

A Training and Extension Unit (TEU) should be created at El Obeid to serve the entire array of research units in West Sudan.

Justification. This unit would operate the Conference Center at El Obeid. There is a continuing need for development of refresher courses to up-date staff on current techniques. These would range from improving typing skills through development of effectiveness in use of the personal computer to biometrical techniques for planning research and analysis of data.

The TEU will develop workshop and training meetings for Extension personnel who work in the rainfed agricultural area, as well as for merchants and technicians of the private sector technicians and for farmers.

This unit will be the driving force to assure that technological packages are documented and delivered for distribution to the intended users of technology. This is one of the major voids in the transfer of technology today.

RECOMMENDATION 5.

There should be a continuation of the program that provides training opportunities at both graduate degree and non-degree levels.

Justification. The need for agricultural research staff continues to grow. As technology develops, there are opportunities for GOS researchers to find higher salaried positions in the private sector and as consultants in foreign countries. The attrition of experienced staff almost keeps pace with training effort. Consequently, any plan for enhancing research programs must include training. Eventually, if this problem is to be solved, institutions within Sudan will have to train their own scientists. It is much too expensive to depend on external universities to do this.

One alternative would be a major donor effort at improving graduate programs at the University of Khartoum and the University of Gezira.

Non-degree training for technical staff should continue at the appropriate IARC and at various short courses sponsored by universities of the U.S. and by the U.S. Department of Agriculture. Refresher courses in statistics, biometrics, farming systems, and use of personal computers are essential to keep ARC/WSARP staff trained for their intended jobs as research scientists. The Project Director is urged to

identify and nominate candidates for non-degree training.

RECOMMENDATION 6.

Technical assistance should be provided to WSARP to help the Sudanese scientists accomplish the research goals they have established for West Sudan.

Justification. The training period associated with the initial phase of WSARP is virtually complete. These scientists will return to their positions within WSARP. These well-trained but embryonic scientists need guidance more than ever at this stage. In addition to the four technical assistants identified by WSARP and being solicited by USAID on personal service contracts, there exists need for a Farm Systems Research scientist to train the Farm Systems Research Unit which is to be headquartered at AID. In addition, until a biometrician is trained and has returned, there is an immediate need for a resident biometrician at El Obeid to assist with research planning and analysis of data.

There should be increasing use of short-term consultants who repeat their visits on a regular basis for library development, documentation of research and tested technology, as well as for developing refresher courses for Sudanese staff.

There should be no delay in recruiting the needed technical assistance and positioning them at the appropriate locations.

RECOMMENDATION 7.

It is recommended that there be continuing input into research support services such as:

a. research planning
b. library development
c. use of personal computers in agricultural research
d. publication of research results.

Justification. The technical assistance needed to assist with research support services has already been mentioned. This should consist of short-term, repeating consultancies. Inputs should include more than technical assistance. The library and documentation center development should involve the ARC headquarters as well as the new library at the El Obeid Agricultural Research Center. Funding should include renewal of subscriptions for scientific journals at both locations. The Project Director should explore opportunities with IDRC to further develop the library network at all stations, as well as at Wad Medani headquarters of ARC. There should be assistance with publication of research results. It is unfortunate that the latest annual report of research

available from ARC covers only the 1977-78 work.

There should be additional use of the personal computers in agricultural research. No tool has provided so much versatility and increased opportunity for increased efficiency to the agricultural researcher. Equipment purchase and extensive training in its effective use is the burden of any development program.

RECOMMENDATION 8.

Purchase of research and farming equipment needs to be continued to permit planned research activities to be completed.

Justification. The request for purchase of research and farming equipment is primarily for the replacement of vehicles that were put into service early in the Project. Many of the vehicles have been in service for five years which is just about life expectancy for vehicles in Sudan. The roads are rough and poorly maintained. When wet, they are virtually impassable. Sudanese drivers have less than appropriate concern for maintenance and possess only minimal driving skills. All of these contribute to the rapid deterioration of transport vehicles and farm equipment.

Certain research equipment cannot be anticipated because of varying interests, projects, and techniques. Much of the equipment that was purchased was based on anticipated activity rather than on planned needs based on the research plans for specific individuals or groups of individuals.

RECOMMENDATION 9.

There should be continuing external inputs into local salaries of WSARP staff and to recurrent operational costs of operating the stations. However, there should be a progressively greater input each year by the GOS until, at project's end, all local salaries and recurrent cost expenses for WSARP are included in the ARC budget.

Justification. It is an accepted fact that the GOS has limited funds budgeted for research. If the government officials have real priority for improved agricultural production through an effective research program, they must begin budgeting now for the day when donor assistance to WSARP terminates. The Project Director and the Director General of ARC were in agreement but, of course, could make no commitments for GOS on this matter. This should be a condition for extended support for WSARP.

RECOMMENDATION 10.

It is the opinion of the evaluation team that the USAID support program for agricultural research should not be restricted to the traditional production systems of the rainfed sector. Plans should be initiated now in order for ARC to reorganize and accommodate research activities of both traditional and mechanized agricultural production systems within a national rainfed agricultural program. An analysis of mechanized rainfed agricultural research was prepared and accompanies this evaluation.

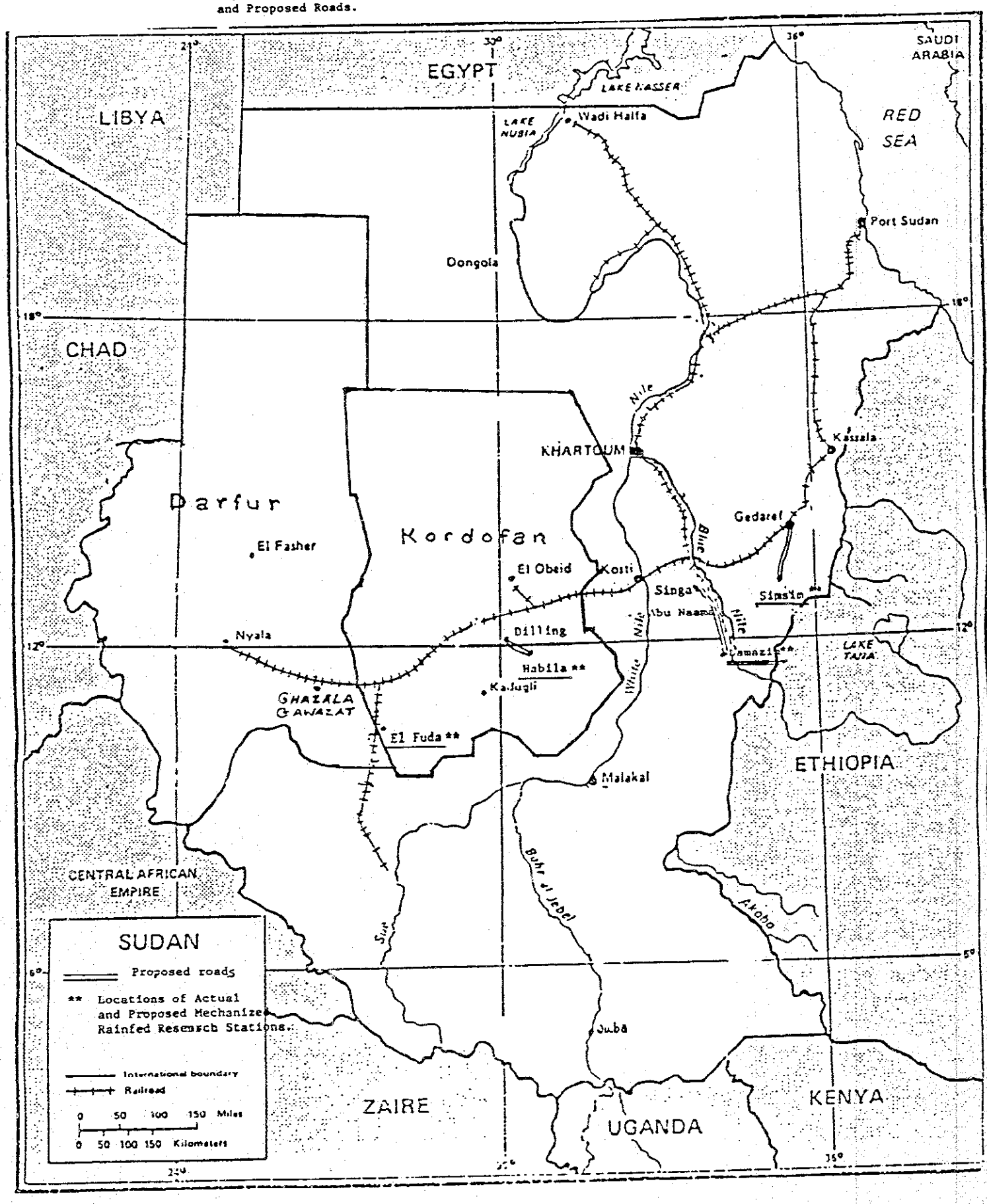
Justification. The mandate for all agricultural research has been given to ARC. It is counter productive to establish assistance programs outside the institution authorized to accomplish the agricultural research needs of Sudan. This team recommends that ARC's research activities be developed for three distinct agricultural subsectors. These are (1) the irrigated subsector, (2) the rainfed subsector, and (3) the tropical subsector.

Within the rainfed subsector, there would be two programs--one for traditional farming systems and one for mechanized farming systems. WSARP is currently assisting with the former.

A suggested organization is presented (Attachment 3) by which ARC can accommodate an assistance program without creating another semi-autonomous organization such as WSARP to facilitate its implementation.

The Director General of ARC and appropriate personnel within the Ministry of Agriculture, Food and Natural Resources, should be challenged to develop a national rainfed agricultural research/ production strategy. This would provide some basis for prioritizing research goals and purposes.

Figure 1. Map of Sudan Showing Relevant Locations of Mechanized Rainfed Research Activities and Proposed Roads.



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List of persons interviewed or who contributed in other ways to the team's understanding of rainfed agriculture in Sudan.

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List of acronyms and abbreviations for Winrock Documents:

ARC	Agricultural Research Corporation
ARS	USDA - Agriculture
AAAID	Arab Authority for Agricultural Investment and Development
AOAD	Arab Organization for Agricultural Development
AID	Agency for International Development
BNIADP	Blue Nile Integrated Agricultural Development Project
CDSS	Country Development Strategy Statement (USAID)
CIAT	Centro Internacional de Agricultura Tropica
CID	Consortium for International Development
CIMMYT	Centro Internacional Mejormiento Maize Y Trigo
COP	Chief of Party
CRSP	Collaborative Research Support Program
FAO	Food and Agriculture Organization
fd	Feddan (1.04 acre)
FRSU	Fields Systems Research Unit
GOS	Government of Sudan
IADS	International Agricultural Development Service
IBRD	International Bank for Reconstruction and Development
ICARDA	International Center for Agricultural Research in Dry Areas
ICRISAT	International Crops Research Institute for Semiarid Tropics
IDA	International Development Association
IDRC	International Development Research Center
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Disease
INTSORMIL	International Sorghum and Millet CRSP
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
LS	Sudanese Pounds ($2.5 official exchange)
MFC	Mechanized Farming Corporation
M.S.	Master of Science Degree
MANR	Ministry of Agriculture and Natural Resources
PEU	Planning and Evaluation Unit
Ph.D.	Doctor of Philosophy Degree
PRU	Production Research Unit
SAB	Sudan Agricultural Bank
SMSS	Soil Management Support Services, USAID
TA	Technical Assistance
TEU	Training and Extension Unit
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USDA/OICD	United States Department of Agriculture/Office of International Cooperation and Development
WSARP	Western Sudan Agricultural Research Project
WSDC	Western Savannah Development Corporation
WSU	Washington State University

ATTACHMENT 1

STEPS IN A SYSTEMS APPROACH TO SOLVING AGRICULTURAL PRODUCTION PROBLEMS

STEPS IN A SYSTEMS APPROACH TO SOLVING
AGRICULTURAL PRODUCTION PROBLEMS

1. **Establish the overall objective of the research.** This is usually done by a government, a department, an organization, a team of researchers, or a combination of the above.

2. **Initial evaluation of research objectives.** This will determine what types of disciplinary or commodity expertise are required on an interdisciplinary systems research team. These disciplines may change as the research progresses.

3. **Establish the interdisciplinary team.** This team will begin the "systems research." The selection of the team is extremely important and should include extension as a discipline.

4. **A definition of the system(s) within which the research is to be conducted.** The initial work of the team will take from three to six months. The team is "field oriented" with continual responsibilities throughout the work period. Steps in the definition process might be the following:

   Diagnostic Phase. Its purpose is to identify problems and constraints and assess their relative economic importance. This includes an appraisal of what the problem is costing, how much a solution would benefit, and how much that solution would probably cost. It also includes an analysis of social aspects of the problem, as well as possible solutions (see economic methodology shown as Attachment No. 2).

   Research Phase. Once problems are identified, this phase begins and involves interdisciplinary, as well as disciplinary, or commodity research. The steps include:

   1. A literature review to determine whether the problem has been addressed/solved elsewhere. Is a solution known? If so, carry out adoptive research if necessary.

   2. If a solution is not known, the problem is presented to disciplinary or commodity scientists or an interdisciplinary team if the problem suggests more than one facet is involved.

   3. Test possible solutions in "paper models."

4. When possible solutions are identified, test on a research station. If changes in solution occur at this stage, again place the modifications into paper models.

5. If on-station tests and paper modeling tests prove successful, test the solutions on producer farms within the appropriate system. If changes occur in any solutions at this stage, the change should be again placed into the "paper model" and retested.

6. If on-farm tests are successful, initial extension and selected farmer/merchant training courses can begin. These may be of the seminar type or longer type courses, depending on the solution.

7. Extend to the remainder of the extension service personnel and to other farmers/merchants.

8. Continue to monitor the system for results of the solution, as well as identifying new problems or constraints. This work involves the use of the field teams which were initially established.

9. Repeat sequence as new problems or constraints arise. Systems research is dynamic!

ATTACHMENT 2

FARM SURVEYS TO ASSESS THE RELATIVE ECONOMIC IMPORTANCE OF AGRICULTURAL RESEARCH SYSTEMS

FARM SURVEYS TO ASSESS THE RELATIVE ECONOMIC IMPORTANCE OF AGRICULTURAL RESEARCH SYSTEMS

Attachment No. 1 of this report indicates the steps involved in using a systems approach in solving agricultural production problems through research. This paper outlines the rationale for doing farm surveys as an initial step in the diagnostic phase for such research.

Survey research provides a way of structuring the problems and constraints to determine their relative economic importance to the family farm unit. While inputs by an interdisciplinary team are extremely important as a diagnostic tool, they have a tendency to regard the constraints as being of equal importance. Also, there are no assured ways of eliminating professional bias or conceptual ambiguity. Survey research methods are the only way of structuring the process to reduce their influence.

The information gathering process should begin by outlining a conceptual framework and asking questions such as: What is the current income structure of the target group? What are the major factors which influence it? How could programs cause favorable changes in these factors? The foregoing questions are oversimplified, but do focus on the data-gathering process with a central issue. A foundation is now in place for a serious survey research effort.

The next step is to determine what information is needed to indicate the structure of the target group incomes, the factors which influence it, and how they could be changed. To have a knowledge of income structure, net income must be estimated. This means accounting for the costs of producing livestock and crops and the economic returns which are gained from production.

Once the sample survey is completed for a target group, the process of using farm level accounting procedures to obtain net income begins. Normally, enterprise accounts are used. These are simply tables which contain inputs and outputs for a particular crop or livestock activity. Enterprise accounting is followed by farm and household income accounts. These are a sum of the individual crop accounts. The household account provides an estimate of income from outside the farm and from non-farm business activities which are undertaken by the farm family. Through enterprise accounts, some inferences can be made about crops and livestock levels of efficiency and the potential of altering the crop mix.

Analysis of the sample surveys allows the development of a more targeted research program. It presents the constraints in a quantitative and precise format which the researcher can then evaluate. For example:

1. Instead of merely stating that there are labor constraints, it can now be determined: (a) what family labor is available, (b) on which crops or crop mixtures labor is used, and (c) in what quantity it is used. When determining the monthly use of labor, one can determine when the labor constraint is more of a problem. Also, if some members of the family are working off-farm during the period of high labor needs, something can be learned about the opportunity cost of labor. The additional value which must be obtained through better weeding practices to compensate for the value of working off-farm can be determined.

2. It is known that crop pests and diseases are constraints, but it is not known the yield loss which occurs on farmers' fields. Farm surveys can determine the potential savings if less seed is required and seed dressings are used to control smut.

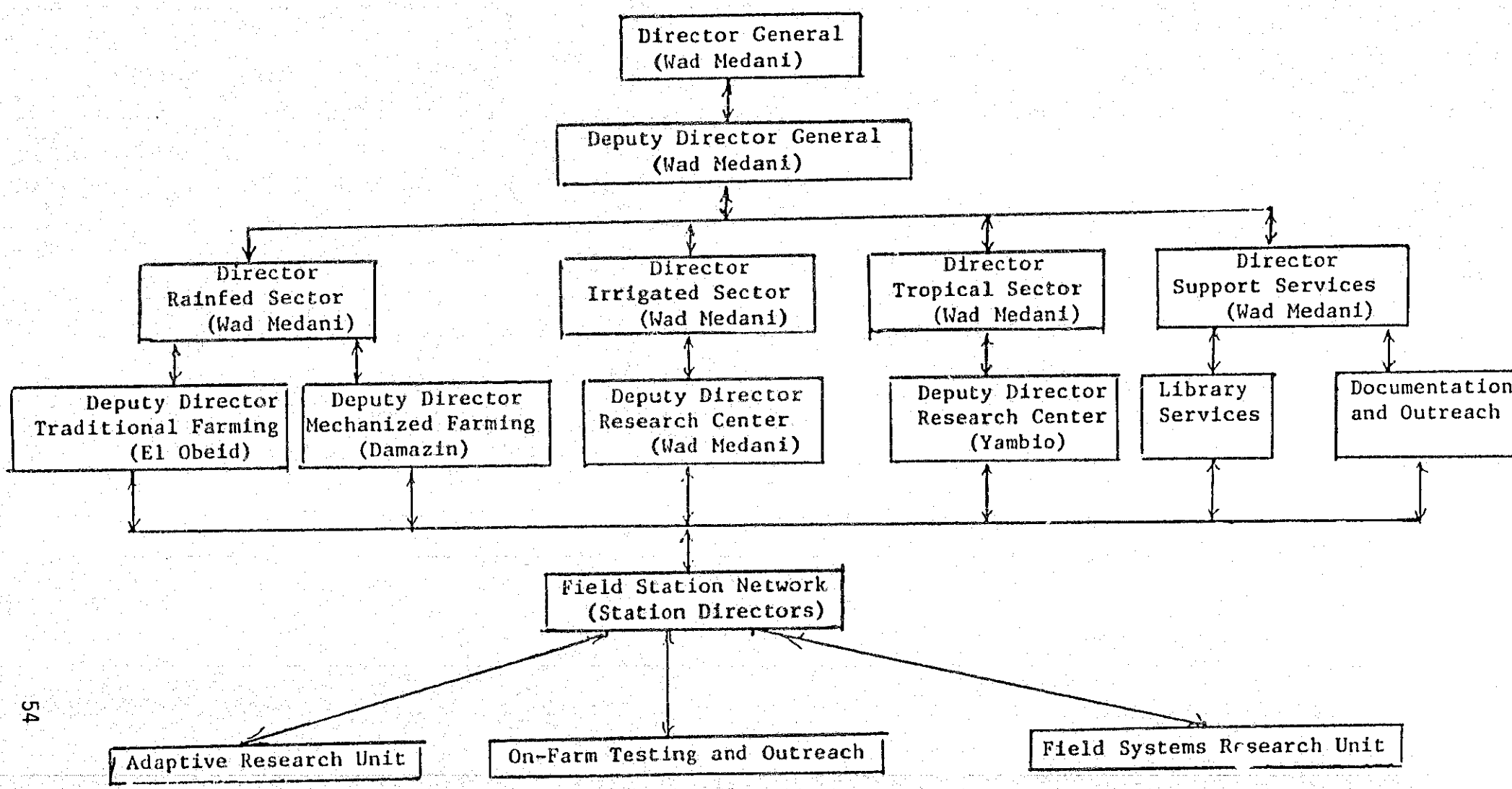
3. Poor agronomic practices are not a constraint which is specific enough to be addressed by a researcher. Selected practices must be identified and the effect an improvement would have on limited resource use must be determined.

The above are but some examples where an early economic analysis is critical to the targeting of research priorities. Secondary information sources are useful in designing questionnaires but seldom are specific enough to target the priority constraints in a particular agricultural system.

ATTACHMENT 3

PROPOSED ORGANIZATIONAL STRUCTURE FOR ARC -SUDAN

Figure 2. Recommended Organizational Arrangement, Agricultural Research Corporation, The Sudan



ARC must consider restructuring its administrative organization if it is to meet the growing demands for research required by producers of the agricultural sector. A possible alternative for the organizational framework is presented in Figure 1. The proposed organization would assist the Director General of ARC to better serve all agricultural sectors of Sudan. It would give all subsectors equal status and make it easier to avoid disproportionate allocations of financial and human resources among them.

There are three major agricultural sectors served by production research activities of the ARC. These are: (1) the rainfed sector, (2) the irrigated sector, and (3) the tropical sector. The latter is a term used by the Winrock International team to designate the agricultural production systems in the high rainfall regions of equatorial Sudan. It is recommended that the Support Services for ARC be considered an organizational equivalent of a research sector.

It is proposed that a director of ARC head each of the sectors. The directors function under and are accountable to the Director General with the administrative framework of ARC.

The rainfed sector will be lead by a director of ARC stationed at Wad Medani. It is divided into two subsectors--mechanized farming and traditional farming systems. Headquarters for the traditional farming systems research would be at the El Obeid Agricultural Research Center. The subsector for traditional farming would be headed by a deputy director of ARC.

The mechanized farming subsector would headquarter at Damazin if the facilities of the BNIADP are made available to ARC. Should this assumption be incorrect, the next logical site would be the Kenana Station at Abu Naama. This unit likewise would be headed by a deputy director of ARC.

The director of the irrigated sector would be located at Wad Medani. He would be responsible for the production research that is associated with the irrigated sector. In addition, he would be in charge of the core disciplinary units that service the special needs of all the sectors for basic research inputs.

The director for the tropical sector should be located at Wad Medani for the most effective interaction with his fellow directors. There would

be grounds for his location at Yambio, but the review committee suggests a Deputy Director at that location to coordinate activities in the southern provinces.

The support services for research would be strengthened by being an organizational equivalent of a research sector. It would be headed by a director of ARC. The sector would be subdivided into two units: (1) Library Services and (2) Documentation and Outreach Programs.

ATTACHMENT 4

TRIP TO JUBA,
EQUATORIA PROVINCE

MEMORANDUM

TO: USAID Mission, Khartoum, Sudan

FROM: Gordon McLean, Consultant, Soils/Agronomy
Robert Temple, Consultant, Animal Production

DATE: February 17-20, 1986

RE: Trip to Juba, Equatoria Province

Purpose:

At the request of the Acting Agricultural Officer, USAID, Khartoum, the consultants were part of a five-person team in Juba to:

1. Briefly review the SARAD I project in southern Sudan and associated components of the project being carried out under its mandate; and

2. Make suggestions for revising the project.

Project Review:

1. Although the time was very brief, discussions were held with the Director General of Agriculture of Equatoria Province and his division heads: The Acting Vice-Chancellor of the University of Juba; the Representative of the Economic Development Fund (EEC/EDF); and the Acting Area Coordinator, USAID, Juba. Travel restrictions in the area limited the visit to the town of Juba, consequently, the review was conducted without on-site inspections through discussions with various personnel.

2. The present activities of USAID in Equatoria are extremely limited due to the security problems in the region and do not cover all the parts of the projects listed in the Project Paper.

   Government personnel in the Agricultural sector were asked for small project proposals where short-term assistance could be affected without technical assistance from AID. The projects that were reviewed are diverse, including crop production, crop research, forestry, fisheries, credit, soil analyses, insect control, assistance to the veterinary department, rinderpest vaccination, tsetse fly survey, cattle and sheep ranching, leather crafting, training of local fishermen, planning, and others.

   These projects were initiated in order to have a USAID presence in the region and to assist where possible. It appears that much of the expenditure has been for operating (recurrent) expenses of the existing departments of the Ministry and not necessarily for the furthering of the projects' objectives listed in the Project Paper. In several cases, little attention has been given to the anticipated

outputs of the Project and little accounting of the outputs has been made. An exception is the fisheries training project in which they reported training over 170 local fishermen out of a target of 500. A request is forthcoming for additional funds so an account could be given on the number of cattle vaccinated.

The proposals submitted for continuation of support during the present six-month period, January-July 1986 were discussed. It was indicated to the Director General that, until the formal report of the last six-month period was received and reviewed, commitments for the subsequent funding during the next period would not be approved.

3. Under the present situation and restrictions on travel in the area, it appears that development activities under SARAD I are not being conducted. Funds from SARAD I are being used, at least to some extent, to keep the Ministry operating.

   Accomplishments from AID assistance appear to be limited and requests for assistance were largely for fuels and spares for existing vehicles.

4. The agricultural research at Yambio is a component of ARC which is a national function and, theoretically, outside of the control of the Director of Agriculture Equatoria Province. Discussions with the Director of Yambio Research Station indicated that he thought that his station had little in common with either the WSARP or the rainfed sector and suggested that Yambio be accepted as a tropical agricultural research facility.

   Research at Yambio has not functioned well because of security problems. There appears to be little or no opportunity for either GOS or USAID to invest in a research program at Yambio at this time, and until such time that peace and political stability are apparent in the Southern Regions, it would be futile to invest in an isolated research facility at Yambio.

Projects for Revision:

1. Discussions with the Acting Vice Chancellor of Juba University and the representative of EEC, indicated that USAID assistance to the University may have comparative merit for the following reasons:

   a. EEC/EDF is presently supporting the building of the first phase of a new campus, 15 km distance across the Nile River from the present campus, for the College of Natural Resources (intended first for the College of Socioeconomics, but this decision had been changed).

   b. A second phase of construction for expansion of the University is presently under consideration by the EEC/EDF.

c. The College of Natural Resources has plans in the future for developing some of the area into a college farm for teaching and research, but no donor agencies have agreed to provide this assistance.

d. A farm complement to the extent of a modern poultry unit (5000 layers, 3000 broilers) a modern dairy (50-100 milking cows), and a 20-acre seed production unit would provide badly needed assistance to the University.

e. Due to a shortage of seeds, poultry, and milk products in the area, such a farm could be revenue earner for the University in the future.

f. Students from all over Sudan attend the University of Juba. Consequently, assistance to the University would benefit not only Equatoria, but all of Sudan.

2. For overall development of the South, two of the major constraints are:

   a. Lack of cheap source of electrical power, and

   b. Lack of roads and, even where roads do exist, many cannot be traveled during the rainy season due to flooding.

   Several studies have shown that the Fula Rapid is a feasible and economically viable site for the construction of a hydro-electrical plant. A source of power in the South would not only greatly benefit all people of the South connected to the grid, but would also be an encouragement to local small and large industries.

3. Further agricultural development in the South is limited by the above two constraints (power and roads). In addition, the government is unable to meet necessary recurrent expenses for the present agricultural programs.

AMENDED PROJECT PAPER FOR

WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

FOR PROJECT EXTENSION

Prepared for:

U.S. Agency for International Development
Sudan

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PROJECT RECOMMENDATIONS AND SUMMARY

It is recommended that the original project paper for the Western Sudan Agricultural Project (WSARP) be amended to allow continuation of selected activities for a period of five years. This period would begin in Fiscal Year 1987 and would carry the project through its third and final phase. It is recommended that grant financing authorization be extended in the amount of $5.745 million in support of WSARP activities.

THE PROJECT

Introduction

The Government of Sudan (GOS) recognizes the critical role of agriculture and agricultural research in meeting the food needs and development goals of the nation. In recognition of this as a continuing constraint, the GOS has requested USAID to develop a strategy to further strengthen the capabilities of the Agricultural Research Corporation (ARC). This is to be done through continuation of WSARP.

In response to this request, the following amended project paper has been prepared and described in the following sections. The basis for this amendment is included in four documents (1) Sudan Agricultural Research Project - Staff Appraisal Report - IBRD, (2) The Sudan Agricultural Research Corporation: Organization, Practices and Policy Recommendations - INTSORMIL, (3) The WSARP - The Sixth Year Evaluation - USAID Khartoum and (4) the original project paper. Numerous site visitations, briefings by USAID, ARC, WSARP, and various GOS officials contributed much to the development of strategies.

Project Purpose

The purpose of the proposed Amended Project Paper is to develop within ARC an effective capability for planning and implementation of relevant agricultural research programs in Western Sudan. This will be one factor contributing to an improved standard of living for farmers, pastoralists, and villagers who live and work in Western Sudan.

Background

Contribution of Agriculture in the West to the Economy. The West, comprising the four provinces of North and South Darfur and North and South Kordofan, covers an area of about 850,000 km^2 or 35% of the Sudan with about 6.75 million or 30% of the country's total population. The West contributes about 90% of the Sudan's millet, 52% of the sesame, 46% of the groundnuts, 17% of the sorghum, 6% of the cotton and 90% of the gum arabic production. An estimated 45% of the cattle (about 7

million), 37% of the sheep (about 6 million), 32% of the goats (about 3.5 million) and 65% of the camels (about 1 million) are raised in the region.

Crop Production. Small-scale subsistence agriculture is the most important economic activity in the West. Other sectors, particularly transportation and industry, are critically linked to agriculture. Only about 3% of the total cultivation in the West is commercial agriculture. This is concentrated in South Kordofan and to a small degree in South Darfur. Rainfed agriculture predominates. The only exceptions are small irrigated plots in the Jebel Marra, at Sag el Naam in North Darfur, and around Nyala. The main crops are millet, sorghum, groundnuts, and sesame, with cotton and maize of lesser importance. Recorded yields reflect not only poor soils and unfavorable weather conditions, but also poor husbandry practices and, in some areas, over-exploitation of the land. For all the major crops, the area under cultivation has been increasing steadily over recent years. Yields have remained stagnant or have decreased over the same period of time. This trend must be reversed if farmers' incomes are to be increased.

Animal production. The conflict between individual ownership of livestock, communal land use, and the seasonal movement of the predominantly transhumant livestock producers inhibits the proper utilization of resources. Use of range, water, and the production potential of the herds is inefficient. During the last 25 years, the number of animals has increased considerably. The increased herd numbers have led to range deterioration without a comparable increase in output.

Constraints to production. There are two main constraints to increased production: (a) ecological limitations imposed by a low and extremely variable rainfall, high evaporation, recurring drought, soils of low fertility, and limited availability of groundwater; and (b) increases in the human and livestock populations change social structure and traditions and create pressures which encourage ecological degradation. The steadily worsening man/livestock population ratio forces many pastoralists to turn to sedentary cultivation. New and more efficient systems of land use and water management should be introduced into existing livestock and crop production systems if this assimilation is to be successful.

Other constraints are related to these basic issues. These can be classified as ecological and socioeconomic. Some ecological issues are deterioration of rangelands, grass fires, parasites and pests, low protein and mineral intakes by grazing stock, reciprocal pressures of livestock and crops in competing production systems, lack of effective technologies of crop husbandry, crop diseases, weeds, pests, inadequate tillage methods, unimproved crop varieties, low soil fertility, and poor water management. The socioeconomic constraints include: the conflict between individual ownership of livestock and communal land use, socioeconomic insecurities in a fragile ecosystem, attempts to buffer social groups against environmental alternation by

overstocking, shifting cultivation sites, increased sedentarization, lack of market opportunities, insufficient demand for consumer goods, and few opportunities for investment of capital other than in livestock.

These constraints do not, generally, represent discreet disciplinary problems that are capable of solution by traditional techniques of experimental agriculture. Rather, they constitute interconnecting links which could only be strengthened through the study of production systems by multi-disciplinary teams. Such research would increase crop and animal production and provide security to producers through the long-term optimum use of resources. It places particular emphasis on water/soil/plant/animal/human inter-relationships.

Project Description

Sudan's agricultural development strategy presented in a Ministry of Finance and Economic Planning document[1/] indicates the need to make full use of existing agricultural resources. Emphasis is placed on the importance of the rainfed sector which contributes more than half of the total agricultural production. More attention to the development of rainfed production is expected from the public sector. This will result in a slow but progressive growth rate to about a 5.2% level within five to ten years.

The report indicates a continuing need to correct the wide variance in productivity and incomes between the commercial and subsistence agricultural producers. As part of this strategy, GOS is according high priority to starting development programs for subsistence farmers and pastoralists in the West. Intensified use of arable land, range, livestock, and water could contribute to reaching the planned development targets in the country and a steady improvement in living standards of the population of the West. This is critically dependent on the development, transfer, and adoption of improved technical packages which call for the support of an accelerated agricultural research program.

The WSARP area includes the Provinces of North and South Kordofan and North and South Darfur. It extends from the Bahr el Arab in the South to the Libyan desert in the North, and from the Nile in the East to beyond the Jebel Marra Massif in the West. The habitable southern two-thirds of the WSARP area is located approximately between 9°30 and 16°N latitude and 20° and 32° longitude. The north-south rainfall gradient

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1/Prospects, Programmes and Policies for Economic Development II, 1983/84 - 1985/86. October, 1983, The Democratic Republic of Sudan, Ministry of Finance and Economic Planning. (Planning). Khartoum.

increases from very arid (about 25 mm per annum) in the northern desert to semiarid (up to 900 mm) along the Bahr el Arab in the south. This embraces the ecological zones of the Sahara, Sub-Sahara, Sahel, and Sudanian savannah. In the south, the rainy season extends over a period of five months (June to October) and progressively decreases in duration toward the north.

Fragmentary soil surveys have identified three broad soil groups in the inhabited southern part of the Project area:

1. The stabilized (Qoz) sands complex is predominant and has low fertility but can be cultivated by hand.

2. The non-cracking clays are widely scattered, with sparse vegetation because of low permeability. Grazing is the most common use of these soils, but they are also suited for cropping once the hard surface pan has been broken.

3. Cracking clays are the most fertile and stable soils. They are predominant in the Nuba Mountains and occur over much of the southern Project area.

Until recently, the nomadic livestock-owning Baggara people were predominant, though a few Baggara and some non-Baggara people have been settled agriculturalists for a long time. Because of human and livestock population pressures, more and more pastoralists are turning to crop production in association with livestock production in areas receiving an annual rainfall over 400 mm. This reduces the land requirements per family and increases the output per unit of land. The range areas, once seasonally rested during cyclic migratory livestock movement, are now subject to intense degradation. Furthermore, cash surpluses accumulated by settled cultivators are largely invested in livestock. Thus, a continuum now exists with varying degrees of settled, semisedentary, and fully nomadic populations that have overlapping needs which create competitive demands for resources.

The variation in natural conditions and economic behavior of the inhabitants can be differentiated into five agro-pastoral production systems, of which two are purely pastoral and three are crop/livestock combinations:

1. The nomadic system. This involves arid livestock production at the desert fringe.

2. The transhumant system includes semiarid livestock production in Southern Kordofan and Darfur that is interspersed with crop production.

3. The sedentary system which is divided into three specific groups.

   a. integrated crop/livestock production on stabilized sands;
   b. integrated crop/livestock production on noncracking clays; and
   c. integrated crop/livestock production on cracking clays.

There is considerable overlap between these systems. For instance, in the wet season the northern limit of the semiarid cattle range coincides with the southern limit of the arid camel/sheep range during the dry season. These range resources are actually grazed year-round and have no opportunity for recovery. Year-round livestock production is difficult in the areas of non-cracking clays due to flooding problems and on cracking clays sites because of mud. Livestock either have to be moved to drier sites outside the area, or fodder conservation is required to maintain the animals during wet weather.

The WSARP would, with extended support for a five-year period, continue to develop and implement the ARC's research program in Western Sudan. In particular, the project would include:

1. Continued strengthening of research programs concerned with:

   a. livestock and crop production systems at El Obeid and Kadugli, with supporting activities at Ghazala Gawazat

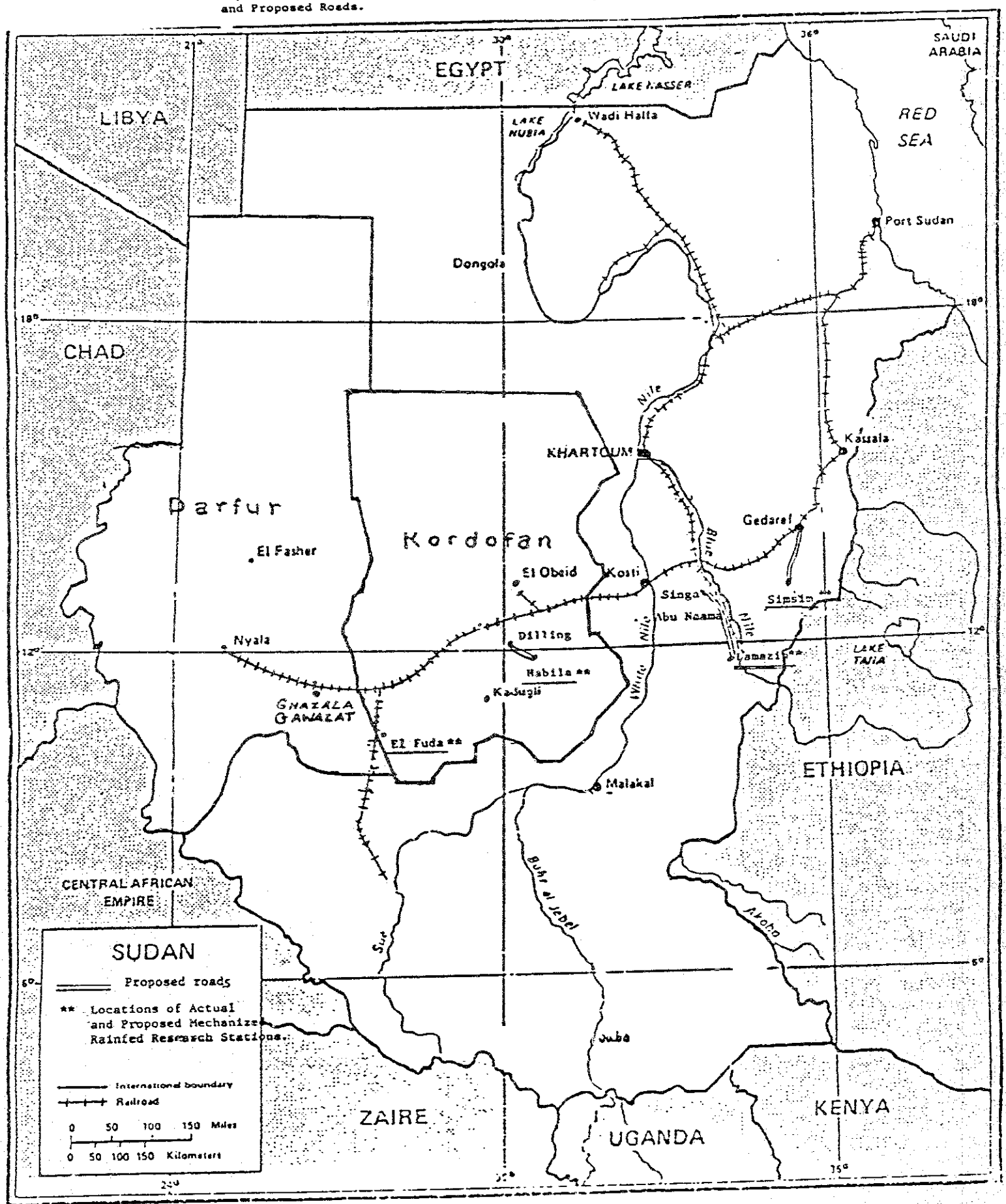
   b. water and land use management research at El Obeid with supporting activities at El Fasher, and

   c. livestock production and range management programs at El Fasher and Ghazala Gawazat for nomadic and transhumant production systems. Programs for El Fasher and Ghazala Gawazat would involve only limited support for technical assistance groups whose responsibilities cover work at the Darfur locations, as well as the research stations in Kordofan.

2. Identification, training, and posting of a Field Systems Research Unit at El Obeid to function throughout the various production systems of West Sudan (Annex 1).

3. Development of Field Systems Research Sections at each research station to test technology interventions for various production systems on the farmers' fields and to implement and monitor farmer-managed tests of the improved technology packages (Annex 2).

Figure 1. Map of Sudan Showing Relevant Locations of Mechanized Rainfed Research Activities and Proposed Roads.



4. Creation of a Training and Extension Unit at El Obeid. This unit will operate from the Conference Center at El Obeid. It will be responsible for development of refresher courses for all research staff as well as training meetings, workshops, and conferences for Extension personnel, private sector technicians, and farmers.

5. A program for WSARP staff which will provide both graduate degree and non-degree training opportunities.

6. Technical assistance to be provided to WSARP to assist Sudanese scientists to accomplish the goals they have established for Field Systems Research.

7. Continued development of research support services such as:

   a. Research planning
   b. Library development
   c. Use of personal computers in agricultural research
   d. Publication of research results.

8. Purchase of research and farming equipment needed to conduct the planned research activities.

9. Inputs into salaries of WSARP staff and recurrent costs of operating the stations. This must involve a progressively greater input each year by the GOS until at project's end it will have assumed full responsibility for salaries and operating costs from budgeted sources.

The project will be financed jointly by USAID, IDA of the World Bank, and the GOS. USAID will contribute $5.745 million, IDA $.8 million, and the GOS $7.980 million over a five-year period for a total project cost of $14.525 million. GOS financing will include progressively increasing levels of local salary and operational costs over the life of the project. IDA contribution will finance operation of the project aircraft. USAID will fund the balance of the costs including technical assistance, participant training, commodity and equipment purchase. The logical framework for these activities are presented in Annex 3.

DISCUSSION OF PROJECT COMPONENTS

Research Programs at El Obeid

Integrated Crop/Livestock Production Research on Non-cracking Clays. Non-cracking clays are elements of the existing production systems in

the WSARP area although they do not constitute a production system in their own right. They are most detectable in the clay pan-sand alternation in the Baggara pattern; and they are interspersed with cracking clays around the Nuba Mountains. They are also located in a stabilized sands/non-cracking clays mosaic south of El Obeid (Figure 1). Non-cracking clays are used mainly for livestock production and as water catchment areas. They are capable of providing range grasses and browse of high mineral content.

The hard surface pan of these basically fertile soils prevents their use by smallholders where traditional hand- and animal-powered tillage techniques cannot prepare them for cropping on a significant scale.

The general approach of research studies would be the same as for the integrated crop/livestock systems on stabilized sands with greater risks of drought. Crop production research would include millet as a major crop. It should focus on moisture conservation and improved tillage technology involving animal traction.

It is recommended that the millet research at El Obeid be planned in a cooperative effort with INTSORMIL and ICRSAT. These international agricultural research institutions can provide the basic research in plant breeding and in disease, weed, and insect control that is necessary to complement and support the applied research effort of WSARP/ARC scientists.

Water and Land Use Management Research Program. This program would support the multi-disciplinary systems research teams in West Sudan. It includes the survey, monitoring, and classification of available land and water resources and their rational use in crop or livestock production. Reducing runoff losses of limited rainfall and efficient use of the resulting soil moisture are essential to the optimization of crop and livestock production in the West. It is critical for the GOS to develop land use policies for the nation. WSARP scientists can contribute to this need by developing a sound data base for making such land evaluations in western Sudan.

An inventory of soil resources in the West would help researchers recommend crops and production technologies for farmers of the region. It would also assist the agricultural researcher to predict yield responses to specific technological interventions. The main lines of research would include:

1. Water management technology, water conservation, infiltration, run-off, harvesting, surface, soil profile and underground water storage, and evaporation. The most efficient, minimal use for crops, livestock, and human populations must be determined.

2. Socioeconomics of water management require that comparative costs and benefits for the techniques of harvesting, storing, and using water be determined. Social structures and economic pressures must be investigated as mechanisms to control and restrict water use for control of livestock numbers. This is necessary for improving Sudan's rangeland resources.

3. Land use planning involves preparation of a land use classification system for the West, based on suitability of land for crop or livestock production. Preparation of land use plans which avoid conflicts between the interests of pastoralists and farmers and which designates dry season grazing reserves and livestock routes for pastoralists would be invaluable. The improvement of traditional farming and identification of further settlement areas for large-scale, mechanized farming and irrigation development would have long-range benefits for Sudan.

A cooperative effort between WSARP and Soil Management Support Services (SMSS) in development of a soil resource inventory and land use evaluation would enhance the research capability of the water and land use management program. See Annex 4 for technical and budget details of a proposal by SMSS.

Field Systems Research Unit. One of the obvious successes of the WSU input into WSARP research was the adoption of the Field Systems Research approach. Although there were errors in the initial diagnostic phase, the procedures were presented to the scientific staff and apparently were understood. It requires development of a special systems research unit to ensure that a multidisciplinary approach to solving production constraints maintains focus. Therefore, it is suggested that a Field Systems Research Unit be developed at El Obeid headquarters. This unit would be headed by a Sudanese economist trained in farm systems management. This person would be complemented by a staff at El Obeid consisting of a production agronomist, a livestock production specialist, and a rural sociologist (see Composition and Function, Annex 1).

Included in the Unit would be four Field System Research Sections, one located at each of the four WSARP research stations (see Duties and Responsibilities, Annex 2).

The FSRU is to function throughout all of the agricultural production systems of Western Sudan. It will collect baseline macro- and micro-economic data as well as monitor changes within production systems as they are affected by technological interventions. This will allow assessment of the economic impact of an improved technology.

It is assumed that the system of review of station research plans as established in the original WSARP project will be continued. This includes review by each station committee, and overall WSARP committee, and finally by the ARC Director General. It is proposed that results of all analyses by the FSRU be distributed to each committee charged with

review and approval of research programs. This would serve to give a basis for determining research priorities, integration of research programs by various scientists, ensure against duplication of effort, and of the applicability of the research across ecological zones.

It is intended that the Field Systems Research Unit will be a direct intermediate link between the research station and the farmer. It will continue to identify constraints and establish priorities for research that are necessary to solve production problems.

Research Programs at Kadugli

Integrated Crop/Livestock Production on Cracking Clays. Cracking clays are characteristic in the southeast of the WSARP area. The major difference between this system and that on stabilized sands would be the substitution of sorghum for millet as the major crop. Sorghum is more tolerant of heavy soils. Likewise, sesame would be substituted for groundnuts as the major support crop. In the Nuba Mountains, cotton is important, replacing gum arabic of the stabilized sands as a cash crop. Livestock differences also exist, desert sheep decline in importance and are replaced by goats and cattle.

In addition to the problems common to all farmers in the Project area, specific constraints exist with regard to the short period for seed bed preparation and planting on cracking clays. The traditional tillage technology limits the area that can be cultivated. The use of unimproved sorghum and sesame varieties, together with weed competition (striga) in sorghum and millet and post-harvest insects in sesame, place severe limits on production. Livestock are seriously affected by mud and flies in the wet season.

Research at Kadugli would be planned to include the following:

1. Crops. Development and testing varieties of sorghum and sesame varieties, developing improved production practices such as controlled plant populations, proper dates of planting, improved weed control, fertilization, and improved harvest procedures: It is suggested that the research capability of the INTSORMIL CRSP and of ICRISAT be involved in the program at Kadugli. It will provide a source of basic research needed to support the applied research effort of WSARP/ARC scientists.

2. Livestock. Animal traction; management and nutrition of local and introduced breeds of cattle, sheep, goats, and their crosses for milk and meat production.

3. **Pasture and forage.** Because of the difficulties of grazing clay soils during the wet season, techniques of forage harvest and storage must be considered.

4. **Tillage techniques.** Evaluation of hand and mechanized tools for more rapid and more efficient cultivation of the difficult black cotton soils. Tillage practices by hand, animal traction and varying degrees of mechanization must be studied in relation to their impact on optimal water use, root penetration and plant growth, soil erosion, timing of tillage, labor requirements, and economic evaluation.

El Fasher, Nomadic Production System.

Nomadic pastoralists exploit the desert fringe with camels, sheep, and goats in response to, and sometimes in anticipation of, irregular rainfall and shifting plant cover. Seasonal movements range from 250 to 500 km and may reach 800 km in years of exceptional rainfall when browse flushes occur in the desert.

The rainfall variability and lack of permanent water require repeated animal relocation. This diverts most food energy to maintenance rather than production. Body weight losses and mortalities are incurred during the long and severe dry seasons. Further constraints include the loss of grazing through fire and inadequate animal disease treatment.

The potential for improving the productivity of this fragile but highly adapted system through technical innovations must be regarded as limited. Research studies on range condition and trend and biomass manipulation through grazing different livestock species, variations in watering regimes, use of grazing management is proposed with a view to stopping the advance of the desert. Studies would also include the structure and productivity of camel herds and sheep and goat flocks. It would involve such underlying technical coefficients as the effect of improved disease control, feeding of mineral supplements and development of drought strategies.

Human resources would be studied over a longer time span with regard to demographic structure and trends, nutritional and health status, the organizational and social context of the production unit, decision-making, socioeconomic value patterns, marketing processes, animal management patterns, and inter-population pressure through competition for resources.

WSARP, with funding from ARC and World Bank sources, plans to initiate research at El Fasher and Ghazala Gawazat when the facilities are completed in 1986. USAID has withdrawn support from WSARP for any research activity associated with these two stations. It is strongly

recommended that USAID sponsored research activities include limited support for WSARP scientists who have responsibilities that include work in the Darfur locations. It is also recommended that if requested by GOS, USAID concurrence should be given to use of PL-480 funds in support of salaries and recurrent costs for research activities at these stations.

Research Programs at Ghazala Gawazat

Transhumant Production Systems. This production zone is characterized by a series of parallel, longitudinal grazing orbits (from below 10°N almost to latitude 13°N). These land use patterns are created by Baggara pastoralists moving either toward fresh grazing (dry season) or away from biting flies and heavy mud. Seasonal movements range from 300 to 600 kms. Cattle are the main class of stock, with some sheep and goats tended in mixed flocks. Dairy produce is consumed for subsistence or sold at local markets in exchange for grain, tea, sugar, or clothing. Cattle offtake for sale is about 5% (mainly mature stock), but small ruminants serve as the main meat supply for subsistence. The labor-intensive livestock system of the Baggara is reasonably efficient in relation to the natural potential. Calving rates of 65%, 120% lambing rates, and 200% kidding rates have been recorded. Millet production for subsistence on the easily tillable Qoz soils is expanding rapidly.

Expanding cultivation by both cattle owners and sedentary farmers, as well as grass fires, reduce the availability of dry season grazing. Cyclical growth and weight losses of livestock are common. Grazing forages and crop residues are deficient in protein and minerals during the dry season. Animal diseases and parasites appear to be more important here than in the north. There are local water shortages and widespread overstocking of the range. Lack of permanent water supplies along the routes of transhumants sometimes forces them to complete the southward migration to the Bahr el Arab before the forage can be fully utilized.

The objective of research activities would be to improve the economic position of the predominantly transhumant pastoralists by improving livestock output. This would be accomplished through improved range, water, and livestock management. The end result would be higher offtake and improved subsistence. New technologies will be developed that are both environmentally advantageous and socially acceptable. The main lines of research would include:

1. **Rangeland production.** The assessment of range condition and trend: The primary productivity and its improvement possibilities through controlled grazing, water, and fire management; the introduction of new species (including leguminous trees and shrubs); the strategic use of localities with better soils or available water; and, to a lesser extent, reseeding and bush control.

2. **Livestock production.** The structure and productivity of cattle herds and the flocks of sheep and goats; the effect of improved health management, providing mineral supplements, and the feeding of crop residues or by-products on livestock production; herd productivity changes resulting from early extraction and fattening of young males.

3. **Pastoral security.** Human resources to be studied include investigations of opportunities for capital investment other than in livestock.

4. **Pastoral systems:** Livestock and human resources would be integrated into proposals for improving traditional systems of livestock husbandry and life style of the people. The key to such changes would be the definition of basic limitations in available resources (particularly soil, vegetation and water) and the need to conserve available resources. For example, models would be developed which consider the introduction of new water management technology, balanced numbers of people and livestock, and increased subsistence cultivation. Basic concepts of land and water use, grazing control, organized land use for pastoralism and agriculture, animal disease control, and drought strategy development would all have to be studied. They must be brought together in the models so that final technology packages could be formulated and demonstrated in a manner appropriate to, and accepted by, the livestock producers.

Integrated Crop/Livestock Production on Stabilized Sands

Sedentary Production Systems. Livestock and crops are integrated in differing proportions and with varying efficiency on stabilized sands in the middle belt of the WSARP area, between 250 and 600-mm isohyets. Millet and groundnuts are the important crops with some production of bamia (okra), sesame and peppers. In the northern areas, Acacia senegal is tapped in the dry season for gum arabic. It provides a marketable product which does not compete for labor with other crops during the harvest season. The agricultural rotation technique includes 4-5 years of cropping, with gradually declining yields, and 8-12 years of bush fallow. Longer fallow periods in the north allow more efficient management of gum gardens. There is mounting land pressure to reduce the fallow period. This could adversely affect gum arabic production.

A typical production unit consists of a family (man, wife or wives, and their children) cultivating 2-4 hectares of land and living in villages of 10-30 huts. Livestock (desert sheep and goats used for milk and meat production and for low volume marketing) are required to stabilize the system because of crop failures in one year out of five.

Marginal and highly variable rainfall, together with low soil fertility, are the main reasons for the fragile production systems. Overstocking is prevalent around villages. Grass fires often destroy most of the

pasture. Over exploitation of crop land through reduced fallow periods encourages erosion and desertification. Technology which would allow crop production to increase by means other than expansion of cultivated areas has not been adopted. There are reciprocal pressures of livestock and cultivation demands in adjoining and competing production systems.

Research on this integrated livestock/crop production program would include: (a) Differential efficiencies and costs of crop and livestock production within the integrated farming systems; (b) the study of integrating factors such as risk minimization, uniform use of labor, utilization of unsalable products, and the effect of manure on soil fertility; (c) evolution of permanent crop/fodder/pasture rotations; (d) small farm economic studies; (e) the social structure of production units; (f) marketing procedures and opportunities; and (g) institutional requirements in the subsistence sector. Technology packages would be developed which would be easily applicable by subsistence farmers. The environmental impact of innovations would be constantly monitored.

In developing these packages, emphasis would be continued on:

1. **Crops.** The testing of food and cash crops, particularly new millet and groundnut varieties supplied by ARC stations, ICRISAT or INTSORMIL; minimum tillage and water management technology; crop protection; weed control; and, to a lesser extent, use of commercial fertilizer.

2. **Livestock.** The use of draft animals; milk and meat production; nutritional values of crop by-products and residues; fertilizer values of animal wastes; and comparative productive and reproductive efficiencies of local cattle, sheep, and goats with highly variable feed supplies and diet quality.

3. **Pasture and forage.** Possible new species such as Stylosanthes and Cenchrus to improve range production; the effectiveness and economics of growing forage crops, and using fertilizers to increase feed supply at critical times; preserved forage cut from pasture and forage crops; crop residues and grain supplements for the maintenance or survival feeding of stock during the dry season.

INSTITUTIONAL DEVELOPMENT

Training activities. Continued training at both the graduate degree and non-degree level is planned to assure continued research capability for serving the traditional agricultural production systems. The need for training four persons to the Ph.D. level and three to the M.Sc. level has been identified by the Project Director as essential to Project activities. Proposed fields of study for the trainees are indicated as follows:

	M.Sc. Degree	Ph.D. Degree
Animal Production	1	1
Economics (agriculture)	1	1
Soil and Water Management	1	1
Biometrics		1

Provision is made for non-degree training for 20 persons. This training would be primarily 1- to 6-month experiences in organized courses at IARCs, universities, or agencies in the U.S.A. It should be directed toward development of the Training and Extension Unit (TEU). The conference center and guest house accommodations provide an ideal circumstance for the TEU to prepare refresher courses for short-term training of scientists in statistics, planning research, use of personal computers, and updating research backgrounds. The TEU would also prepare and distribute brochures and pamphlets for extension activities.

The TEU staff is to be identified and located at El Obeid in the initial year (FY 1987) and the first training activities are to be conducted in the second year. Short courses for training extension and private sector personnel in new technologies would be organized and conducted by TEU with assistance from TA specialists and Sudanese research scientists.

Technical Assistance

It is projected that there will be a total of 26 scientist-years of resident technical assistance provided. In addition, there will be five years of home office management. The specialty and location at which each will work are:

Speciality	Location	Years
Research Planning and Field Systems Research	El Obeid	5
Soil and Water Management	El Obeid	4
Agricultural Economist	Kadugli	3
Agronomist (sorghum, millet)	Kadugli	3
Livestock Production	Kadugli	3
Biometrician	El Obeid	3
Administrative Support Officer	Khartoum	5
Home Office Management	U.S.A.	5

The team leader could well be selected from any one of the disciplines. However, to provide a continuing input to research planning over the contract period, it is suggested that the team leader be trained in farm systems research. He should be recruited for the 5-year period. The remaining consultants should be recruited for the terms of projected

duration for the period. The more continuity in tenure of specialists, the more effective their input will be.

There needs to be continued emphasis on research planning to ensure that there is justifiable confidence in results of research activity. A biometrician is included in the technical assistance support for El Obeid Station. This TA is to assist with research planning and to provide training to resident staff at all research stations.

The position of Administrative Support Officer for the project could well be filled by a local hire person.

Provision is made for 30 man-months of short-term consultants during the life of the project. These are to be used for research planning, computer training, project evaluation, library planning and organization, external review, and other needs as they may be identified.

Unfortunately, there has been inadequate training of Sudanese personnel in the procedures for using the personal computers. Technical assistance is needed to provide "hands-on" training of Sudanese scientists in the analysis, management, and storage of data within the capabilities of the personal computers. Scientists must also have "user-friendly" software for statistical analysis of data and for developing basic typing skills. Inadequacy of available secretarial help delays reporting and publishing of research results.

Research Support.

Library materials, books in particular, have been purchased by WSU/CID staff. A temporary library was established in the Khartoum headquarters. This will be moved to El Obeid upon completion of construction. Journal subscriptions were cancelled in 1984 because the hard currency required for such subscriptions would not be available after the end of the CID contract.

The library network within the West Sudan stations and its interfact with the ARC library at Wad Medani will continue to be of great priority. A short-term consultant should be brought to Sudan at the time the move of library materials from Khartoum to El Obeid is anticipated. Not only would this person supervise library organization, but also would inventory missing gaps in the various professional journals. It will be necessary to assist the Sudanese to secure missing volumes and to reactivate journal subscriptions. Somehow, a method must be developed to ensure the availability of adequate foreign exchange to permit payment of subscriptions.

The publication and dissemination of reports and research publications is a continuing problem. Although there was some assistance given to ARC in order to strengthen its publication ability, the output is still inadequate when compared to needs.

It is necessary to bring a short-term consultant to Sudan who would assist ARC at Wad Medani to make its documentation efforts more efficient. This consultant would assist the Project Director to assess the status of the IDRC grant to ARC for strengthening the documentation capabilities of the organization. This TA would also ascertain the plans of the World Bank to strengthen the documentation capabilities of ARC through a proposed program entitled, "Agricultural Research, Extension, and Training Project."

The evaluation team recommended that ARC research efforts should be expanded to include the total rainfed agricultural subsector. If this is to be accomplished, the initial step would require an appropriate diagnostic survey of the subsector. The purpose of the survey is to identify constraints to production and assess their economic importance. Such an appraisal would provide a basis for establishing priorities in development of research. It could be accomplished by appropriate teams of short-term consultants prior to the time any planning for implementation of a research program is undertaken. Annex 1 and 2 provide information relative to this kind of diagnostic work.

RECOMMENDATION FOR ENVIRONMENTAL ACTION

Environmentally, AID's primary concern with projects of this nature are the long-term socioeconomic and cultural implications of applied research results. While application of research is not part of the WSARP, AID is the major donor and can directly influence the environmental impact through provision of the technical services that prepare the research plans.

The program, as outlined, acknowledges the need to examine socioeconomic and cultural impacts when conducting research which may lead to possible developmental activities. Any application of research should have the benefit of thorough environmental analysis at the research stage. The specialties of the AID-financed technicians assure WSARP's capability to perform this environmental analysis.

The inherent environmental focus of the research program that has been suggested here should assure that the project will have no significant adverse effects on the environment. Therefore, it is recommended that a negative environmental determination be made.

USAID. USAID will finance the following inputs toward achieving the purpose of the amended project paper.

1. Technical assistance. It is projected that there will be a total of 26 man-years of resident technical assistance provided. In addition, there will be five years of home office management. Terms of reference for the proposed technical assistants are included as Annex 5.

   Provision is made for 30 man-months of short-term consultants during the life of WSARP. These are to be used for research planning, computer training, project evaluation, library planning and organization, external review, and other needs as they may be identified.

2. Participant training. USAID funding is to be utilized for training seven additional Sudanese research staff. Four would be for Ph.D degrees and three are identified for M.Sc degrees. Twenty non-degree specialized training participants are proposed for 1-6 months each.

   Proposed fields of study for the trainees are indicated as follows:

	M.Sc. Degree	Ph.D. Degree
Animal Production	1	1
Economics (Agriculture)	1	1
Soil and Water Management	1	1
Biometrics		1

3. Capital costs. USAID will fund 100% of the following project costs:

   .Research equipment for laboratory, field vehicles, and farm equipment.

   .Small purchases fund.

   .An illustrative list of anticipated equipment and vehicles for procurement is provided in Annex 6.

IBRD (World Bank). Operating costs for the WSARP aircraft.

Government of Sudan. GOS will support WSARP operations by financing the following inputs on the basis of the schedule indicated below.

	Percentage Contribution				
	1st Year	2nd Year	3rd Year	4th Year	5th Year
Local Salaries					
Budgeted funds	30	40	50	60	75
PL-480 funds	70	60	50	40	25
Recurrent Operating Expenses					
Budgeted funds	0	20	40	60	80
PL-480 funds	100	80	60	40	20

PROJECT OUTPUTS

1. Research programs have been implemented and are adequately supported at rainfed agricultural research stations in Western Sudan.

2. There is an improved human resource base for conducting research as a result of training.

3. A Field Systems Research Unit is in place at El Obeid and functioning throughout the traditional agricultural production systems of Western Sudan.

4. Field Systems Research Sections have been identified at each research station and are functioning to conduct technology testing on the farmers' fields.

5. A Training and Outreach Unit has been organized at El Obeid to provide refresher courses for WSARP Staff and develop training programs and conferences for research and extension personnel, as well as for private sector participants.

6. Research infrastructure has been complemented by purchase of transport vehicles, research equipment, and supplies.

7. The Government of Sudan will have demonstrated its capacity to continue the project after donor support is terminated.

Technical Analysis.

This project will provide GOS with the essential elements required to continue development of a viable research program in Western Sudan. Extended support for the ARC headquarters will assist the ARC in its ability to serve the research needs of the traditional farming systems of the rainfed agricultural subsector. IBRD funding of aircraft operations will ensure reliable and timely transport of staff and materials between Khartoum and the four research stations.

The research program that has been developed by the previous contractor and the ARC-WSARP scientists is related to plant and animal production techniques. The program for each research station and for the different commodities involved at these stations must be reviewed and revised where necessary to meet the planned research needs.

There should be increased emphasis on the socioeconomic base for planning research so that economically sound priorities can be placed on constraints that have been identified in previous studies or that have resulted from increased contact with the target populations.

The research conducted by Sudanese scientific staff and the AID funded technicians will be directed primarily at plant and animal production techniques. The technical specialist is to work with his Sudanese counterpart at the regional station where his expertise is of greatest importance.

In some instances, the technician must assist in development of more than one location. His responsibilities would be to assist in developing commodity programs within a production systems research context for the base station and the other appropriate satellite stations. They must assist in assuring the transmission of pertinent data and information from local sources, as well as from international data banks, to the groups planning research activities. This will help to assure relevant research programs that are not duplicating previous effort unnecessarily.

There is a continuing need for identification and selection of scientists for support in advanced training within graduate and non-degree programs. This will involve new participants who have been selected by ARC/WSARP for key planning, organization, research, and training positions with funding by USAID.

The technical approach as identified in the IBRD appraisal and developed by CID-WSU and WSARP staff[1/] remains basically sound. Changes are suggested for planning procedures by the sixth-year evaluation teams. The variations resulting from withdrawal of support from the Darfur locations have necessitated a revision of some strategies for the Darfur stations at El Fasher and Ghazala Gawazat.

Financial Analysis

The project will be jointly financed by a grant from USAID, regular budget contribution by the GOS, use of PL-480 funds, and through a grant by the IBRD. Table 1 indicates the extent of the individual contributions. Total project cost is estimated to be approximately $14.5 million.

Based on a precedent set by the initial phase of WSARP, GOS will continue to support local salaries and recurrent operating costs. By mututal agreement with the Director of WSARP, the percentage of support coming from PL-480 funds will decline over the life of the project. Budgeted funding from ARC will assume a greater proportion each year. At the project's end the entire budget will have been assumed by this source of funding.

Recurrent operating costs were supported at the 100% level in the initial phase. An incremental reduction from 100% funding to 20% support in the final year has been developed. Projected recurrent costs (Table 2) reflect a 15% inflation rate from the current situation to the anticipated end of project.

The contribution expected of USAID (Table 3) is $5,745,000. Capital costs are minimal. The major portion of the projected capital cost to be used for replacement vehicles.

The World Bank, through IBRD, will continue support for the WSARP aircraft. This support totals $800,000 over a 5-year period for the WSARP budget.

1/WSARP Publication No. 13 and 14. October 1982.

Table 1. Financing schedule (US $000).

	INPUT BY DONORS				PERCENTAGE OF TOTAL		
	IDA	AID	GOS	TOTAL	IDA	AID	GOS
I Capital Cost		600		600		100	
II Operating Cost							
Local Salaries			2411	2411			100
Recurrent Cost			5569	5569			100
Aircraft Operation	800			800	100		
III Technical Assistance		5145		5145		100	
TOTAL	800	5745	7980[1/]	14525			

1/ of the total obligation for the GOS, 47% of the salaries and 56% of the recurrent costs will come from PL-480 funds.

Table 2. Recurrent cost summary and projections for Western Sudan Research Stations and Shambat Headquarters. Fiscal year 1984-1985 through fiscal year 1998-1991. 9000 LS.1/

Station	Target Funding	Actual Funding 84/85	Budgeted Funding 85/86	PROJECTED FUNDING 86/87	87/88	88/89	89/90	90/91	Total
Kadugli	206.5	128.5	188.5	206.5	206.5	206.5	206.5	206.5	1032.5
El Obeid	1294.0	160.0	233.5	794.0	1294.0	1294.0	1294.0	1294.0	5970.0
Shambat HQ	514.0	1142.5	1461.0	1014.0	514.0	514.0	514.0	514.0	3070.0
TOTAL	2014.5	1431.0	1883.0	2014.5	2014.5	2014.5	2014.5	2014.5	10072.5
Inflation 11%/year				221	467	740	1043	1379	3850
TOTAL				2235.5	2481.5	2754.5	3057.5	3393.5	13922.5
U.S. Dollar Amount Ls2.5/$1.00				894	993	1102	1223	1357	5569

1/The recurrent costs include the cost of aircraft operation.

Table 3. USAID financing schedule (U.S. $ 000).

	86/87	87/88	88/89	89/90	90/91	TOTAL
Capital Costs						
Vehicles		100	125	100	100	425
Farm Equipment	60	65				125
Laboratory		10	10	15	15	50
Sub Total	60	175	135	115	115	600
Technical Assistance						
International Staff 1/						
(Resident)	1000	1000	1000	500	375	3875
Short-Term						
Consultants 2/	54	54	54	54	54	270
Home Office Staff 3/	50	50	50	50	50	250
Training 4/	186	186	186	132	60	750
Sub Total	1290	1290	1290	736	539	5145
					Total	5745

1/Based on 125000/man years

2/Based on 30 man months at 9000/month - includes travel

3/Includes Salary, fringe benefits and travel.

4/Degree training 17500/year. Non degree 6500/month.

Economic Analysis

At this stage of the WSARP project, there are few of the essential ingredients present on which to base a short or even medium term estimate of economic benefit to producers or to society as a whole. While some recommended and viable production methods can be developed with a few farm family cooperators, there are limitations as to how the recommendations could be transferred by the exisiting Extension Service to the bulk of farmers for their adoption. Technology transfer will then have to be stressed in the short run by other development oriented projects, that use recommendations that are developed by WSARP.

The location of the project in a remote area of Sudan where producers are served by poor roads and distant market centers minimizes viability of adaptive research which depends upon farmers being supplied with bulky and costly off-farm inputs which have to be brought overland and distributed. Also, the traditional producers, towards which this project is directed, would have little access to sources of credit at reasonable rates of interest.

Agricultural research in Western Sudan is costly, and in order for it to be economically viable, it must concentrate on programs which affect the major sources of economic livelihood by producers. The thrust, therefore, should be directed towards constraints in the production and marketing of major crops such as millet, sorghum, peanuts, and sesame; and to increase the economic offtake of cattle, sheep, and camels.

Economics of Production Systems

To encourage producer adoption, the recommendations from research must produce high marginal returns at low cost for both capital and labor. While the makeup of prioduction systems differ depending on the ecological area, Table 4 gives an illustration of one major area, that of the Qoz sands of Southern Darfur and Kordofan. Some relevant economic constraints, on which the project might seek to focus its efforts in the systems research program, are noted as follows.

1. Millet is the major food crop in this area and its improvement would have a major economic impact on the family. Of 16.6 feddans planted on the farm, this crop constituted 11.9 feddans or 72 percent of the total cultivated land. Note also that of the almost two tons that are produced, over half is eaten by the family. Yields are very low and could be enhanced by better varieties, improved fertility, and improved cultural practices. In fact, the average yield of 164 kilograms per feddan is exceedingly low when compared to against traditional systems in areas such as northern Nigeria and Cameroon and south Niger.

Studies conducted in Sudan in the 1970s[1/] concluded that in excess of 25 percent of yields of sorghum and millet were lost in western Sudan due to the effects of Striga hermonthica. Therefore, tolerant strains of millet varieties could be identified and incorporated into the on-farm trials, the resultant economic benefit would be quite spectacular. Some promising programs have been successful using ethylene and pack sprayers for application. These sprayers were furnished to ARC some years ago for experimentation. While it is known that ethylene is effective in Striga control, there is the logistic problem of local sources of pressure tanks and gas. However, if some method of control could be developed, it would eliminate the need for catch crops; or as a final solution, the abandonment of lands for long periods to permit loss of seed viability.

While Striga is increasing due to more frequency in bush fallow cultivation, another alternative is to study the economic benefit of using catch crops as a means of control.

2. Groundnuts is a cash crop and its use as a human food would increase protein and improve human productivity. Groundnuts adapt well as an intercrop and per feddan productivity can be improved of associated and follow through nitrogen availability. Inoculants are cheap and easily transportable, however while good results have been shown on experiment stations, they tend to lose their effectiveness when not kept in proper storage by retailers.

   Phosphorus applications at low levels also have appeared to be more profitable in groundnuts than other crops, and is a cheaper fertilizer to use than nitrogen. Using an analysis such a 0-46-0 tends to lower transport costs and contributes to making fertilizer a viable economic option.

3. The sale of livestock accounted for about half of the farm income received by the family (although small animals were in the form of consumption income). Its inclusion in the systems research is very important form an economic standpoint. In both sedentary and transhumant livestock systems it is to be expected that less short-run economic payoff will come about.

1/ PID, DSB/AID/W, 1978. "Proposed Research Program for Striga hermonthica," Robert Eplee, USDA/APHIS: Fred Parker, Oxford University, and Winton Fuglie, AFR/DR/AID/W.

4. While sesame is not shown as a crop in the example, it is a major crop amongst traditional producers in some areas of Western Sudan. It is commonly reported that over 30 percent of the crop is lost through shattering which would constitute a huge economic loss. Research work should therefore study the effectiveness of using the drying rack during field harvest, a common practice in the Benu Basin of Nigeria and Cameroon.

5. Family labor is often underemployed and returns per day are very low. However, additional labor must be hired during the peak seasons of weeding and harvest. The economic implications are for animal traction research to minimize hired labor in peak seasons and to increase land areas for farming by the family.

Economics of Land Use

The project should undertake studies to determine economic benefits to producers by shifting of sedentary production away form the marginal sandy soils and for their utilization primarily as grazing lands or for occasional use in bush fallow systems. While decentralization of authority for allocation of lands for mechanized agriculture has occured there needs to be some baseline information assembled to permit development of national land use policy. This would assist in the prevention of land degradation and would tend to protect the rights of transhumants, nomads and sedentary farmers. (See Document No. 3, "Analysis of Mechanized Rainfed Agricultural Research," for a more detailed discussion of the depth and extent of this problem.)

Technology Transfer and Input Distribution

Document No. 3 mentioned above indicates that there has been a past history of rapid production response to economic incentives by the mechanized rainfed farming sector in Sudan. Also, that the is a better communication between producers, better market institution, credit facilities, and better extension services through activities of the Mechanized Farming Corporation.

If the Mechanized Rainfed Research Project is initiated, there is a component suggested for the establishment of Farm Service Centers to provide agric-business services. It is believed that the traditional sector could not support such centers on its own. Traditional procedures could also benefit it the centers were strategically located, and if sufficient sub-agents were contracted to provide services to them. This could involve credit and sales for animal drawn equipment, livestock diet supplements, cattle dip treatment, internal parasite medication, pesticides, hand sprayer rental, small irrigation equipment, seed dressings, improved seeds, legume inoculants, and possibly fertilizers.

Table 4. Farm budget, Qoz Land System, Southern Darfur, 1985 prices.

Gross Return Crops	Area (fed)	Yield (kg)	Prod. (kg)	Value (Ls)	Gross Return (Ls)
Millet	11.9 @	164 =	1950 X	333 =	649.9
Sorghum	0.7 @	240 =	.168 X	220 =	37.0
Groundnut	3.8 @	282 =	1072 X	620 =	664.6
Misc.	0.2			=	100.0
Sub Total	16.6				1451.5
Livestock					
Cattle	1.5 head x 7 pct = 1 head @ Ls 400.0 =				400.0
Sheep	4 head x 25 pct = 1 head @ Ls 75.0 =				75.0
Salvage (dead,cull) 1/					240.0
Sub total					715.0
Grand Total					2166.5
Home consumption 2/					724.1
Gross cash income					1442.4
Cost of Production:					
Seed 3/					69.8
Tools					10.0
Sacks					82.0
Drugs					2.0
Hired Labor 4/					158.8
Misc. Production costs					30.0
Total costs					352.6
Net cash income for farm family labor					1089.8

1/ Equivalent of 1.5 head per year, sold at 40 percent of market value.

2/ Per family of six 1 mt of millet, 30 percent of groundnuts, 80 pct of misc. and all small stock off-take.

3/ 6 kg/ha for sorghum and millet, and 60 kg/ha for groundnuts.

4/ 106 man-days of peak-season labor and 21 man-days off-season labor

Source: WB Staff Appraisal, Krt. Sudan, WSP, Phase II, Nov. 1985.

Social Feasibility

This project seeks to address the economic and technical problems facing the various production systems of traditional farm families of Western Sudan. Through a systems approach the researchers will seek to understand, and to work within the social and cultural norms which now exist in order to find viable solutions to production problems which face traditional farm families.

Critical to the successes of such research is the participation of socioeconomic analysts. The continued participation of such disciplines on the systems research teams at the western stations will ensure that sociological considerations are incorporated into each technical package.

The previous WSARP project sociological studies identified a number of facts concerning division of labor by sexes, age groups, work teams, etc. which will have to be taken into account when working with production systems in the villages. Also, the ownership and control of land is not always vested in the male head of the family. Women play a major role in decision-making, and it is essential that WSARP employ women on the production research teams to work with the female producers.

Social acceptability of WSARP hinges on whether the research can identify the means by which productivity can be enhanced in the major food crops that are consumed. With at least 90 percent of the family labor now devoted to production of subsistence cereals and livestock, it is imperative that major research be concentrated on crops such as millet, as well as livestock improvement.

The degradation of the land base in many parts of the project area is causing pressure on land resources through a southward movement of many families whose original farm lands were in marginal production areas. Research must identify ways by which fragile lands can be preserved and restored, so as to minimize the effects of social and economic pressure on the better lands now being farmed at greater and greater intensities.

THE IMPLEMENTATION PLAN

The Implementation Schedule (Table 5) is somewhat simplified and illustrative of proposed WSARP activities. The Project Director and the team leader (when designated) will prepare a more detailed schedule for implementation of research activities, training, and procurement.

Table 5. Implementation schedule.

	FY 87	FY 88	FY 89	FY 90	FY 91
Training 4 to Ph.D. level	X	X	X	X	
Training 4 to M.Sc. level	X	X	X	X	X
Team Leader	X	X	X	X	X
Agricultural Economist	X	X	X		
Agronomist	X	X	X		
Livestock Specialist	X	X	X		
Biometrician	X	X	X		
Soil and Water Management	X	X	X	X	
Administrative Support	X	X	X	X	X
Home Office Support	X	X	X	X	X
Annual Evaluation and Planning	X	X	X	X	X
Detailed Research Planning	X	research in progress			

Evaluation plan. An evaluation will be conducted at the end of year two to review the research and plan for years three through five. A final review in year five should provide an analysis of project achievements.

CONDITIONS AND COMMITMENTS

The following conditions precedent to disbursement will be included in the Grant Agreement.

1. An executed agreement committing the IBRD to contribute to WSARP in the approximate amount described in the financial plan.

2. Evidence that the GOS accepts the responsibility for assumption of local salary support and operational expenses on a step-by-step basis over the life of the Project.

3. Approval by USAID of specific equipment and vehicles to be financed under the grant and certification by AID that the cost estimates for equipment and furnishings are reasonable.

ANNEX 1

Amended Project Paper

Composition and Function of the
Field Systems Research Unit

Composition and Function of the Field Systems Research Unit

A Field Systems Research Unit (FSRU) is an integral and continuing part of any research program. It is a team of scientists that is constantly identifying constraints and testing innovations. They monitor what happens to the microsystem (the farmer), as well as the macrosystems (groups of farmers, villages, sectors, regions, etc.). They conduct surveys and continuing benchmark analyses in order to know what trends are occurring, but more importantly, they are both the diagnostic and testing arms for production systems research.

The FSRU will select farmers, producers, herds, etc. as their experimental units and continue with these as long as feasible. Some farmers may be dropped, others added as the work progresses and other parameters in the system within which one is working become important. The FRSU technicians do not carry out disciplinary research themselves on the problems and constraints they identify. They transfer the problem to the core scientists (mostly disciplinarians) at the research center who work on either a disciplinary basis or an interdisciplinary basis, whichever the problem requires. When an answer or intervention is available from the core scientists, it then goes back to the FRSU for testing in the system.

The ideal situation is to have a concurrently "Systems Modeling Team" (SMT) that is taking field data from the FSRU and modeling (computer modeling) the system "on paper." The connection between the FSRU and the SMT is a recurring one where information flows both ways and a continuous process of "feed-in" and "feed-back" occurs. This may be a bit advanced for WSARP, but if a systems oriented University such as the University of Florida became interested they could act as the SMT.

It is possible to make an important distinction between the persons on the FSRU and other research scientists. Members of the FSRU should not be highly trained specialists but rather "disciplinary generalists." They may have an M.Sc. or perhaps only a B.Sc. and are interested in research from a general point of view and not from a particular special interest.

The FSRU should have a basic team of three to four people, each from a desired discipline, but in addition there can, and probably should be, intermittent inputs from other scientists. For example, a full-time economist, veterinarian, or soils scientist may not be necessary on the team but having one make periodic inputs or take periodic information is productive. In a mixed crop-livestock system, it is desirable to include an agronomist, a social scientist, and an animal scientist on the team. Their work would basically be in the field, not necessarily living in a village or transhumant camp (although at times, that is desired and even required to get information) but being frequently in contact with the experimental units. This team should be guided by a

ANNEX 2

Amended Project Paper

Field Systems Research Sections

Field Systems Research Sections.

In the WSARP Project schedule just completed, one of the research constraints was the lack of adequate support to successfully conduct on-farm research. The lack of support was reflected in much time spent by senior researchers in the organizational work necessary for conducting such research with farmers. The result was that only a few trials were established, and not all were carried to completion. It has indicated the necessity of having at least one Field Systems Research Section (FSRS) organized at each of the four research sections in Western Sudan. Administratively, these Units would be responsible to the Station Director. The work responsibilities for the FSRS would be jointly planned and supervised by the Field Systems Research Unit at El Obeid and by the local station.

The FSRS concept has worked successfully in similar projects which involve working in the village environment. Roles assigned to such units include the following:

1. **Assist in the implementation of diagnostic, benchmark, and result surveys.** Using sampling techniques and questionnaires developed by the systems research team, the production units would conduct surveys of farmers and households. It would collate the data and make summaries. Such surveys would usually be done in the dry season when field work on actual trials would not be as demanding.

2. **Organize village support groups.** In order for researchers to work effectively in traditional farming systems, it is imperative that adequate groundwork preparation be done through the village support group. The success of these groups as a "sounding board" and to provide peer pressure is the identification of leadership roles both by the local chief and his elders, as well as the "nafeers" which is the traditional work group organized for performing field and herding tasks. It cannot be overstated that the success of systems research with individual farm families rests with the sponsorship of such groups. Feedback from the group is received as to acceptability of the change in technology that is being proposed, or the listing of further constraints which need to be addressed before making general recommendations to extension for teaching the target population of farmers.

3. **Facilitate the establishment of systems research work with individual farmers and general on-farm trials.** It has been found that there is considerable supervision and coordination required to get field trials established with farmers. Cooperators and sites need to be carefully selected and identified which represent the norm for the system to be studied. Farmers, their wives, or nafeers need to be trained in how to do such practices that are necessary to successfully establish the trials. Also, supplies need to be

brought to the site, plots measured, and follow-up visits made to ensure that the trial was established and operated according to the directions given. Usually a member of the team should actually be on the site at the time of establishment to ensure that it is done properly.

4. **Supervision during the growing season.** There will be a series of practices which need to be carried out during the growing season. Without at least weekly supervision and reminders, the farmers tend to forget or ignore the practices which they were advised to do. While it is assumed that farmers might do this on their own, previous experience has shown that they need constant encouragement. If necessary, the team refers back to the leadership group which sponsored the trial in order to get support in the form of peer pressure.

5. **Evaluation of results.** The Field Systems Research Section would be on hand to assist when harvest is taking place in order to measure the results that were obtained. The village support group and the cooperator(s) are then queried to obtain the necessary feedback.

In all cases, the supervision and training of the FSRS is under the FSRU from El Obeid. It is recognized that by having a FSRS working in the villages, a certain amount of technology transfer will be taking place. Researchers should encourage the enthusiasm of the team by testing technology at the research station, but only technology packages which have been previously tested by the FSRS team and found successful should be disseminated to the target populations.

Personnel components of the FSRS. A specialist in crop or livestock production should be designated as leader of each team, depending upon the nature of the production systems within which the team is functioning. Input from social scientists is essential in training for and planning on-farm research activities. The team leader should hold an M.Sc. degree in his particular discipline area. The remainder of the team (three or four persons) do not necessarily need that level of training. Motivation and enthusiasm to work with people and improve their standard of living is more essential than advanced degrees. Certainly, need for specialized training by the FSRU at El Obeid is apparent. This will ensure that the section will plan and conduct its work activities in a manner that contributes to total research program objectives.

Support for the Unit. It is essential that the Field Systems Research Sections have access to adequate transportation. Funds for petrol and travel expenses must be assured. In certain situations motorcycles equipped with a metal box to transport seed, scales, small equipment, or chemicals have been adequate. In circumstances where work sites are widely dispersed over large areas and where team approaches are needed at the site, the use of pickups or vans will be more effective.

ANNEX 3

Amended Project Paper

Logical Framework Matrix

LOGICAL FRAMEWORK MATRIX - AMENDED PROJECT PAPER

ANNEX 3

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATIONS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Goal: Increasing agricultural production and rural development in Sudan.	Measures of goal achievement: 1. Increases in food and livestock production. 2. Increased rural incomes.	GOS statistics and field surveys of household income.	1. GOS developmental and budget priorities stress agricultural production and development of rural sector. 2. Precipitation remains normal. 3. An improved infrastructure exists to stimulate food production by agricultural producers.

LOGICAL FRAMEWORK MATRIX - AMENDED PROJECT PAPER

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NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Subgoal: An increased standard of living for farmers and pastorilists of the rainfed agricultural sector of West Sudan.	Measures of Goal Achievement: 1. increased production of major agricultural crops of the rainfed sector. 2. Sustained increases of livestock offtake from nomadic transhumant, and sedentary production systems.	1. Socioeconomic studies 2. MANR annual statistics reports.	Subgoal Assumption: 1. That GOS will continue to support agricultural research and provide funds for recurrent costs at an increasing rate over the life of the project. 2. That agricultural research will be a key stimulant to increasing agricultural production. 3. Sources of water can be developed for both human and livestock use, as well as for use in certain agricultural technologies.

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Purpose: To develop within ARC an effective capability for planning and implementing relevant agricultural research programs in the rainfed agricultural sector of Western Sudan.	Conditions that will indicate purpose has been achieved EOPS: A research staff in place at ARC that is: 1. Capable of identifying and prioritizing constraints to production systems. 2. Can plan interdisciplinary and implement research programs to solve the constraints, and 3. Will demonstrate these solutions to target populations.	Contractor reports, project evaluations, ARC annual reports.	Purpose assumptions: that qualified staff can be trained and be willing to work at research assignments in the rainfed agricultural sector.

PROJECT OUTPUTS	MAGNITUDE OF OUTPUTS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
1. Research programs have been implemented and are adequately supported at rainfed agricultural Sudan.	1. Traditional agricultural production systems of West Sudan are benefited by farm systems research programs functioning at four locations in West Sudan - El Obeid, Kadugli, El Fasher and Ghazala Gawazat.	1. Published reports and site visitations.	1. That personnel now in training will be staffing the research stations as planned and that they will continue to work at remote locations.
2. There is an improved human resource base for conducting research as a result of participant training.	2. Seven Sudanese are trained to graduate degrees - 4 Ph.D. and 3 M.Sc. degrees. Twenty Sudanese have benefited from non-degree training.	2. Diplomas or certificates awarded by training institutions or agency.	2. Staff persons can be identified and released for training.
3. A Field Systems Research Unit is in place at El Obeid and functions to provide prioritized constraints to the researchers and to evaluate the impact of specific interventions on the various agricultural production systems.	3. A Field Systems Research Unit is functioning at El Obeid to support Research Stations in Western Sudan.	3. Project evaluations and contractor reports.	3. That staff can be identified and trained to function as a field systems research unit.
4. Production Research Units have been identified at each station and are functioning to conduct technology testing on the farmers field.	4. Production Research Units have been identified and are functioning at the various stations.	4. Project evaluation. Annual research reports Contractor reports.	4. That staff can be identified and trained for "on farm" production research units.
5. A training and outreach unit has been organized at El Obeid for training staff and planning and organizing conferences and work shops.	5. Training of all research scientists in use of the personal computer is completed. A workshop concerned with research planning in each of the Agricultural production systems of Western Sudan have been sponsored and proceedings published.	5. Proceedings from workshops and conferences. Contractor reports.	5. That adequate support and technical assistance is available to develop training programs and workshops.
6. The research infrastructure is complete after the purchase of vehicles, research equipment, and supplies.	6. The inventory of vehicles and research equipment is of sufficient magnitude that it can no longer be considered a constraint to research activities.	6. Inventory lists.	6. That equipment and vehicle needs have been correctly identified.

PROJECT OUTPUTS	MAGNITUDE OF OUTPUTS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
7. The Government of Sudan will have demonstrated its capacity to continue the project after donor support is terminated.	7. The budget for ARC will be sufficient to sustain all of the activities of the research stations in Western Sudan.	The published budgets for ARC/WSARP.	7. That the Ministry of Finance and Economic Affairs will approve scheduled budget increases.
PROJECT INPUTS			
USAID will finance 26 man-years of resident technical assistance and 5 man-years of home office management Provision is made for 30 man-months of short-term consultant assistance. Participant training for 7 graduate degrees and 20 persons for non-degree training is planned. Operational costs including local salaries and recurrent costs. Capital costs for laboratory equipment, vehicles, and farm equipment will be essential.	MAGNITUDE OF INPUTS See Table 1, 2, and 3 of Financial Analysis	Audit Reports	

ANNEX 4

Amended Project Paper

Soils Resource Inventory, Land Evaluation
and a Land Use Database

SOILS RESOURCE INVENTORY, LAND EVALUATION AND A LAND USE DATABASE FOR THE DEMOCRATIC REPUBLIC OF SUDAN

A Project Proposal

Presented by

SOIL MANAGEMENT SUPPORT SERVICES

of the

AGENCY FOR INTERNATIONAL DEVELOPMENT

March 26 1986

Table of Contents

Soils Resources Inventory, Land Evaluation and a Land Use Database for the Democratic Republic of Sudan

1 Land Evaluation - Objectives of the Cooperation Request

An increasing number of questions have to be answered at present by the Soil Survey Administration of the Democratic Republic of Sudan's Ministry of Agriculture. Among them are: what are the potentials of land types in a development area and what is their acreage? What is the technology to be used on the land? What crops will produce the highest returns on a given land type? Which land is best suited for a particular crop? Based on accumulated knowledge the Soil Survey Administration (SSA) wants to increase its capacity to provide these services.

As a basis for the land evaluation and land use database system, the Sudan SSA needs to have a complete soils resource inventory at a scale of 1:1,000,000. In this respect SSA, with the help of the Soils Geography Unit (SSA/USDA), is in a good position to compile a Sudan soil map using *Soil Taxonomy* as a reference system. This map would be a generalized map based on all existing soil survey information now available for Sudan, complemented by extrapolation on remote sensing data.

SSA has already made one important contribution related to *Soil Taxonomy*, the USDA system of soil classification. SSA cooperated in the organization of the Fifth International Soil Classification Workshop in 1982.

The Sudan Soil Survey Administration needs to continue strengthening its capacity to provide vital information on land resources in a fast way, and therefore feels the need to train personnel in handling soil and land information by computers. It is through the establishment of a land evaluation database that the SSA will be able to use most effectively its soils and agronomic data which has been acquired and compiled though much time and effort but until present has not been used to its fullest potential.

After the compilation of the soils resources map at 1:1,000,000 what is needed next is to produce optimum benefits from the available soils and land use information. A specialized training of technical personnel at all levels to develop a land resources database processing unit, which would promote interactions between soil scientists, agronomists and planners is proposed.

To achieve these purposes, and as a necessary corollary to the proper functioning of a land resources database processing unit, it would be desirable to obtain, on a cooperative basis, outside institutional help preferably SMSS and the USDA/SCS Soils Geography Unit to compile the 1:1,000,000 *Soil Taxonomy* soils resources map. In addition, a U.S. university would develop and install a fully functioning database system tailored to the needs of the Sudan SSA. The SCS Soils Geography Unit, a cooperating institution, would be responsible for helping in remote sensing and the compilation of the 1:1,000,000 soils resource map. The

university department would assist in the development of the soils database and land evaluation software and also be responsible for training SSA technicians in its use.

Specialized software and training is not currently available in Sudan. The present request outlines the actions to be taken to achieve these goals and increase the expertise of the Sudan SSA.

2 Compilation of a 1:1,000,000 Soil Taxonomy Map of Sudan

Land evaluation needs a secure resource database from which to derive a set of land qualities information to be used in the land evaluation matching tables. The Sudan Soil Survey Administration with the cooperation of the USDA/SCS Soils Geography Unit with all the available soils resource data and supplementary remote sensing data sources (to be determined) will compile a 1:1,000,000 generalized soils map with units named by *Soils Taxonomy*.

3 Land Evaluation Procedures

Land evaluation is in fact a comparison between the qualities of land types and crop requirements (or other uses). While most agricultural planning is concerned with crops, the same procedure may be used for city or regional planning, the selection of recreational areas, or other uses.

Land evaluation requires predictive measure of the benefits a farmer, a community or a country may obtain from land with the inputs it is willing to pay. Theoretically, any kind of land use is possible for a given piece of land, but only a few are practical. Land evaluation is only complete when it involves comparison between alternative uses, to allow decision makers to make the best choices.

Cooperation from agronomic divisions at the SSA to assess crop requirements is warranted. These objectives and principles are the basis for a practical procedure which make land evaluation a reproducible data-processing system to achieve more accurate results. A computerized "expert system" is the best choice.

3.1 Land Evaluation as an Expert System

Expert systems incorporate experience from a great number of sources, accumulated during many years, into the central core of a computer program, and use it to make decisions and judgements on a number of questions and issues. In land evaluation programs, the "experience" is summarized in the "matching table," which the evaluator prepares for a given land-use or crop.

One of the objectives of this assistance request is to select the best available system to build and incorporate agronomic experience in the database. United States institutions have the expertise to help the Soil Survey Administration to make the right choices in the software which various U.S. agencies and institutions have already been using.

3.2 Land Data Sets

The Soils Survey Administration has been gathering soil resource information for many years. And they have been introduced to using the USDA *Soil Taxonomy* classification system to name the mapping units of their soil surveys in the Fifth International Soil Classification Workshop in November 1982. Soil survey results are now also nearing completion for a large area of the country.

This basic information will now have to be confronted with crop performance data produced in agro-ecological zones of Sudan, and combined in a land evaluation database system. The Soil Management Support Services (SMSS) is asked to provide guidance in the preparation of 1:1,000,000 soils resources map and in the preparation of a relational database system to achieve the land evaluation objectives.

3.3 The Matching Tables

To produce a matching table the major crop requirements, and the responses of these crops to changes in land qualities or new technologies have to be known. The response curves of the crops to variations in the land qualities are to be qualified.

A matching table incorporates the effects of growth factors on the performance of a crop. Each matching table is specific for a particular crop, under a given set of conditions, which may relate to a broad variety of production factors, marketing conditions, etc. The SSA's division's cooperation will be necessary to obtain the crop performance data needed to build in each agro-ecological zone the matching tables for the most important crops.

4 Project Implementation and Duration

It is anticipated that the project will last two years from the time of inception. This should allow ample time for the compilation of the *Soil Taxonomy* soils resource map and for the development of the database/expert system and the training of Sudanese technicians to use and maintain the expert system after it is transferred to Sudan.

Since the project is envisaged as a cooperative arrangement between the Sudan Soil Survey Administration and SMSS (and its contracted institutions), it is necessary to delineate the responsibilities of each cooperator.

4.1 Sudanese Contribution

The Sudan Soil Survey Administration will provide three technician/trainees for four months each for land evaluation training and in the formulation of the database/land evaluation software at the cooperating U.S. institution. These trainees will also aid the Soil Survey Administration and the SCS Soils Geography Unit in the compilation of the *Soil Taxonomy* soils resources map. They shall visit several cooperating SMSS institutions and will cooperate in the selection and tailoring of the software system.

The Sudan Soil Survey Administration (assisted by the SCS Soils Geography Unit) will be responsible for the gathering of information and the compiling of the 1:1,000,000 soils resources map. (Supplementary remote sensing data and training in the use of this data will be provided by SMSS and/or its cooperating institution, the Soils Geography Unit.)

The Soil Survey Administration will also provide services for gathering,. selecting, editing and maintaining all the local Sudan soils, agronomic and land use data in order to test the database/land evaluation system.

The Soil Survey Administration will provide office space for the compilation of the soils resources map and installation of the database/land evaluation system. The space allocated will conform to the needs of the map compilation task and the complete computer system and staff necessary for its operation and maintenance.

Transportation and travel expenses for field checking of the soils resources map and validation of land evaluation programs in the field will be provided by the Soil Survey Administration.

4.2 SMSS Cooperating Institution Contributions

SMSS will facilitate involving the SCS Soils Geography Unit and a suitable university in the U.S. From past experience in other SMSS cooperative projects Cornell University's Department of Agronomy would be a very competitive candidate.

The SCS Soils Geography Unit will aid in training the Sudanese technicians in the uses of remote sensing to extrapolate the classification of soils of unknown areas based on knowledge from existing surveys and other projects. This university department will help to set up a database system for soils to be used in the land evaluation project.

The cooperating university will also be asked to assist in the selection and development of microcomputer hardware/software. Overall, the project will be coordinated in the U.S. by the database managing specialist at the university in cooperation with SMSS and the SCS Soils Geography Unit.

The cooperating institutions both will also be responsible for the

training of the Sudanese technicians. This will include round-trip travel between the U.S. and Sudan and a stipend to cover educational and living expenses.

The cooperating institutions will provide consultants for a total of eight months (four visits of two months each) in Sudan. These consultants will be responsible for helping in the compilation of the soils resources map and installing the hardware/software and on-the-job training of Soil Survey Administration staff.

4.3 Products

The first Product will be a 1:1,000,000 soils resources map with map units names according to *Soil Taxonomy*.

Products, in addition to the installed and functioning soils database/land evaluation system, will include an atlas of land evaluation maps of the surveyed areas of Sudan. The land uses or crops forming the bases of the land evaluation will be determined by the Soil Survey Administration. The interpretive maps will indicate suitability classes for the major crops.

4.4 Timetable

In the first year project members and cooperators will concentrate on compiling and finishing this 1:1,000,000 soil resources map and strengthening the soils analyses laboratory of the SSA. Also, during this period land use and management data should be assembled for input in to the land evaluation database.

The second year will be devoted to refining the land evaluation expert system and database, training SSA staff in it use, and inputting soils resources, land use and management data. Field checking and refinement of the system is also included in this time period.

5 Appendix - Budget

1. Personnel:

- Consultants (9 mos.)	$60,000
- Database manager specialist (9 mos.)	26,145
- Computer programmer (9 mos.)	22,410
- Secretary (9 mos.)	10,272
- Temporary (2 mos.)	4,000
Total	$122,827

2. Sudanese trainees:

living stipend: 3 trainees x 4 mos. x $900/mo.[1] = $10,800
training fee: 3 trainees x 4 mos. x $650/mo.[2] = 7,800

Total $18,600

3. Compilation of soils resources map - SCS Soil Geography Unit:

- purchase and use of remote sensing imagery and systems
- training Sudanese technicians in use of the imagery
- final compilation of the soils resources map
- sampling and analyses of 30 pedons

Total $200,000

4. Use of computer system - hardware and software:

- Lease of IBM systems for optimum use of software transferred to Sudan:

basic systems lease:	$10,000
use of professional geographic information systems software:	$10,000

- ample supply of diskettes and tapes: $ 1,000
- coverage of software maintenance fees: $ 1,000

Total $22,000

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1. AID regulation rates.

2. AID regulation rates.

5. **Materials and supplies:**

- estimate $30/mo. for copying = $900[3]

- paper, printing cartridges, other office supplies estimated at $100/mo. = $3000[4]

Total $ 3,900

6. **Telephone, communications and postage:**

- Telephone, telexes, etc., $150/mo. = $4,500[5]

- postage at $50/mo. = $1,500[6]

Total $ 6,000

7. **Travel:**

- three trainees roundtrip Khartoum/Ithaca:
3 x $2700 = $8,100

- four consultant roundtrip Ithaca/Khartoum:
4 x $2700 = $10,800

- per diem, Khartoum:
8 mos. x 30 days x $180/day = $43,200

Total $62,100

8. **Drafting of maps and reports:**

- drafting and complete preprinting preparation of land evaluation atlas including report text (10 mapsheets at 1:1,000,000), at $1000/sheet (final printing to be handled in Sudan) = $10,000

Total $10,000

9. **Equipment and laboratory glassware for Soil Survey Administration soil characterization lab:**

Total $50,000

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3. For 2 1/2 yrs.
4. For 2 1/2 yrs.
5. For 2 1/2 yrs.
6. For 2 1/2 yrs.

10. Administrative costs:

- custodial		$ 9,885
- library		$ 9,885
- secretarial pool		$ 9,885
- accounting services		$ 9,885
	Total	$39,540
	Total	$534,967
25% overheads (SMSS and cooperating institution(s))		$133,742
	Grand Total	$678,709

6 Payment Schedule

- First six months: $250,000
- Second six months: $200,000
- Third six months: $128,709
- Fourth six months: $100,000

ANNEX 5

Amended Project Paper

Terms of Reference
for
Proposed Technical Assistants

Terms of Reference for
Team Leader
and
Farming Systems Research Specialist

A. Duties and Responsibilities

This position is to be filled by a qualified scientist who has specialized in Systems Research. Experience in mixed farming activities in arid environments is preferable. This specialist will also be designated as Team Leader for the resident expatriate staff. The person will be stationed at El Obeid, although his duties will require him to undertake research and other activities throughout Western Sudan. The appointment will be for five years.

Specific responsibilities include:

1. Serve as an advisor to the Director and Deputy Director of ARC/ WSARP in matters relative to research administration and planning.

2. Assist the Director and ARC personnel in selection of international scientists and Sudanese staff for WSARP activities.

3. Assist the Director in preparation of required reports to contractor, donor, and Government of Sudan.

4. Encourage and assist the Director to maintain contacts with International Agricultural Research Centers.

5. With assistance from the Director and the Deputy Director, identify components and train personnel of the Field Systems Research Unit (FSRU), as well as monitor their activity in the field.

6. Provide direction for the Director and WSARP staff in using inputs from the FSRU in developing and prioritizing research activities.

7. Cooperate with Sudanese scientists to ensure that the capacity to design and implement a research program is transferred.

8. Assist in transition of project activities to a continuing research effort, including briefing of new research scientists, and identify critical follow-up issues and recommendations for the research agenda.

The Director may adjust and/or extend these responsibilities within these general terms of reference.

B. Reporting and Planning Requirements

The Team Leader and Farming Systems Research Specialist will:

1. Prepare program for training of the FSRU at El Obeid.

2. After approval for the program by the Director of WSARP, implement training activities.

3. Work with the FSRU as it makes its plans for beginning activities.

4. Assist the FSRU to implement programs for the farm production systems at all four of the WSARP locations.

5. Encourage Sudanese staff to analyze data collected by the FSRU and utilize it for identifying constraints and prioritizing research.

6. Report on progress of these activities at the appropriate times.

7. Assist the WSARP Director to compile regular reports required by the contracting agency.

C. Relationships

The project will be implemented through the Agricultural Research Corporation. Consequently, the Team Leader will work cooperatively with and under the general supervision of the WSARP Director.

Terms of Reference
For
Agriculture Economist

A. Duties and Responsibilities

This position will be filled by a highly qualified agricultural economist with experience in farm production systems within developing countries. He must have experience in the design, validation, and use of farm survey instruments and possess the skills necessary to analyze the data from them. The Agricultural Economist will be stationed at Kadugli but will undertake and evaluate research activities on other project stations. The appointment will be for three years. Specific responsibilities include:

1. In consultation with the Project Director and other staff scientists, assist in determination of research priorities and take prime responsibility for incorporating economic analysis into the research program. Particular emphasis should be given to building upon research findings to date.

2. Plan and implement a research program with the support and input of other scientists to assure that findings include complete technical input from all relevant disciplines.

3. Create opportunities to participate in practical extension of technology packages to farmers, merchants, farmer cooperatives, and other groups capable of adopting or commercializing research products.

4. Maintain contact and coordinate with relevant units of the Ministry of Agriculture and Natural Resources, the ARC, and other USAID and donor projects either engaged in similar work or capable of using their resources to test or disseminate research products.

5. Maintain contact and coordinate with international institutions (particularly the IARCs and analytic centers) to assure a constant inflow and exchange of new technical information and maximize the potential to build upon basic findings.

6. Cooperate with Sudanese scientists to ensure that the capacity to design, implement, and analyze/evaluate a research program is transferred. The scientist must keep in mind that a primary objective is training of counterparts, although the training will be informal and on-the-job.

7. Assist in the transition of project activities to a continuing research effort, including briefing of new research scientists, identification of critical follow-up issues, and recommendations for the research agenda.

The WSARP Director may adjust and/or extend these responsibilities within these general terms of reference.

B. Reporting and Planning Requirements

The Livestock Specialist will:

1. Prepare a research plan (following a review of relevant research carried out in-country or by the IARCs) for his technical specialty and then work with the scientists in other disciplines to integrate this plan into a comprehensive research program.

2. Prepare a report on research findings at the end of each agricultural season (including an assessment of their potential contribution) and participate, and perhaps lead, in the preparation of the annual station report.

3. Participate, or perhaps lead, in the preparation of recommendations on technical packages emanating from past and current research findings.

4. Prepare any other papers/reports as may be appropriate or requested by the WSARP Director.

C. Relationships

The Livestock Specialist will work under the day-to-day supervision of a Sudanese Station Director in Kordofan Region of Western Sudan, and under the overall supervision of the WSARP Director.

Terms of Reference
for
Soil and Water Use Specialist

A. Duties and Responsibilities

This position will be filled by a scientist with high scientific qualifications in soil science. Extensive field experience in arid agricultural zones with land and water use planning and conservation, including field experience in developing countries, is preferred. In addition, this person must have experience with field research projects, working with scientists in other related disciplines such as agricultural economics, livestock and crop production, and civil and water engineering. The Soil and Water Use Specialist will be stationed at El Obeid, but will undertake and evaluate research activities on other project stations. The appointment will be for four years. Specific responsibilities include:

1. Review previous research programs applicable to the rainfed sector, with special emphasis on Western Sudan, and help identify major findings requiring further development.

2. Identify research findings from the International Agricultural Research Centers that hold promise for adaptation to conditions prevalent in Western Sudan and integrate these into the research program.

3. Taking into account points 1 and 2 above and in consultation with other staff scientists, assist in determining research priorities within the scientist's discipline and for the research station.

4. Implement the approved research program and, with the support and input of other scientists, assure that findings include complete technical input from all relevant fields.

5. Create opportunities to participate in practical extension of technology packages through on-farm demonstrations (or other means) to farmers, merchants, farmer cooperatives, and other groups capable of adopting or commercializing research products.

6. Maintain contact and coordinate with relevant units of the MANR, the ARC, and other donor projects either engaged in similar work or capable of using their resources to test or disseminate research products.

7. Maintain contact and coordinate with international institutions (particularly the IARCs and analytic centers) to assure a constant inflow and exchange of new technical information and maximize the potential to build upon basic findings.

8. Cooperate with Sudanese scientists to ensure that the capacity to design and implement a research program is transferred. The Soil

and Water Use Specialist must keep in mind that a primary objective is training of counterparts, although the training will be informal and on-the-job.

9. Assist in the transition of project activities to a continuing research effort, including briefing of new research scientists, identification of critical follow-up issues, and recommendations for the research agenda.

The WSARP Director may adjust and/or extend these responsibilities within these general terms of reference.

B. Reporting and Planning Requirements

The Soil and Water Use Specialist will:

1. Propose a research plan (following a review of relevant research carried out in-country or by the IARCs) for his technical specialty and then work with scientists in other disciplines to integrate this plan into a comprehensive research program.

2. Prepare a report on research findings at the end of each agricultural season (including an assessment of their potential contribution) and participate, and perhaps lead, in the preparation of the annual station report.

3. Participate, and perhaps lead, in the preparation of recommendations on technical packages emanating from past and current research findings.

4. Prepare any other papers/reports as may be appropriate or requested by the Director of WSARP.

C. Relationships

The contractor will work under the day-to-day supervision of a Sudanese Station Director in Kordofan Region of Western Sudan, and under the overall supervision of the WSARP Director. The project is implemented through the ARC which is the institution responsible for all agricultural research in Sudan.

Terms of Reference
for
Agronomist

A. Duties and Responsibilities

This position will be filled by a qualified agronomist who is experienced in mixed farming activities (livestock and crop production in integrated systems) in arid environments. In addition, this person must have experience with field research projects, including collaborative research with scientists in related disciplines. This specialist will be stationed at Kadugli, but will undertake and evaluate research activities on other project stations. The appointment will be for three years. Specific responsibilities include:

1. Review previous research programs applicable to the rainfed sector, with special emphasis on Western Sudan, and help identify major findings requiring further development.

2. Identify research findings from the International Agricultural Research Centers that hold promise for adaptation to conditions prevalent in Western Sudan and integrate these into the research program.

3. Taking into account points 1 and 2 above and in consultation with the other staff scientists, assist in determining research priorities within the scientist's discipline and for the research station.

4. Implement the approved research program and with the support and input of other scientists, as appropriate, to assure that findings include complete technical input from all relevant fields.

5. Create opportunities to participate in practical extension of technology packages through on-farm demonstrations (or other means) to farmers, merchants, farmer cooperatives, and other groups capable of adopting or commercializing research products.

6. Maintain contact and coordinate with relevant units of the MANR, the ARC, and other donor projects either engaged in similar work or capable of using their resources to test or disseminate research products.

7. Maintain contact and coordinate with international institutions (particularly the IARCs and analytic centers) to assure a constant inflow and exchange of new technical information and maximize the potential to build upon basic findings.

8. Cooperate with Sudanese scientists to ensure that the capacity to design and implement a research program is transferred. The scientist must keep in mind that a primary objective is training of counterparts, although the training will be informal and on-the-job.

9. Assist in the transition of project activities to a continuing research effort, including briefing of new research scientists, identification of critical follow-up issues, and recommendations for the research agenda.

The WSARP Director may adjust and/or extend these responsibilities within these general terms of reference.

B. Reporting and Planning Requirements

The crop scientist will:

1. Prepare a research plan (following a review of relevant research carried out in-country or by the IARCs) for his technical specialty and then work with the scientists in other disciplines to integrate this plan into a comprehensive research program.

2. Prepare a report on research findings at the end of each agricultural season (including an assessment of their potential contribution) and participate, and perhaps lead, in the preparation of the annual station report.

3. Participate, or perhaps lead, in the preparation of recommendations on technical packages emanating from past and current research findings.

4. Prepare any other papers/reports as may be appropriate or requested by the Director of WSARP.

C. Relationships

The crop scientist will work under the day-to-day supervision of a Sudanese Station Director in Kordofan Region of Western Sudan, and under the overall supervision of the WSARP Director. The project is implemented through the ARC which is the institution responsible for all agricultural research in Sudan.

Terms of Reference
for
Biometrician

A. Duties and Responsibilities

This position will be filled by a qualified biometrician who has experience in planning and analysis of agricultural research programs and projects. The experience should include past activities in developing countries.

Preference will be given to a biometrician who has capability in modeling production systems. The appointment will be for three years. The position is to be established at El Obeid.

Specific responsibilities would include the following:

1. The biometrician would serve as an advisor to provide technical assistance to all scientists at all the WSARP stations.

2. Participate in research planning committee meetings at each station and at WSARP headquarters.

3. Assist scientists to develop statistically sound designs for their research projects.

4. Advise the Project Director of the appropriateness of statistical design of ongoing and proposed research projects.

5. Develop and present specialized training courses to update WSARP and ARC scientists in design of experiments and in statistical analysis of data. Special attention should be given to data management relative to the use of personal computers.

6. Create opportunities to participate in practical extension of technology packages to farmers, merchants, farmer cooperatives, and other groups capable of adopting or commercializing research projects.

7. Assist in the transition of project activities to a continuing research effort. This includes briefing of new research scientists, identification of critical issues, and making recommendations for the research agenda.

The WSARP Director may adjust and/or extend these responsibilities within these general terms of reference.

B. Reporting and Planning Requirements

The biometrician will prepare a plan for training and research planning activities for approval and implementation by the Project Director. He will participate, or perhaps lead, in the preparation of technical packages that are developed from current or past research findings. It

will be necessary to prepare any other papers/reports as may be appropriate or requested by the WSARP Director.

C. Relationships

The biometrician will work under the day to day supervision of the WSARP Director and the Team Leader of the contracting institution.

ANNEX 6

Amended Project Paper

TENTATIVE LIST OF EQUIPMENT TO BE PURCHASED

ANNEX 6

An Illustrative List of Equipment Suggested for Purchase in Support of Proposed Project Activities.

8 pickups @ $17,000	$136,000
4 12-passenger vans @ $23,000	88,000
4 Landrover station wagons x $20,000	80,000
4 IBM PCs @ $5,000	20,000
4 Farm tractors (80 - 100hp)	200,000
Laboratory and field research equipment	56,000
Small Purchases	20,000
Total	$600,000

AN ANALYSIS

SUPPORT FOR MECHANIZED RAINFED AGRICULTURAL RESEARCH IN SUDAN

Prepared for:

U.S. Agency for International Development
Sudan

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May, 1986

AN ANALYSIS
SUPPORT FOR MECHANIZED RAINFED AGRICULTURE RESEARCH

IN SUDAN

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SUPPORT FOR MECHANIZED RAINFED AGRICULTURE RESEARCH IN SUDAN

I. Introduction

A. Scope of Work

USAID indicated to the WINROCK International consultants that it wished an examination of: (1) the potential for moving technical assistance into a more commodity-oriented research approach, and (2) a strategy for a movement away from the previous exclusive focus on traditional rainfed farming systems. The rationale in this approach would be to generate technology which might offer a dramatic increase in grain production in Sudan during the short term, thereby increasing food self-sufficiency. It wished, however, to continue emphasis on the Western Sudan Agricultural Research Project (WSARP), an effort which had previously devoted its efforts to traditional systems in four western provinces.

B. Development Strategies in Rainfed Agriculture

1) General:

The development strategies of both the Government of Sudan (GOS) and USAID stress the importance of the rainfed sector in producing food grains; and in providing an exportable surplus of grains for earning foreign exchange. The rainfed sector has provided an average of 64 percent of the agricultural GDP during the most recent five year period of 1981/82 - 1985-86. It is also estimated that 14 million people (two thirds of the population) rely on rainfed agriculture for their livelihood.

The rainfed sector is composed of four production subsectors: (1) mechanized crops, (2) traditional crops , (3) livestock, and, (4) forestry and wood. The mechanized subsector is perhaps the most dynamic and definitive covering 10 million feddans and 6,000 relatively well-educated farmers. Mechanized farming is concentrated in the 450-800mm annual rainfed belt, has the problem of declining average yields, and a reputation for contributing to the degradation of land resources in the country. However, it is the backbone for food security and self-sufficiency would not be possible without the subsector.

2) GOS Strategy in the Mechanized Subsector

This strategy calls for technology improvements, production-oriented measures, and support measures to generate productivity increases. But yields have declined steadily for 25 years, with the area under cultivation continuing to expand.

3) Proposed USAID Strategy in the Mechanized Subsector

The proposed strategy would adhere to the Country Development Strategy Statement (CDSS) by concentrating on rainfed agriculture research. In addition, it would bring all mechanized farming research back under the umbrella of the Agricultural Research Corporation (ARC) by eliminating such research from diverse organizations such as the Blue Nile Integrated Agricultural Development Project (BNIAD) and the Mechanized Farming Corporation (MFC).

4) The proposed strategy would serve to open a research program in a new geographic area (eastern and central regions) which is meeting the food deficit with a production growth of over 500 percent in one year on a 10 million feddan area.

5) The strategy proposed would not greatly add to the government staff but largely reassign existing scientists presently working on an ill-equipped and isolated station to a more accessible and centrally located facility that has housing, warehouses, workshops, developed land, and most of the necessary field equipment. The facilities and equipment, funded under a previous USAID grant, are presently either standing idle or underutilized.

6) Associated with a thrust into rainfed mechanized research would be complementary and supporting projects that could eliminate other major constraints in the subsector. These include farm-to-market roads, rural water development, and private sector operated farm service centers. These high priority projects could be implemented by USAID or other donors. If implemented, they would complement the subsector by providing stability of production and increase its profitability. All have provisions for producing revenue and thus be self-supporting through land rents, user fees, and commodity sales.

II. Background to Mechanized Rainfed Agriculture

A. Geographic Setting:

The Central Rainlands area of Sudan represents one of the largest reserves of cultivatable land in the world. It forms a belt across the country between 10° and 14° north latitude. Suitable land for cultivation in this area ranges as high as 65 million hectares. Rainfall ranges from 450 mm in the north to 900 mm in the south. Due to its suitability for agriculture it has received considerable development attention as a potential supplier of surplus food for other parts of Africa and the Middle East. Within the Central Rainlands and along the Nile River lie the irrigation schemes which produce cotton and other crops. Further away begins the vast area which is farmed by either mechanized or traditional systems. Availability of permanent water supplies determined the patterns of traditional settlement. Occasionally, water was found and it became the site for a village and its sedentary agriculture. More often it was grazed only partially in the dry season by transhumants who utilized surface water supplies.

The livestock were driven south during the dry season when the surface water became unavailable.

B. History of Mechanization:

In 1944 the British began mechanized farming in the Central Rainlands in the Gedaref area close to the Ethiopian border. Its purpose was to feed its soldiers in Ethiopia as well as satisfying local requirements for sorghum which was then rationed in Sudanese towns. They used tractor-drawn disk plows and mechanized seeders, however the weeding and harvesting was done by hand.

In 1949 the leasing of holdings was given to local merchants. They paid the government for plowing and seeding services, but the size of acreage allotment was low. However, this was the start of the private mechanization system which exists today in a greatly expanded form. The scheme was abandoned in 1954 due to low crop yields and inefficiency both on the part of the cultivator and the "sheil" credit system which reduced the profitability and incentive to produce.

In 1954 the government-owned machinery was sold to the new tenants and the roads built for the scheme were handed over to the local councils. Subsequently, land was rented out in blocks of 1,000 feddans each. The new tenants were usually merchants with capital and management ability. They prospered and acquired more farms.

From 1961-71 the National Development Plans devoted attention to expanding cotton production as a means of import substitution of short-staple American types. It was introduced to mechanized schemes but failed. Cotton turned out to be labor intensive and costs were not justified by the yield levels obtained. Sesame was also tried in rotations during this period, but also failed due to sensitivity of the plants to soil moisture variability and high labor requirements during the critical harvest period.

In recent years sorghum production has dominated the mechanized subsector. It now accounts for at least 87% of the acreage. Sesame is probably planted on 10% and millet on the remainder.

C. The Role of the Mechanized Farming Corporation (MFC)

In 1970 the MFC was given the responsibility for surveying and allocating lands for mechanization, assisting private investors, management of state farms, promoting adaptive research, collecting rents, and providing credit and other services for mechanized farmers.

The World Bank established IDA credits of $US 5 million to the MFC for the purpose of providing the foreign exchange costs associated with developing the Simsim district of Gedaref. This included heavy construction machinery to build roads and water reservoirs, credit for purchasing of farm equipment, research and extension equipment and

supplies, and for salaries of expatriate and selected local staff. Essentially the program was designed to stimulate crop and cotton production on heavy clay soils that could not be cultivated with either the hand hoe or animal powered equipment. Individual farms were initially designed to be 750-1000 feddans in area. This size was later increased to 1500 feddans with the intention that one fourth of the land would remain in fallow. Land was allocated on a 25 year lease at the very modest rent of LS 0.10 per feddan. A later loan from the World Bank in 1971 was for $US 11.25 million and started a 350,000 feddan unit at Um Seinat northeast of Simsim. Cotton was later dropped from all rotations due to lack of profitability.

III. The Importance of Mechanized Agriculture to the Economy of Sudan

A. Size and Scope:

For planning purposes the mechanized farming subsector comprises about 10 million feddans distributed as follows:

Type of Development	Million Feddans
Demarcated lands now farmed	4.5
Undemarcated lands now farmed	4.5
Demarcated lands not developed	1.0
Total:	10.0

These lands and production were divided among the three major rainfed crops in 1985/86 as follows:

	Area (000 Fed.)	Production (000 MT)	Yield (Kg/Fed.)
Sorghum	7,335	2,626	358
Sesame	1,213	110	91
Millet	31	10	328
Total:	8,579	2,746	

B. Markets and Prices:

Sorghum is the most reliable and profitable crop to grow in the mechanized subsector. However, repeated production of the crop on the same land over 15 to 20 years explains the low yields that are received. Other contributing factors include the presence of weeds such as Striga hermonthica (a parasitic weed specific for sorghum) and wild

sorghum, increased presence of pests, and a greater frequency of sorghum diseases - all indicative of problems caused by monoculture cultivation.

Because of the local absorption capacity of sorghum and the profitable export markets that heretofore existed, the farmers have been encouraged to grow the crop year after year. Export markets in the Near East and Saudi Arabia have up to now been quite elastic and able to absorb surplus sorghum from Sudan at reasonable and even quite profitable producer prices.

Sesame, a high quality oilseed, has a limited market but one that does reward the exporter with a premium price. There is a steadily increasing market for sesame seed for bakery and confectionary purposes.

Millet is the grain preferred by some tribes in Sudan and is consumed locally. However, it is only a minor part of the cropping system and is more frequently used as a "catch crop" that can be planted late, or is sown on land that is heavily infested with Striga hermonthica.

C. Impact on Total Food Production by the Mechanized Subsector:

The subsector has been a decided asset to the country and its economy. While it does not have the consistent yield reliability of the irrigated sector, it is the major supplier of high caloric food for the urban sector, as well as being a consistent earner of foreign exchange.

With the combined advent of refugees, inadequate and erratic rains, and a drought in Western Sudan, there has been an embargo on sorghum exports for the past two years. A lack of a food security program and strategic food reserves has resulted in imports of PL 480 sorghum, a ban on sorghum exports and a substantial increase in sorghum prices in 1984/85.

In 1985, both the mechanized rainfed, irrigated, and traditional subsectors increased sorghum acreage in response to price incentives (see Attachment 2, Table 2B). Total increase over 1984 was over four million feddans (50 percent) but proportions for each subsector varied as follows:

	Millions of Feddans		
Sub Sector	From (1984)	To (1985)	Percent Increase
Mechanized rainfed	4.5	7.3	62
Traditional rainfed	2.07	3.7	37
Irrigated	0.8	1.1	38
Total	8.0	12.1	51

Whereas the traditional rainfed subsector responded to price incentives by increasing acreage 37 percent, the mechanized rainfed subsector increased by 62 percent. Considerably higher yields from the latter was also recorded, but was due primarily to bringing new lands into production.

IV. Proposed Project Description

A. Perceived Problem:

1) Retention of Export Markets

The rainfed sector produces four major crops (sorghum, groundnuts, sesame and cotton) which enter export markets and provide the country with badly needed foreign exchange. Sudan has been unable to maintain its level of exports in sesame, groundnuts and sorghum because of a decline in production, and recently has found that its traditional markets for these crops are being captured by other suppliers. Short staple cotton exports have also declined due to world surpluses and lack of demand for its poor lint quality.

2) Declining Yields and Productivity

Rising prices reflecting shortfalls in production have resulted in increased planting of sorghum in both irrigated and rainfed subsectors. However, the bulk of the sorghum grown is in the rainfed sector (89 percent) of which 61 percent is grown on large scale mechanized farms, and 28 percent grown by traditional producers.

Yields of sorghum, however, are low in all sectors when compared with other major exporters of sorghum. While sorghum under irrigation is averaging 430 kilograms/feddan, the rainfed mechanized subsector averages only 288 kilograms, and traditional growers average only 208 kilograms. Competing countries are able to exceed these yields five fold or more. Thus, if Sudan were to expand its area to produce more sorghum it would find difficulty competing with countries which are able to produce five times the yield per unit of area.

Vertical expansion (yields) has fallen far behind horizontal expansion (area). In fact, over a 22 year period (1961/83) overall yields have declined almost 16 percent. But, in the same period the area planted to sorghum increased by 77.4 percent with the traditional subsector increasing 18 percent and the rainfed mechanized subsector increasing 249 percent.

Sudan has been increasing production at the expense of expanding area concurrent with accepting declining yields. Tractors and machinery are pushing into undeveloped areas to sustain and increase production. With the increasing prices of equipment and fuels, the Sudan will eventually reach a point where yields have declined to the extent that it is no longer profitable to grow sorghum. It will then be

left with a depleted land resource base caused by lack of attention to crop and soil husbandry practices which promote long-term productivity for agriculture.

3) Research Constraints and Lack of Priority

At present there is little being done in research which is applicable to the mechanized rainfed subsector. The ARC has designated the Abu Naama station to conduct such research, however its research has little relevance. Technology developed remains to be tried and tested on farmers lands, and due to the station's isolation it has little access to the majority of the mechanized schemes. Much of the research needed concerns tillage and machine selection on the hard cracking clay soils, however it has no equipment to do this type of practical research.

Due to lack of priority and/or funding, the staff members are restricted in their travel and essentially have no incentive to conduct off-station tests. Housing, laboratories and offices built in 1963 have not been maintained. Probably the absence of supervision and contact with other scientists reduces the efficiency also.

Some very obvious research needs to be conducted - and the hypothesis is that results would result in high marginal returns necessary to vertical versus horizontal expansion. These include germplasm comparisons on sesame, sorghum hybrid development for yields and improved harvesting, tillage practices, weed control, insect control, harvesting practices for sesame, and planting practices.

B. Project Goals and Purpose:

Attachment No. 1 is a preliminary logical framework which provides an overview of the goal, sub goal, purposes, inputs, and outputs concerning the proposed project.

The goal is to obtain increased and sustained production from the existing mechanized farming land base. This would be in contrast to current systems where increased production is obtained only through vast expansion into virgin lands which result in depleting soil fertility, cause land degredation, and infringement on traditional grazing lands of the transhumants.

The sub goal is to enhance domestic food self-sufficiency, maintain and increase surpluses for export, and increase the standard of living for those engaged or dependent upon the mechanized farming subsector.

The project purpose is to improve the capability of ARC to provide the research and technologies needed to overcome present constraints to rainfed mechanized farming systems. These include a close cooperation with the MFC in on-farm testing, and later extension diffusion of the technologies that are found to be technically and economically viable. Strong linkages are also to be made to

agricultural credit agencies which order and supply farm equipment, as well as to encouragement and support of the private sector to supply off farm inputs conducive to obtaining high yields.

C. Expected Achievements and Accomplishments:

These could be many fold in the project. They include reversing the declining sorghum yield trend, increasing total production, increasing area sown to sesame, increasing profitability of mechanized farming, encouraging rotation, and protecting the environment by introducing erosion control techniques.

The introduction of new and improved combinable varieties and hybrid sorghums, the use of fertilizer, the use of herbicides and insecticides when needed, the shifting to more efficient machinery and implements, the improvement of post harvest storage, and the organization of efficient markets are all facets of the new technology to be tested, confirmed, and extended.

There will be a concurrent training of scientists, the influencing of government policy makers and the encouraging of the private sector to have a greater involvement in the mechanized rainfed subsector.

There are possibilities for considerable technology transfer of the research results generated in this project as opposed to that geared for traditional farmers in Sudan. If technical and economic feasibility can be shown, there could result large surpluses of sorghum for export as well as sesame. The rationale for this hypothesis is as follows:

a. Nature of producers: The owners of the means of production are investors, with the intent of obtaining high returns to capital. They have more knowledge, better access to markets and probably are able to take advantage of credit capital at more reasonable rates of interest. They have larger holdings, and even on demarcated schemes where the acreage is restricted per farm, the owners may control larger holdings through blocks rented by close relatives.

b. An extension system: If cost-effective technology is developed through research, the adoption would involve a large number of feddans per individual. The owners would be easier to contact through an extension system as they are usually living in the urban areas and not scattered about in villages. An extension system does now exist in the form of the MFC.

c. Short term and intermediate loans: Mechanized farmers do have the opportunity, at least on the demarcated schemes, to obtain loans through the Sudanese Agricultural Bank.

d. Farm service centers: The emphasis in this project on the establishment of sources of critical farm inputs such as machinery spare parts, fertilizers, dessicants, pre-emergent weed

control herbicides, and locust control insecticides will help to minimize the vagaries of supply of off-farm inputs inherent to many agricultural development projects. The ability of the mechanized farming entreprenuers to purchase and use these inputs effectively and efficiently also would minimize the amount of credit and training support needed when dealing with the traditional subsector.

D. The Functioning of the Project Within The Existing Research/Extension System.

1) Present Research Organization: The 10 million feddan mechanized rainfed subsector is presently served by two relatively inefficient research organizations:

a) MFC research which was specifically established to service the mechanized rainfed subsector in the East and Central Regions at the following locations (see Figure 1):

Simsim State Farm - Gedaref
Agadi State Farm - north of Damazin
Habila - east of Dilling

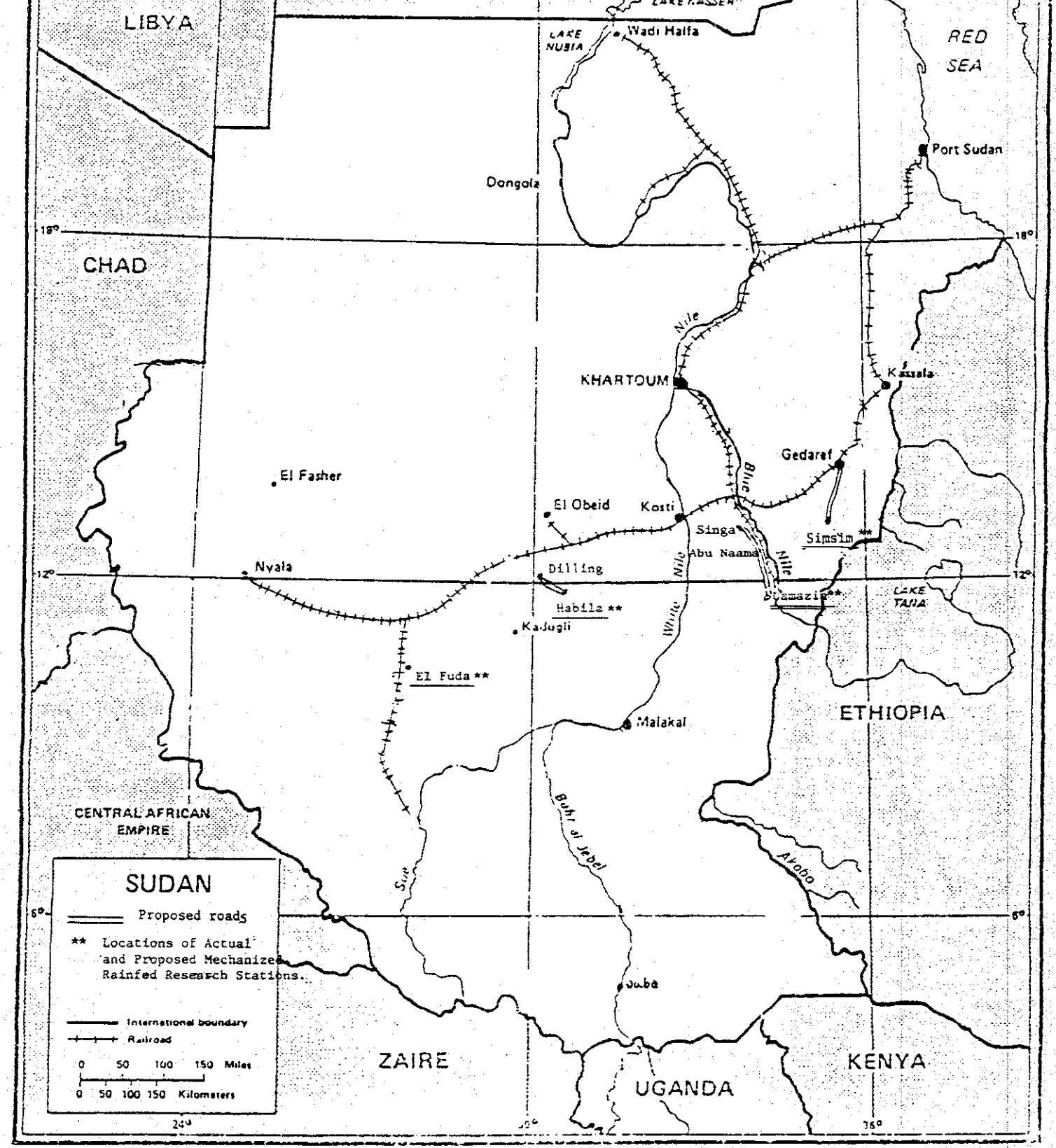
The Agadi State Farm now belongs to the Arab Authority for Agriculture Investment and Development in the Sudan (AAAIDS). The organization conducts its own research and appears to have done very well in operating its own experiments with both varietal and agronomic trials. Consequently they neither need nor want any further trials conducted by MFC on their farm.

MFC also conducts agronomy and machinery tests at the El Fuda Development Center. This is a facility in Southern Kordofan situated on the loamy sands and sandy loams that might have potential for mechanized mixed farming. Some trials at El Fuda are directed towards the mechanization of the traditional sector and concentrates on plant populations of traditional and new crops, fertilizer requirements, problems of crust formation on problem soils, better adapted varieties of millet, groundnuts, sesame and sorghum, and the potential for new crops such as cowpeas, guar, sunflower, forage crops, and grain legumes. Trials for moisture conservation and controlling erosion are also being done with various cropping rotations. Much of the El Fuda research duplicates that done by WSARP at Kadugli. El Fuda is roughly 100 kilometers west and south of Kadugli.

The WSARP Kadugli station is also near the Habila research farm but here the soils and scale of mechanization are significantly different from both El Fuda and Kadugli.

The MFC has employed ARC scientists to monitor their trials and make suggestions to improve crop research. Such reviews are made by the senior staff of ARC.

Figure /. Map of Sudan Showing Relevant Locations of Mechanized Rainfed Research Activities and Proposed Roads.



b) ARC Kenana Station at Abu Naama (Figure 1). This facility was developed to serve the agriculture of the rainfed sector in the eastern and central regions of the country. The station was also assigned the research responsibility of supporting the kenaf production in an adjacent area. Consequently, Kenana also conducts some irrigated research.

The station has nine scientists, four of which have PhD's, and five which have M.S.'s. Disciplines represented include two agronomists, an entomologist, a weed specialist, two plant breeders, a soil scientist, an agricultural engineer, and a plant pathologist. While the mix of disciplines is to be commended, it is lacking a production economist and an animal scientist if the station were to cover the major disciplines for the mechanized rainfed subsector. The concept of cropping systems and the farming systems approach is understood, but is not implemented at the station..

2) Evaluation of, and Future for MFC Research

Machinery research trials are very extensive in area and comprise several thousand feddans at each site. Consequently such trials with replications are both expensive and time consuming. Due to rainfall patterns during the period 1982/84 the agronomic and mechanization trials were confounded and as a result there were few, if any, conclusive results which could be relayed to farmers. MFC does, however, recommend rotational cropping, combinable sorghum varieties, row planting, and two or more weedings. Recommendations from the machinery trials suggest use of chisel plows, precision planters and combine harvesters. Recommended herbicides are "sorgoprim" for sorghum and "maloran" for sesame.

Research funding has been largely through IDA sources. This funding ceased in 1985 and the Sudanese agronomist in charge was terminated at the end of 1985. The Chairman and Director of MFC has planned to continue the research function on a reduced scale. However, if the value and extent of agronomy and machinery research was marginal with IDA support and leadership, it cannot be expected to improve with reduced funding and direction. Consequently the agronomy and machinery research program for MFC will probably be less effective and considered as only salary support for the technicians with little or no funding for operations, spares, and training.

3) Proposed Research Program and Organization

A five year development assistance program is suggested for upgrading staff and facilities for research in the mechanized rainfed subsector. Some key points which should be included or considered in the design are the following:

a) Graduate training for at least five scientists who would be obligated to work in rainfed mechanized research for at least five years after returning from training.

b) Rather than build new facilities and housing, or to invest in the complete rehabilitation of Kenana Research Station, it is

recommended that the headquarters of mechanized farming research be moved from Kenana to Damazin, 110 kilometers south (see location on Figure 1). Damazin is adjacent to Roseires Dam and has ample electric power, water, and an all weather airport with limited commercial flights.

Site of the research station would be in the facilities previously occupied by the Blue Nile Integrated Agricultural Development Project (BNIAD). The facilities consist of a 24 office block, a workshop, warehouse, seven expatriate homes, and 22 houses for Sudanese staff, of which eight are three bedroom and five are two bedroom houses.

c) Station research at Damazin can be carried on at a 150 feddan fenced farm that has previously been used for research trials in the BNIAD. It is located only two kilometers from the headquarters buildings, and is equipped with a well, warehouse and shed.

d) The BNIAD has three other larger farms at Abu Gumei, Abu Shaniena and Karen-Karen. These function as demonstration training centers with additional roles of providing producers with custom tractor services, credit, and seed. It is hoped that the provincial government of the Blue Nile would assume support for these centers and in the near future they could become self supporting. There is presently no need to have a mechanized rainfed research program assume the role, staff, equipment and housing presently at these three farming centers.

e) Vehicles and equipment presently assigned to BNIAD could be utilized by the rainfed mechanized research program. These consist of 29 vehicles, 14 tractors, planting, harrowing, weeding, and spraying equipment, as well as workshop equipment for repair and maintenance.

f) At least five Abu Naama ARC scientists could be transferred to Damazin and be supplemented with two expatriate scientists to provide the necessary critical staff to implement a dynamic research program staff at the Damazin Development and Verification Farm. This would subsequently be renamed the **ARC MECHANIZED RAINFED FARMING CENTER** . The research talents necessary to the center would be an agronomist, a plant breeder, a weed scientist, an entomologist, and an agricultural engineer. Expatriate staff would consist of a machinery specialist and a sesame specialist with agronomy training. Abu Naama would retain the services of an agronomist, a soil scientist, a plant breeder, and a plant pathologist. An agricultural economist could be subsequently assigned to Damazin to complete the staff.

g) Research would initially follow along the 17 trials established by the BNIAD in their agronomy verification trials (see attachment on BNIAD experiments). This research is in its third and fourth year of testing. The crop rotation and fertilizer trials are of a long term nature and should be continued even if the concept of the mechanized farming research center is rejected.

h) Salary incentives of 25 percent, similar to the WSARP, could be provided, but is not considered essential. The posting to Damazin would be more advantageous than Abu Naama where no incentives are presently received. It is believed that the opportunities for post-graduate training and practical training, improved housing, shopping, medical, and school facilities are sufficient incentives to encourage posting to Damazin as opposed to Abu Naama.

i) Judged to be of more importance than salary incentives are operational funds. ARC at present is unable to secure sufficient recurrent funds to take on additional research activities. Consequently, a five-year operation cost of $US 400,000 is programmed as a line item for the center (see estimated costs, Section V.D.)

j) Technical assistance component involves two full time positions, each for a five-year period. Those most critical include a machinery specialist with considerable experience in both training and extension. He/she would test mechanization concepts, train counterparts, and extend findings to the mechanized sector. The second advisor would be a sesame production specialist and would supervise the trials associated with sesame. Sesame appears to be a reliable cash crop in the subsector and could be rotated effectively with sorghum. The problems of sowing and harvesting remains to be solved and presently there is no competence in sesame research and production in the Sudan.

V. Factors Affecting Project Selection and Further Development

A. Social Analysis

1) General

The mechanized rainfed subsector has been, up to now, a source of part-time employment for the rural poor of Sudan. Some workers reside in the area and do subsistence farming; others migrate long distances from Western and Northern parts of the country to work as migrant laborers.

The present mechanized technology in sorghum production consists, essentially, of a tractor drawn disk-drill for land preparation and sowing, and a stationary thresher. Hand labor is used for weeding, clipping of heads and stacking into piles at harvest, and feeding of the heads into a stationary thresher. In the case of sesame, the crop is usually cut, stacked and threshed using hand labor.

The research envisioned in the project calls essentially for increasing productivity of existing farms. From a technical standpoint it involves trials on crops, varieties, cultural practices using mechanized implements, rotations, and other productivity related activities. From an economic standpoint the research would study the profitability of improved production and soil conservation practices to the individual farm owner as opposed to the existing system, and of the

possible impact that increased productivity would have both for domestic consumption and increased exports.

Social considerations appear to hinge on two categories: the utilization of underemployed labor, and the lower costs of production which might cause further encroachment of lands presently used for livestock grazing 1/ and traditional agriculture. These considerations are also linked to environmental consequences, as lower cost of production could encourage more cultivation in the fragile soil areas, and in areas where there is under 400 mm of rainfall. Both are contributing factors to soil erosion and loss of permanent vegetation.

2) Labor Utilization

In the late 1970's a study 2/ indicated the following labor requirements needed for sorghum and sesame in the mechanized subsector:

	Labor Hours per Feddan	
	Sorghum	Sesame
Burning off crop residue	0.25	0.25
Weeding once	20.0	20.0
Sorghum head cutting/stacking	8.0	---
Sesame cutting and stacking	---	30.0
Sorghum threshing from piles	3.0	---
Sesame threshing by hand	---	2.5
Sorghum threshing, stationary	0.25	---
Total hours:	31.5 hrs	52.75

Sorghum labor and value: A second study conducted in 1985 3/ indicated that the costs for hand labor in mechanized sorghum operations averaged in excess of Ls 25.00 per feddan. Jobs performed were identical to the 1978 study. In that sorghum under mechanization accounted for 7.335 million feddans in 1985, this hand labor usage is

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1/See Attachment 6 "Implications of Mechanized Farming on Livestock Production.

2/"Alternative Strategies for Agriculture Development in the Central Rainlands of the Sudan," Univ. of Leeds, R. D. Study No. 3, 1978.

3/"Expected Yields, Production and Costs of Sorghum in Rainfed Mechanized Areas of Sudan," PAEA/MANR, December, 1985, Sudan.

particularly important from the standpoint of employment in the Sudanese economy. It represents 29.3 million person days of work by the underemployed traditional farmers. At Ls 25.00 per feddan the amount spent was over Ls 183 million.

Sesame labor and value: The researchers suggest adaptive research on the use of desicants for sesame to hasten ripening, as well as land preparation and planting practices to permit machine cultivation. The use of dessicants would permit swathing and pickup combining, or possibly straight combining without the swathing operation. The results would be an increase in yields of from 25 to 40 percent due to reduction in shattering losses. Owner adoption of the practices would again depend on whether the substitution of capital and practices utilizing machines would be more cost effective than the use of labor. In 1985 the mechanized acreage for sesame was estimated at 1.313 million feddans. While no recent studies indicate the labor costs per feddan it is estimated at about 67 percent higher than sorghum. This is due to the fact that hand labor is used entirely for the harvest and threshing operations. If one used Ls 41.00 (AGRODEV estimate of 1985) as a cost per feddan for hand labor, then the amount received by laborers in 1985 was Ls 58.8833 million.

3) Ownership and Management

Generally, but not always, the owners are merchants having management knowledge and access to capital. Many are of northern Sudan and Khartoum origin where arable land is scarce and livelihood needs to be made in other areas of the country. Historically, the owners are middlemen and deal with buying and selling, and practicing the "sheil" system. Actual day-to-day management of the farm is in the hands of a foreman who also supervises a tractor operator/greaser. The owner will reside in one of the larger cities and makes occasional visits to the farm. The foreman and tractor operator will stay on the farm less than six months of the year.

4) Land Allocation and Encroachment

On the demarcated areas Ls 1.00 per feddan is charged as land rent and must be paid regardless of whether the land is farmed or fallowed. The rental was proposed to be raised to Ls 2.00 per feddan a few years ago; however, there was much political opposition and the matter was dropped. While there is a limitation of between 1,000 and 3,000 feddans per owner (depending on the scheme), there are considerable joint holdings in the names of close relatives which are subsequently farmed as one large unit. At the present time there are over 6,000 tenants on the demarcated schemes, with as many more requesting leases. A crop tax which is approximately the value of 10 percent of the production at Ls 20.00 per 90 kilograms is paid to local rural councils for use in health, school, civil service salaries, road construction, etc.

On the undemarcated areas the village "sheik" would give the right to farm unused land to mechanized operators. This authority

was later transferred to an elected rural council with the power given to one of its members to grant leases. More recently the right to use undemarcated lands has been allotted or approved by various levels of local government, from as low as the local rural council to as high as the regional Minister of Agriculture or Governor. In this sense, all land not approved by MFC or the Agricultural Investment Commission is considered undemarcated.

5) Summary

The above discussion indicates that there are many social implications of research in the mechanized rainfed subsector. Under the present system there is a large labor input from nearby traditional and migrant farmers who regard the mechanized farms as a source of supplemental income. Others benefiting from this employment include the thousands of refugees from Ethiopia and Eritrea, Uganda, Chad, and Zaire who now work and reside in Sudan.

One might say that the loss of work opportunities by traditional farmers would force them to do a better job of farming their traditional plots, but it is doubtful that this would occur to any great extent. The thousands who now work make more by going off the farm rather than staying home. Hand labor is required for a longer seasonal period on mechanized farms, whereas family labor bottlenecks on traditional farms occur mostly in the weeding period.

Income distribution is not equitable in the subsector. Owners of the means of production are largely speculators and they control large holdings.

The method of land allocation on the undemarcated areas very frequently does not consider the traditional users, such as the transhumants, who are present only at certain times of the year. Lands of the permanent sedentary farmers have been more secure, as they can complain to the local sheik and obtain redress.

B. Financial Analysis:

1) Present Economics of Farm Operations:

Using only three pieces of field equipment (a 60-70 horsepower tractor and a wide-level disk planter) the farm manager or tractor operator disks up the field soon after the weeds have germinated in the early part of the rainy season. After a few days the planting is done using the same wide-level disk, but now planting the crop at the same time that the field is being disked. While the crop should be planted into rows to facilitate weeding and uniform depth of planting, the mud thrown up from the disk planter plugs the seed hoses. To rectify the problem, the operator cuts off the hoses and the seed is then broadcast rather than row planted. By planting into rows and at a uniform depth there is presumed to be an increased economic efficiency of production. By not delaying the second cultivation (to allow weeds to

germinate and grow) the crop could get off to a better start with the possibility of higher yields, and the assumption is that economic efficiency could again be enhanced.

The farm operations, however, appear quite rational from the standpoint of the economic situation in which the owner finds himself. He seeks to maximize returns from the limited capital obtained through fairly reasonable interest rates, and from subsidized prices in the case of farm machinery. He is only able to purchase a limited type and range of equipment because that is all that is being imported into Sudan. He is not concerned in maximizing returns to land, as it is almost a "free good" once the land clearing at Ls 30-35 is completed. Even on the demarcated schemes he is allowed to use additional land as an alternative to the block he has depleted due to continuous cultivation. The concern of the owner is cost per sack of sorghum produced, and to minimize costs for expensive fuel and machinery repairs.

The present machinery is quite unsophisticated and doesn't require well-trained mechanics for operation and adjustment. Even if more and varied equipment were available it would increase the needs for spare parts which are difficult to obtain for the machines now used in Sudan.

The farm manager is getting maximum efficiency from the limited capital investment in machinery. He runs the tractor and drill unit for approximately 20 hours per day by hiring two tractor drivers and two greasers. Each works a 10-hour shift. In fact, the same equipment listed above can very easily be used to farm a 1500 feddan unit as effectively as a 1000 feddan unit.

When the crop emerges and weeds appear, the manager hires weeding crews to work on a piecework basis. He divides the field into 60 feddan units, and the work force contracts to weed the units at a negotiated price, depending on the amount of weeds that are present. The work groups consist of traditional farmers and their sons who might live in nearby villages, or they may be transient laborers from traditional farming areas many hundreds of miles away. There has always been an abundance of hand labor available and the labor rate has only been slightly more than Ls 1.00 per day. However, the owner supplements this salary by providing some dried fish, okra, sorghum flour and other food so the laborers can prepare meals on the farm. The owner also provides water, as sources are usually scarce in the area where the mechanized farms are located. In 1985 the labor contracts were slightly higher than in previous years, as it was a favorable year for planting and more acreage was seeded due to the higher expectations of price (prices had been driven upwards by the drought of 1984). But labor efficiency is good because of the piecework contracts and normally runs between Ls 15-20 per feddan.

The harvesting method differs depending on whether the crop is sorghum or sesame. If sorghum, the labor crew cuts and stacks the heads in piles around the field. There will be three to four of these piles per feddan. In the case of sesame, the entire stalk is cut and tied into individual bundles and then shocked in the field to dry. However,

the great bulk of acreage planted is in sorghum simply because this crop is more profitable and easier to grow.

The threshing for sorghum consists of a custom combine which arrives at the field with the operator and a crew of probably 10 people. Half the crew works for 10 hours and the other half another 10 hours. The combine is moved from pile to pile and the laborers fork the heads into the cylinder to be threshed. Large burlap bags, each holding about 90 kilograms, are filled at the grain spout and the sack is tied with twine. Only about one in 50 farmers have a combine. The economic use efficiency of the combine is high with approximately 20 hours operation per day. In addition, there is little movement around the rough fields, thus minimizing wear and consumption of expensive fuel. Heads are cut by hand due to uneven stalk height. The practices suggest that it is cheaper to use manual labor to bring the crop to the combine rather than a straight combining operation, or using two operations if the crop has to be swathed due to high moisture content of the crop. Many of the combines move to the Gezira Irrigation Project after harvest where more custom work is done threshing wheat in the dry season.

Threshing of sesame is done entirely by hand. A labor crew comes to the field, up ends and beats the bundles to separate the seed from the straw and then winnows the seed. It is then placed into large burlap bags and awaits transport to the buildings for later marketing.

Farm buildings consist of a few native-style huts which are used for storage and also as housing for laborers while they are at the farm. The owner or manager hires a lorry at Ls 5.00 per bag to take the crop to the nearest market center where it is sold to middlemen.

2) Management and Investment Income Analysis (1500-Feddan Farm under Three Cropping Systems)

a) Present System (0.28 tons per feddan):

Table No. 3A, Attachment No. 3 is shown to give a perspective of the present level of income per feddan of sorghum. Returns to family labor is not included as it is not normally involved in the farm's operation.

The yield of .280 tons per feddan is the five-year average for the period 1979-83 in the Gedaref area. Average yields dropped there to 0.137 tons in 1984 due to the drought, but rose to 0.316 tons in 1985, a good crop year. The average price of Ls 300.00 per ton is considered low, but prices have been unstable due to the 1984 drought and the oversupply due to good crop in 1985. Alternative management/investment income is presented for Ls 350.00 and Ls 400.00 per ton.

The crop tax is paid at a fixed rate of Ls 25.00 per sack of 90.9 kilograms and does not increase or decrease with changes in sale price. Neither does the rental charge of the land. This indicates a couple of reasons why farmers have found it profitable to expand the

land area. The unavailability of fertilizers and herbicides and lack of equipment for application have also been contributing factors.

Returns for sesame are not shown, as farmers are now raising very little of that crop. They also ignore the recommended fallow system and plant the entire farm to sorghum.

b) Improved System (0.50 ton per feddan, Medium Efficiency):

1) Table No. 3B, Attachment No. 3, is shown to give potentials for income increases on the same 1500 feddan farm under an improved system with medium efficiency. Changes from the present system includes a 15 percent versus 10 percent of original cost for repairs, and a charge of Ls 10.00 per feddan versus Ls 5.00 for permanent staff.

2) The system incorporates the use of summer fallow (one-fourth of the farm) to control Striga hermonthica, herbicides, row seeding, and improved varieties. In the example there is an investment in a chisel plow at Ls 20,000, a precision planter at Ls 30,000, sprayer at Ls 15,000, and two tractors each costing Ls 50,000. This is an alternative to the present investment of Ls 50,000 for one tractor, and a wide level disk planter at Ls 24,000.

3) Land preparation at the beginning of the rainy season includes one operation on the summer fallow and two operations on the existing sorghum stubble prior to planting. Planting is done immediately after land preparation using a precision planter. The weed sprayer immediately follows planting to apply a pre-emergent herbicide.

4) Through the planting in rows and application of herbicide it is possible to eliminate three-fourths of the hand weeding expense; however, the existing hand harvest and stationary combining operation is left in place.

5) Management/investment income before financing is shown for farm-gate prices of Ls 300, 350, and 400 per ton.

c) Improved System (0.60 tons per feddan, High Efficiency):

1) This system shown as Table 3C, Attachment No. 3 is identical to the recommended practices shown under medium efficiency, with the exception that yields are increased to .60 tons per feddan, repairs to machinery are kept at 10 percent of original cost per year, and permanent staff costs are not increased from the present system.

2) Management/investment income before financing is shown for market prices of Ls 300, 350, and 400 per ton.

FINANCIAL INTERNAL RATES OF RETURN (FIRR)
(1500 feddan farm under three cropping systems)

1) Tables No. 3D, 3E, and 3F Attachment No. 3 show cash flows under the above three alternatives over a 14 year period at farm gate prices of sorghum at Ls 300, 350, and 400 per ton. Summary of the tables is as follows:

Table 1. FIRR of 1500-feddan farm, various efficiencies and sorghum farm gate prices.

Cropping System	Financial Internal Rate of Return Ls 300/ton	Ls 350/ton	Ls 400/ton
Present system 0.28 tons/feddan	13.5	52.5	113.2
Medium efficiency system 0.50 tons/feddan	(-)7.7	22.0	53.7
High efficiency system 0.60 tons/feddan	35.4	80.2	157.1

2) Summary:

a) Farm gate prices are more likely to be under Ls 350 per ton in the long term. Farmers must therefore obtain high efficiency and more than double present yields in order to profitably adopt present recommendations. This would be a considerable increase and is not realistic.

b) There is high variability of rainfall between seasons and within seasons. Extra machine cost with medium and high efficiency systems is a fixed cost, while under the present system weed control is a variable cost. Other risk factors include availability of spare parts, and obtaining skilled staff to run and service the added equipment.

c) Higher land rental costs, longer term leases, and higher hand weeding costs would encourage vertical as opposed to horizontal expansion to obtain productivity increase.

C. Economic Analysis:

This analysis reflects profitability from the viewpoint of society as a whole. While not normally done for research projects, it should be done during the project preparation phase for the Rainfed Mechanized Research Project. Some points which should be considered in the analysis include:

1) Adjustment of Transfer Payments: Because of the possibilities for improvement of seed through research of sorghum hybrids, the saving of shattering losses in sesame, and the use of better tillage, planting and weeding practices, the improved technology could serve to set the stage for large increases in export of these crops. Other items which need to be addressed include the use of rental monies on the demarcated schemes, and the crop tax which is imposed by local councils. In the case of the latter, varying amounts seem to be paid (or not paid at all) and there is no way to determine the amounts unless a query is made to the regional and local governments.

It is also known that there is a transfer payment occurring in the rates of foreign exchange for the purchase of farm machinery. While purchases for most machinery in the demarcated schemes is coming through loans from the Sudanese Agricultural Bank, the exchange is reported to be at the official rate and overvalued. There are also distortions in the debt service which is reflected in non-payment of loans by producers.

2) Prices on Foreign Exchange: The official exchange rate is in the process of change and there needs to be a more timely study done to determine the shadow exchange rate. This is of great importance in that much of the research is actually adaptive in nature and if adopted might result in more imports of machinery, chemical, fertilizer, and possibly hybrid seed. The value of these inputs, especially farm machinery, have spiraled in their countries of origin and a value given today can be much underestimated a year from now. Also, as the Agricultural Bank of Sudan actually does some imports in bulk through its loan program, one needs to know the amount of discount that is obtained through such bulk purchase.

3) Shadow Pricing of Land: While this is valued at its opportunity cost, it is unknown what this amount really should be. Some estimates place it as Ls 5.00 per feddan, while others state that it goes as high as Ls 10.00.

4) Shadow Pricing of Labor: The present mechanized subsector involves the invester and his agent, plus a high amount of unskilled hired labor. There is skilled labor at one shadow price, unskilled and underemployed at another, each with varying costs depending on the demand for labor on their own farms. There must also be placed a value on in-kind support to the labor including water, transport, housing, and food.

5) Exports: The mechanized subsector produces mostly sorghum and sesame for export. The traditional farmers produce for both domestic consumption and export. There have to be estimates made of economic export value based on converting local to foreign currency, costs of storage, loading, and transport to Port Sudan.

6) Intangible Benefits: While these are usually ignored in economic analysis, they do have some relevance if it becomes cost-effective to substitute machinery for hand labor in the subsector (see social analysis).

The increased yields brought about through capital oriented technology can produce some increased revenue for traditional communities. Local taxes, now estimated at 10 percent of the value of production at Ls 25.00 per 90.9 kilograms, might trickle down in terms of better roads, schools, clinics, and hospitals.

Farm adoption of the practices would hinge on whether the substitution of capital for labor is cost-effective. If credit capital is available, then it would also make horizontal expansion more profitable as the land resource is cheap at about Ls 40.00 per feddan for one-time clearing and Ls 1.00 or less per feddan for annual rental either from the FMC or local government organizations. Unless land were made restricting it may encourage more intensive farming of fragile lands heretofore used by occasional grazing and fallow type agriculture. On the existing lands the shorter-strawed varieties will result in a lesser amount of fodder for nomadic camel herds which now graze the stubble during the dry season. For traditional agriculturists it would necessitate more frequent farming of existing lands. This would result in a loss of fertility and lower productivity. The possibilities for encroachment would also hold true for sesame, however, the amount of fodder left for nomadic grazing in the dry season would be unaffected.

D. Administrative Analysis

Mechanized rainfed research would be placed under the administrative control of the Director General, ARC at Wad Medina, and be added to the responsibilities of the Deputy Director, WSARP. The Director General would name a station director and staff at Damazin similar to that of the present four stations of WSARP. At a later date, there would be a director assigned to handle the entire rainfed research sector in ARC. Two research subsectors would be supervised by him, that of traditional and mechanized rainfed farming. Other directors would be named to administer research in the southern tropical and irrigated areas and to supervise support services such as a central library, outreach, and documentation.

Figure No. 2 is shown to illustrate the four-director concept and to show how research into mechanized farming could be integrated into the present research structure of the ARC.

E. Estimated Costs:

The following are estimates of costs of the project over a five-year term.

Figure 2. Recommended Organizational Arrangement, Agricultural Research Corporation, The Sudan

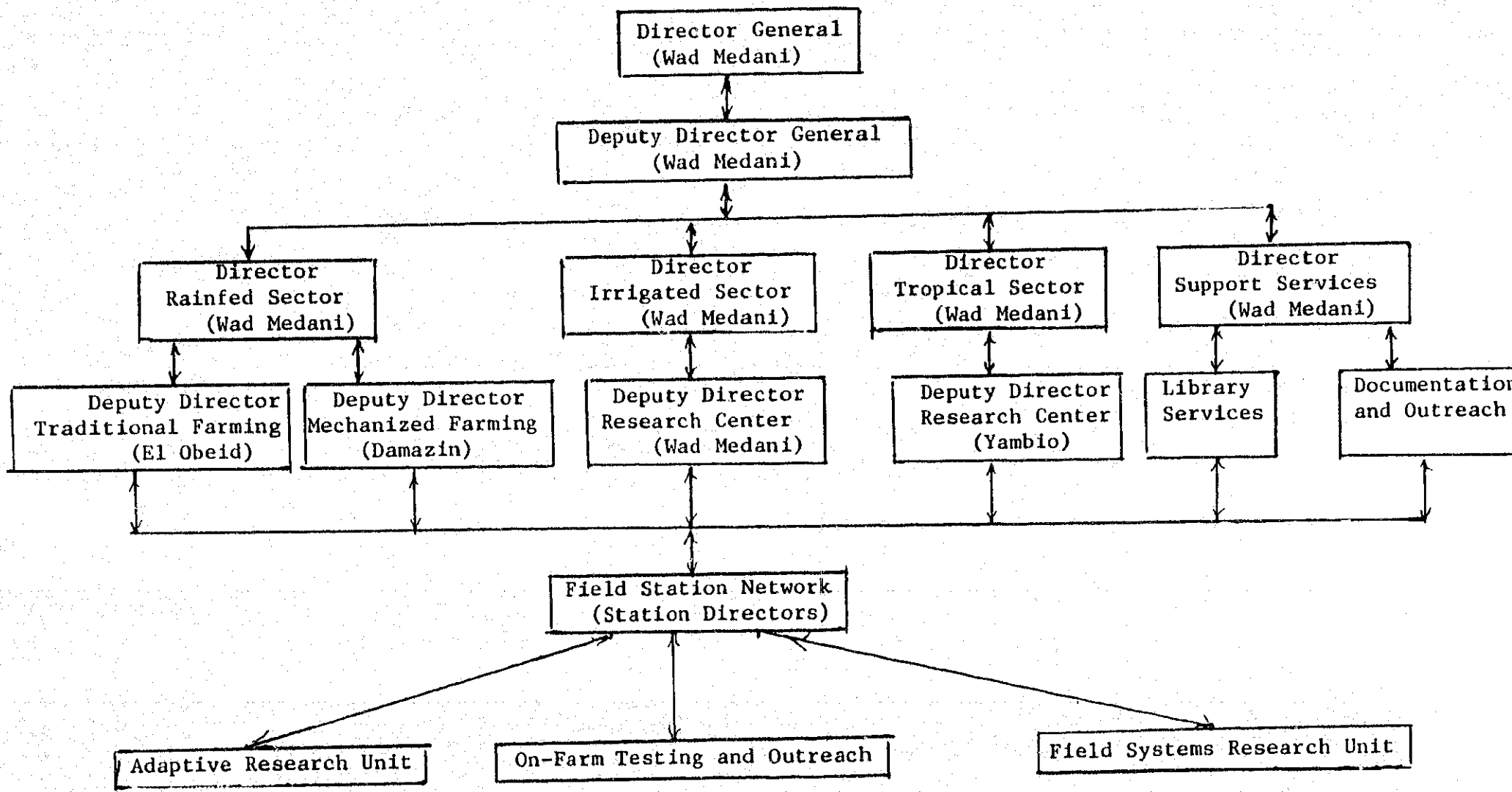

Table 2. Estimate of USAID Cost, Mechanized Rainfed Agricultural Research Project

Item	Description	Cost
Technical assistance (long term)		
Agronomist	5 yrs @ $125,000	$625,000
Agricultural engineer	5 yrs @ $125,000	625,000
Technical assistance (short term)		
64 person years	Economics, soils, plant pathology, entomology, etc., @ $13,000/month	832,000
Participant training		
Long term	16 yrs @ $30,000	480,000
Short term	100 months @ $10,000	1,000,000
Commodities (*)	Tractors/equipment	400,000
Recurrent costs	$50,000 @ 5 yrs.	250,000
	Total:	$4,212,000

(*) Assumes BNIAD facilities available at Damazin.

F. Design Strategy:

1) Pre-Design: It is recommended that approximately a one month's consultancy be done by a sociologist/economist prior to the design of the project paper. This individual would direct efforts towards the following areas:

a) Extent of migrant and resident hired labor now employed in the mechanized rainfed subsector. Determine opportunity costs of such labor during periods when high labor inputs are required. This would include alternative employment in irrigated and traditional agriculture, as well as the amount of work done by refugees.

b) The level of labor skills required that are presently required in mechanized agriculture, and the upgrading of skills required through use of machines such as sprayers, precision planters, row cultivators, swathers, and combines.

c) Make an assessment of loss in employment of labor if the subsector were to become increasingly mechanized in its operations.

2) Project Design: The project paper design is quite straightforward and would require no more than a four week consultancy by a highly trained agronomist and agricultural engineer.

a) Agronomist: Should have had much experience with research in sorghum and sesame crops. If a combination of skills cannot be found, then two agronomists on the team would be useful. The needs for the sorghum specialist is in the area of highly adaptive research intended for technology transfer. In sesame, a specialist in plant breeding/variety selection for non-shattering characteristics, the use of dessicants, and cultural practices under mechanized operations would be most desirable.

b) Agricultural engineer: This individual should be experienced and knowledgeable concerning improved cultural practices and machinery selection for use in sorghum production under dryland conditions; and with problem soils where special machine requirements and cultural practices are needed. The engineer should bring along current price information regarding purchase costs in the U.S. for chisel plows, smooth harrows, row planters, press drills, row cultivators, sorghum and sesame pesticides, sesame dessicants, and current recommended harvesting techniques for sesame in the United States.

Suggested sources for sorghum agronomists are from states in the Great Plains area. USDA/OICD might suggest sources of sesame specialists either from the ARS Special Crops Division, or through the Land Grant System in Southwestern United States.

G. Environmental Assessment:

The project will be emphasizing research which, when extended, will serve to reduce present degradation of the land resource taking place in the mechanized rainfed subsector. The thrust will be to improve soil fertility of the existing land that is used, rather than expanding horizontally to "mine" new lands which have proven to have limited long-term productivity.

To make existing lands more productive in the long term necessitates the use of fertility rejuvenation crop rotations, fertilizers, more efficient planting techniques, weed control to reduce nutrient competition from weeds, and earlier planting dates to maximize use of early crop season moisture.

To accomplish the above, there will be some research work and supervised field trials using herbicides and insecticides presently recommended for sorghum and sesame in the developed countries. The use of pesticides and herbicides are not new to Sudan. They are used extensively in the irrigated and rainfed sectors for crops such as sorghum, peanuts, wheat, sugar cane, and cotton.

Clearance for use of pesticides is regulated by the Agricultural Research Corporation. Training courses are provided to users by the Plant Protection Administration, and the Agricultural Extension Service of the Ministry of Agriculture.

In all cases, the research into pesticides use will emphasize that which has minimum residual effect on the environment, and/or those which do not pose dangers to humans and livestock which either reside in the areas, or use the lands for grazing during the dry season. None will be recommended for general use until assurances can be made that users are trained and properly supervised.

H. Complementary Projects Supportive of the Mechanized Rainfed Research Project:

There are several voids in the infrastructure of the mechanized rainfed subsector that need attention and concurrent development if the subsector is to assume its fully productive role in the national economy. In addition to research and its subsequent extension, the obvious voids are roads, rural water supplies, and the provision of a multitude of agricultural inputs, plus a mechanism for storing and marketing the expanded production.

Attachment No. 4 includes a discussion of the following complementary activities:

Farm to Market Roads (see location on Figure 1, Page 1a)

Water Yard Development at Gedaref

Supplies of Off-Farm Inputs for Rainfed Farming

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ATTACHMENT 1

PRELIMINARY LOGICAL FRAMEWORK MATRIX

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ATTACHMENT 1

PRELIMINARY LOGICAL FRAMEWORK MATRIX MECHANIZED RAINFED AGRICULTURAL RESEARCH PROJECT

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
GOAL:			
Increased production from the mechanized production systems.	Increases in food and livestock production.	National statistical reports completed from production field surveys.	Agricultural research will contribute to improved agricultural production, and new technologies will be adopted by the farmers.
SUBGOAL:			
To enhance domestic food supplies, develop grain surplus for export, increase standard of living for those engaged in mechanized farming in rainfed agricultural subsector.	Sustained increases in yield of major crops of the mechanized subsector of rainfed agriculture.	Statistical reports of agricultural production.	That new technologies will lead to economic increases in yield and supply of food grains.
	Improved incomes for the rural inhabitants of Sudan that are involved in rainfed mechanized farming.	Field surveys of farm and household income.	That these economic yield increases result in improved incomes for the rural component as well as the urban manipulators of the system.
PROJECT PURPOSES:			
1) To improve the capability of ARC to provide research for technologies needed to overcome constraints to rainfed mechanized farming systems.	Research staff is in place within the ARC infrastructure for research that can (1) identify and prioritize constraints to production systems. (2) Plan and implement interdisciplinary research programs to solve constraints.	Contractor reports. ARC annual research reports.	That staff can be identified for training and work at research assignments in the rainfed sector.
2) To develop linkages between ARC and MFC for conducting "on farm" tests for improved technologies.	MFC has tested new technology packages in field situations.	Project evaluations. Site visits.	That MFC will provide staff and equipment for testing new technologies.
3) To stimulate the private to provide necessary inputs to the sector for adoption of the new technologies.	An Agric. Service Center for providing production inputs needed for adopting new technology for rainfed mechanized farming as functioning within the private sector.		That the private sector has an interest in becoming involved in support of mechanized farming programs.

ATTACHMENT 1 (continued)

Project Outputs	Magnitude of Outputs	Means of Verification	Important Assumptions
1. Functional research stations with relevant programs for mechanized agricultural production systems are in place.	1. A research headquarters developed at Damazin with a supporting station upgraded at Abu Naama. Relevant research programs are underway at both.	Contractor reports.	1. GOS make available to ARC the Blue Nile Development facilities at Damazin.
2. A cadre of trained scientists is planning and conducting research programs for rainfed mechanized production systems.	2. Four staff members identified and trained, and all functioning within the rainfed mechanized farming research program.	Annual research reports of the ARC.	2. ARC approves the development of a research headquarters at Damazin.
3. A farm systems research unit is functional and providing baseline data for identifying and prioritizing constraints to mechanized farming systems for rainfed agriculture.	3. Four production scientists (Agr. Engn., Agron., Econ., and Sociologist) are trained and functioning throughout the mechanized rainfed agriculture subsector to identify and prioritize constraints to production.	Evaluation reports, site visitations, published budget figures.	Scientists can be recruited for training, and complete training on schedule.
4. The MFC is conducting "on farm" research testing of technologies and monitoring farmer managed interventions into production systems.	4. MFC is working with ARC scientists in testing station proved technologies through on-farm trials at Simsim, Damazin, Dilling, and Habila.		MFC is willing to cooperate with ARC thru field testing programs for improved technologies.
5. A Farm Service Center is functioning under the private sector.	5. An Agric. Service Center has been developed at Damazin which is operated by the private sector to provide the agricultural inputs needed to sustain adoption of improved technologies on rainfed mechanized farms.		The private sector is interested in development of Agric. Service Center.
6. The GOS has demonstrated its ability to support a viable research program for ARC when donor support is terminated.	6. The GOS, through its research institution ARC, is meeting salaries, equipment, and recurrent operational costs for rainfed agricultural research at the end of project.		The Ministry of Finance and Econ. Affairs provides scheduled budget increases.

ATTACHMENT 1 (continued)

Project Inputs	Magnitude of Inputs	Means of Verification	Important Assumptions
1. Technical research assistance in agronomy, engineering, and related fields to MRAR.	1. Long term: 10 person yrs @ $125,000 = $1,250,000. Short term: 64 person yrs @ $13,000 = $832,000.	Contractor reports.	Highly qualified and motivated researchers which can be recruited to work at remote research stations in Sudan.
2. Participant training of MRAR staff.	2. Long term: 16 person yrs @ $30,000 = $480,000 Short term: 100 person mos @ $10,000 = $1,000,000	Contractor reports.	Suitable candidates can be identified and released for training; and trained to technical competence.
3. Training and coordination of FMC ext. staff for on-farm trials and extension to private sectors.	3. a) Training classes and conferences on trials and recommendations. b) Training classes in technology, in machine use, calibration, chemical use, plot layout.	Contractor reports.	MFC will cooperate to provide extension component and to assist in on-farm trials.
4. Logistic and commodity support.	4. Commodities, tractors, and equipment: $400,000	ARC reports.	Foreign exchange funds provided.
	5. Recurrent costs: $50,000/ year x 5 years = $250,000. Total project cost: US$4,212,000		Waiver by USAID of minimum percent contribution by GOS; also availability of Title III currency.

ATTACHMENT 2

TRENDS IN FOOD SUPPLIES AND PRODUCTIVITY, PRODUCTION AREAS, AND PERCENTAGES BY SECTOR, SUDAN

TRENDS IN FOOD SUPPLIES AND PRODUCTIVITY, PRODUCTION AREAS, AND PERCENTAGES BY SECTOR, SUDAN

A. Food Supplies and Productivity

1) Sudan's people consume mainly a cereal based diet. Average annual per capita consumption by its 22.5 million people is between 119 and 126 kilograms of cereals of which sorghum, millet, and wheat account for as high as 98 percent of the total. Table No. 1 shows an estimate of total requirements of these cereals. Sorghum's share ranges from 60 to 66 percent of the consumption in the 1980's. The consumption of millet is declining, dropping from 23.1 percent in 1980/81 to only 10.1 percent in 1984/85. Wheat consumption is rising as a result of demand in the urban areas and reflects possibly some income elasticity, government bread pricing policy, and concessionary imports from the United States.

2) Drought in 1984/85 created an overall deficit of all cereals, however estimated production response in 1985/86 will again satisfy consumption requirements except for wheat. While the overall projection for 1984/85 leaves a surplus, eight of the country's provinces are deficit and only three are surplus. Surplus provinces are Kassala (685 percent), Blue and White Nile, Gezira (247 percent), and Southern Kordofan (19 percent). Surplus production is all from the mechanized rainfed sector.

3) The abundant agricultural resources of Sudan suggest that the country should not have problems in meeting future domestic demands for the major cereals, however decreasing productivity is occurring in both the rainfed mechanized and traditional sectors. Lower productivity is offset in the mechanized sector by the abandonment of marginal production areas, and increasing the total area planted to cereals, mainly sorghum.

4) The following table 2A provides an overview of consumption and production of three cereals which together constitute practically all of the cereals consumed. Note that over the five years between 1979/83 there was a surplus of sorghum and millet, and a deficit in wheat. 1984 was a drought year and considerable deficits were recorded in all three cereals. Huge surpluses in sorghum and millet were recorded for 1985, a good crop year.

Table 2A. Average Consumption per Capita of Major Food Grains in Sudan as Compared With Actual Production Levels (000MT)

Major Food Grain	Annual Per Capita Cons.kg 84/85	[1]Total Requirement	Ave. Prod. 1979/83	Total Prod. 1984/85[2]	Total Prod. 1985/86
Sorghum	74.0	1665	2118	1097	3843
Wheat	36.0	810	180	79	195
Millet	7.5	169	392	158	479
TOTAL	117.5[3]	2644	2690	1334	4517

[1]Based on 22.5 million population

[2]Drought year

[3]Other cereals at 1.7 kg bring consumption to 119.2

B. Production Trends of Four Major Food Crops (Table No. 2B)

1) Sorghum:

This is the most important food crop in Sudan. In the 11 year period from 1972 to 1983 its share of production area was 47 percent. Its share of total tonnage produced was 56 percent. About 11 percent of the production is irrigated, 61 percent is rainfed mechanized, and 28 percent is grown by traditional farmers. Over the past 22 years Sudan has been a net exporter of sorghum averaging 112,000 tons per year.

Average area planted to sorghum by mechanized rainfed farmers was 984,000 feddans during the period 1961-72. From 1972 to 1983 it increased to 3,434,000 feddans an increase of 249 percent. In 1985 it took a further jump to 7,335,000 feddans which made a total increase of 645 percent. Tonnage went from 324,000 in 1971 to 2,626,000 in 1985. While the 1985 jump can be attributed to high price expectations as a result of the 1984 drought it does point up the growth in this subsector and its responsiveness to supply and demand.

The traditional rainfed subsector has not been as responsive. It went from 2,254,000 to 2,657,000 feddans in the same period for a change of only 18 percent. But it too responded by going to 3,703,000 feddans in 1985 for a total increase of 64 percent. But its increase was mainly at the expense of groundnut production.

2) Millet:

This is primarily a subsistence crop with 96 percent of the tonnage and 98 percent of the area in the traditional rainfed subsector in 1985. About 91 percent of the feddans and 89 percent of the tonnage is in the four western provinces, however yields are low averaging only 142 kilograms per feddan. Three of the four provinces in the west are deficit and do not produce enough for consumption by its inhabitants. Low productivity of the soils coupled with subsistence farming practices are the reasons for the deficit. Millet is commonly grown where there is a short growing season and where only marginal levels of rainfall are received.

3) Sesame:

This is a cash crop planted by both the mechanized and traditional rainfed subsectors. About 34 percent of the tonnage was produced in the mechanized subsector from 1979-83, however its share went to 52 percent in 1984 and is expected to be 51 percent in 1985. During the five year period 1979-83, 72 percent of the feddans were in the rainfed traditional subsector but it dropped to 53 percent in 1985. Reasons for the drop is the drought in 1984 and higher price expectations for millet and sorghum for 1985. The 1985/86 production of sesame is about the same as the five year average between 1979 and 1983.

4) Groundnuts:

The relative position of groundnuts in total food production in Sudan is increasing. It increased from 12.9 to 19.5 percent as a production share of major food crops during the period 1961 to 1983. In area it rose from 11.9 to 14.9 percent during the same period. Yields per unit area showed a positive growth rate during the period and was especially evident in the irrigated areas. Average yields there rose from 627 kilograms per feddan to 885 kilograms per feddan. Increases in yield over time were also made in the rainfed areas of the Blue Nile and Kordofan regions, but in Darfur and southern regions there was a decline in yields due to rapid expansion of area under cultivation.

While the irrigated area was only 13.1 percent in 1985, it produced over 32 percent of the total tonnage in the country. The traditional subsector is however the main producer and accounts for between 65 and 70 percent of the total tonnage produced. No groundnuts are planted in the clay soils of the mechanized rainfed subsector due to difficulties in harvest.

The decline in planted area from 1984 to 1985 is due to high production coss and the fact that many producers responded to the 1984 drought by planting more sorghum and millet.

C. Mechanized Production Areas, Production Levels and Percentages

Tables 2C, 2D, 2E, and 2F show the production areas and levels of production by the mechanized rainfed subsector, and how it compares with

the irrigated and traditional subsectors for four major food crops. Only the period 1979-1983 is shown in detail as 1984 and 1985 are considered abnormal years due to the drought.

1) Sorghum (Table 2C):

About 56 percent of the feddans and 60 percent of the tonnage was from this subsector. Production concentration is still in the eastern rainlands but movement into the western regions is taking place. Yields per feddan average about 14 percent higher than the traditional subsector but are partially offset by more land abandonment and movement to virgin production areas.

2) Millet (Table 2D):

Only 5,000 feddans is planted by the mechanized subsector and indicates both a comparative and economic disadvantage for mechanization. Millet is considered a subsistence crop for production areas having a short season, with low rainfall and poor soil conditions. Production concentration is on the sandy soils of North Kordofan, and North and South Darfur.

3) Groundnuts (Table 2E):

No production is presently in the mechanized rainfed subsector as the unirrigated heavy soils pose problems for harvesting. The crop is particularly suited to the traditional subsector where sandier soils exist. However, under irrigated conditions on the heavy soils, groundnuts gave over 350 percent higher yields than in the traditional subsector.

4) Sesame (Table 2F):

28 percent of the feddans and 34 percent of the tonnage was produced under rainfed mechanization. The mechanized subsector yields were slightly higher than under traditional production. Sesame is reported to produce higher returns than sorghum under mechanization, however it has severe shattering problems under present harvesting practices.

Table 28. Production Summary of Four Major Crops in Sudan for Period 1979-83, and Actual Production Levels, 1984 and 1985

Type production	1979-1983 Five Year Average				1984				1985			
	Area	%	Tons	%	Area	%	Tons	%	Area	%	Tons	%
SORGHUM												
Irrigated	582	7.4	250	11.8	766	9.6	436	39.7	1154	9.5	693	16.8
Rainfed mechanized	4398	55.9	1267	59.8	4534	56.8	389	35.5	7335	60.2	2626	64.0
Rainfed traditional	2883	37.6	601	28.4	2687	33.6	272	24.8	3703	30.4	813	19.7
Total	7863	100	2118	100	7987	100	1697	100	12192	100	4131	100
MILLET												
Irrigated	14	0.5	5	1.3	20	0.6	10	6.3	22	0.6	9	1.9
Rainfed mechanized	5	0.1	1	0.3	11	0.4	1	0.6	31	0.8	10	2.1
Rainfed traditional	2711	99.3	386	98.5	3095	99.0	147	93.0	3708	98.6	453	96.0
Total	2730	100	392	100	3126	100	158	100	3261	100	472	100
SESAME												
Irrigated	0	0	0	0	0	0	0	0	0	0	0	0
Rainfed mechanized	571	28.0	72	34.1	603	32.5	70	52.6	1213	46.8	110	51.2
Rainfed traditional	1469	72.0	139	65.9	1250	67.5	63	47.4	1377	53.2	105	48.8
Total	2040	100	211	100	1853	100	133	100	2590	100	215	100
GROUNDNUTS												
Irrigated	299	14.2	241	36.0	326	18.5	257	67.0	146	13.1	111	32.3
Rainfed mechanized	0	0	0	0	0	0	0	0	0	0	0	0
Rainfed traditional	1812	85.8	422	64.0	1432	81.5	129	33.4	987	86.9	233	67.7
Total	2111	100	663	100	1758	100	386	100	1113	100	344	100

Table 2C. Five Year Production Averages by Sector for Sorghum 1979/80 - 1983/84 (000's)

Type production and geographic area	Total feddans	Percent feddans	Production (MT)	Percent tonnage	Yield average kg/feddan
Irrigated	582	7.4	250	11.8	430
Rainfed mechanized:					
Damazin	941	12.0	278	13.1	295
Kosti	225	3.0	59	2.8	262
Gedaref	2546	32.3	735	34.7	289
Dilling	333	4.2	88	4.2	264
Rank	342	4.3	107	5.1	313
South Darfur	11	0.1	3	0.1	273
Subtotal	4398	55.9	1270	60.1	288 Avg.
Rainfed traditional:					
Blue Nile	602	7.7	162	7.6	269
Gezira	154	2.0	38	1.8	247
White Nile	149	1.9	28	1.3	188
North Kordofan	436	5.5	58	2.7	133
South Kordofan	370	4.7	89	4.2	241
North Darfur	48	0.6	5	0.2	104
South Darfur	362	4.6	84	4.0	232
South Region	762	9.7	137	6.5	180
Subtotal	2883	36.7	601	28.4	208 Avg.
Grant Total (78/80-83/84)	7863	100	2121	100	270
Total for 84/85	7987	100	1097	100	137
Total for 85/86	12168	100	3843	100	316

Table 2D. Five Year Production Averages by Sector for Millet 1979/80 - 1983/84 (000's)

Type production and geographic area	Total feddans	Percent feddans	Production (MT)	Percent tonnage	Yield average kg/feddan
Irrigated	14	0.5	5	1.3	357
Rainfed mechanized:					
Gedaref	5	0.2	1	0.3	200
Rainfed traditional:					
Blue Nile	64	2.3	10	2.5	156
Gezira	6	0.2	1	0.3	167
White Nile	77	2.8	14	3.6	182
North Kordofan	1045	38.3	103	26.3	99
South Kordofan	41	1.5	8	2.0	195
North Darfur	410	15.0	56	14.3	137
South Darfur	984	36.0	180	45.9	183
South Region	84	3.1	14	3.6	167
Subtotal	2711	99.3	386	98.5	142
Grant Total	2730	100	392	100	144
Total for 84/85	3095	100	147	100	47
Total for 85/86	3858	100	460	100	119

Summary:

1. Note that production is primarily in the traditional sector.
2. They expect three times the 84/85 harvest for 85/86.
3. About 91 percent of the feddans are in the four western provinces.
4. About 89 percent of production is in the four western provinces.

Table 2E. Five Year Production Averages by Sector for Groundnuts 1979/80 - 1983/84 (000's)

Type production and geographic area	Total feddans	Percent feddans	Production (MT)	Percent tonnage	Yield average kg/feddan
Rainfed traditional:					
Blue Nile	20	0.95	9	1.4	450
White Nile	49	2.3	15	2.3	306
North Kordofan	673	31.9	161	24.3	239
South Kordofan	34	1.6	8	1.2	235
North Darfur	90	4.3	17	2.6	189
South Darfur	704	33.3	160	24.1	227
South Region	242	11.5	52	7.8	215
Subtotal	1812	85.8	422	64.0	233 Avg.
Irrigated	299	14.2	241	36.0	809 Avg.
Grant Total (79/80-83/84)	2111	100	663	100	314 Avg.
Total for 84/85	1758	100	386	100	219
Total for 85/86	1043	100	328	100	314

Summary (Five Year Averages):

1. Bulk of feddans are in the traditional rainfed section (85.8 percent with remaining in irrigated (14.2 percent).
2. The traditional rainfed sector produces about 67 percent of the total tonnage.
3. The four western provinces produce 52.2 percent of the tonnage.

Table 2F. Five Year Production Averages by Sector for Sesame 1979/80 - 1983/84 (000's)

Type production and geographic area	Total feddans	Percent feddans	Production (MT)	Percent tonnage	Yield average kg/feddan
Rainfed traditional:					
Blue Nile	246	12.0	31	14.7	126
White Nile	34	1.7	4	1.9	118
North Kordofan	723	35.4	52	24.6	72
South Kordofan	114	5.6	15	7.1	132
North Darfur	11	0.5	1	0.1	91
South Darfur	178	8.7	14	6.6	79
South Region	163	8.0	22	10.4	135
Subtotal	1469	72.0	139	65.9	95 Avg.
Rainfed mechanized:					
Damazin	202	9.9	22	10.4	109
Gedaref	311	15.2	42	19.9	138
Dilling	22	1.1	3	1.4	136
Rank	36	1.8	4	1.9	111
Subtotal	571	28.0	72	34.1	126 Avg.
Grant Total (79/80-83/84)	2040	100	211	100	103 Avg.
Total for 84/85	1853	100	133	100	72
Total for 85/86	2590	100	214	100	83

Preliminary summary for report:

1. About 72 percent of total feddans are in traditional rainfed sector and producing 66 percent of tonnage.
2. Mechanized sector had 28 percent of feddans and 34 percent of tonnage.
3. Yields in mechanized sector are slightly higher than traditional sector.
4. The four western provinces in the traditional sector had 50 percent of total feddans and produced 34 percent of total tonnage.
5. If project expands to rainfed mechanized sector, it would be involved with 92 percent of feddans and about 90 percent of total production. Only exclusion is southern region.

Trends: Increases in sesame production in 1985/86 due mostly to mechanized rainfed in the Damazin area.

ATTACHMENT 3

DETAILS OF FINANCIAL ANALYSIS AND FIRR

Table 3A. Average Management and Investment Income, 1500 Feddan Farm, All Planted to Sorghum, Gedaref Area, 1985 (Present System)

Item	Cost or Returns[1] One feddan	1,500 feddans	Remarks
Yield (tons)	0.28		5-year average Damazin/Simsim
Price per ton (farm gate)	300		
Gross output (LS)	84	126,000	See comment below[2]
Variable Costs:			
Seed	4.50	6,750	1.5 kg/feddan
Land rental	1.00	1,500	Leased from MFC
Crop tax	8.40	12,600	Production at fixed tax
Land preparation	6.40	9,600	Mostly fuel
Labor:			
Weeding	14.80	22,200	Average is 20 hr/feddan[3]
Harvest	10.20	15,300	7-8 hours cutting/piling[3]
Repairs	7.40	11,100	10 percent original costs
Threshing	1.80	2,700	Custom stationary combine
Staff salary	3.00	4,500	Driver/greaser and agent
Sacks and string	9.24	13,860	1 per 90.0 bag @ LS 3.00
Other costs	3.00	4,500	Local taxes, etc.
Subtotal	69.74	104,610	
Fixed Costs:			
Depreciation	6.34	9,510	7-yr life and 10 percent salvage LS 50,000 for tractor and LS 24,000 for disk drill
Total Costs:	76.08	114,120	
Management Investment Income Before Financing:			
LS 300/ton	7.92	11,880	
LS 350/ton	21.92	32,880	
LS 400/ton	35.92	53,880	

[1] Cost data per feddan from PAEA/MANR, Khartoum (except depreciation and repairs).
[2] Gedaref price for sorghum was LS 216 in March 1984, LS 1200 in April 1985, and in October 1985 was LS 588. In March 1986 it was LS 333. Farm gate price is LS 5.00 per 90.0 kilogram bag less Gedaref market price.
[3] Hand labor averages from "Alternative Strategies in Agricultural Devleopment in Central Rainlands of Sudan," University of Leeds, 1978.

Land clearing cost not included.
US$1.00 = 2.5 Sudanese Pounds (LS).

Table 3B. Projected Management and Investment Income, 1500 Feddan Farm, One-fourth to Fallow and Remainder to Sorghum, 500 Kg/feddan, Gedaref (Medium Efficiency)

Item	Cost or Returns		Remarks
	One feddan	1,500 feddans	
Yield (tons)	0.5		Lower yields than high efficiency
Price per ton (farm gate)	300		
Gross output (LS)	180	168,750.00	
Variable Costs:			
Seed	10.0	11,250.00	
Land rental	1.0	1,125.00	
Crop tax	13.75	15,468.75	
Land preparation	6.50	7,312.50	
Fallow work	1.50	1,687.50	
Precision drill	3.00	3,375.00	
Herbicide	20.00	2,250.00	
Repairs	22.00	24,750.00	15% original cost instead of 10%
Hand weeding	6.00	6,760.00	
Hand harvest	15.00	16,875.00	
Threshing	2.50	2,812.50	
Staffing	10.00	11,250.00	
Sacks and string	16.50	18,562.50	
Other costs	2.35	2,643.75	
Subtotal	132.10	148,612.50	
Fixed Costs:			
Depreciation	18.86	21,217.50	
Total Costs:	150.96	169,830.00	
Management Investment Income Before Financing:			
LS 300/ton	-0.96	-1,080.00	
LS 350/ton	24.04	27,045.00	
LS 400/ton	49.04	55,170.00	

Land clearing cost not included.
US$1.00 = 2.5 Sudanese Pounds (LS).

Table 3C. Projected Management and Investment Income, 1500 Feddan Farm, One-fourth in Fallow and Remainder to Sorghum, 600 Kg/feddan, Gedaref (High Efficiency)

Item	Cost or Returns		Remarks
	One feddan	1125 feddans	
Yield (tons)	0.60		
Price per ton (farm gate)	300		
Gross output (LS)	180	202,500.00	
Variable Costs:			
Seed	10.00	11,250.00	Hybrid at increased cost
Land rental	1.00	1,125.00	Leased from MFU
Crop tax	16.50	18,562.00	Production at fixed tax
Land preparation	6.50	7,312.50	2 harrowings on 1125 feddans
Fallow work	1.50	1,687.50	Based on 375 feddans
Seeding with precision	3.00	3,375.00	Uniform depth in rows
Spray premerge herbicide	20.00	22,250.00	Only estimate (on low side)
Spray premerge herbicide	2.00	2,250.00	Fuel only
Repairs	14.67	16,503.75	10 percent original cost
Hand weeding	6.00	6,750.00	1/5 of original amount
Hand harvest	15.00	16,875.00	All hand labor
Threshing	2.50	2,812.50	Stationary custom combine
Staff salary	5.00	5,625.00	
Sacks and string	19.80	22,275.00	LS 3 per 90.9 kg sack
Other costs	2.35	2,643.75	Local taxes
Subtotal	125.82	141,547.50	
Fixed Costs:			
Depreciation	18.86	21,217.50	2 tractors @ 50,000 each; one planter @ 30,000; one sprayer @ 15,000, chisel plow 20,000, 7-yr life, 10 percent salvage
Total Costs:	144.68	162,765.00	
Management Investment Income Before Financing:			
LS 300/ton	35.32	39,735.00	
LS 350/ton	65.32	73,485.00	
LS 400/ton	95.32	107,235.00	

Land clearing cost not included.
US$1.00 = 2.5 Sudanese Pounds (LS).

Table 30. Cash Flows for 1500 Feddan Farm All Planted to Sorghum, With 0.28 Ton Yield Per Feddan, and Using Varying Farm Gate Prices (Present System)

Item	Years 1	2-7	8	9-14	FIRR
		LS 300/TON FARM GATE PRICE			
Inflows:					
Gross sales	126,000	126,000	126,000	126,000	
Outflows:					
Clearing land	45,000				
Investment	74,000		74,000		
Cash costs	104,610	104,610	104,610	104,610	
Total	223,610	104,610	178,610	104,610	
Cash Flows:					
Without land clearing	-52,610	21,390	-52,610	21,390	33.5 percent
With clearing	-97,610	21,390	-52,610	21,390	13.5 percent
		LS 350/TON FARM GATE PRICE			
Inflows:					
Gross sales	147,000	147,000	147,000	147,000	
Outflows:					
Clearing land	45,000				
Investment	74,000		74,000		
Cash costs	104,610	104,610	104,610	104,610	
Total	223,610	104,610	178,610	104,610	
Cash Flows:					
Without land clearing	-31,610	42,390	-31,610	42,390	133.3 percent
With clearing	-76,610	42,390	-31,610	42,390	52.5 percent
		LS 400/TON FARM GATE PRICE			
Inflows:					
Gross sales	168,000	168,000	168,000	168,000	
Outflows:					
Clearing land	45,000				
Investment	74,000		74,000		
Cash costs	104,610	104,610	104,610	104,610	
Total	223,610	104,610	178,610	104,610	
Cash Flows:					
Without land clearing	-10,610	63,390	-10,610	63,390	597.4 percent
With land clearing	-10,610	63,390	-10,610	63,390	113.2 percent

Land clearing cost: LS 30/feddan.
Investment: 1 tractor at LS 50,000 and disk-drill at LS 24,000. Cash costs and average yield from MANR study Gedaref area, 1985. No salvage value on equipment taken but prices for repairs may be low.

Table 3E. Cash Flows for 1500 Feddan Unit, One-fourth Placed into Fallow and Remainder to Sorghum, 500 Kg/feddan (Medium Efficiency)

Item	Years 1	2-7	8	9-14	FIRR
		LS 300/TON			
Inflows:					
Gross sales	168,750	168,750	168,750	168,750	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	148,612.5	148,612.5	148,612.5	148,612.5	
Total	358,612.5	148,612.5	313,612.5	148,612.5	
Cash Flows:					
Without land clearing	-144,862.5	20,137.5	-144,862.5	20,137.5	-5 percent
With clearing	-189,862.5	20,137.5	-144,862.5	20,137.5	-7.7 percent
		LS 350/TON			
Inflows:					
Gross sales	196,875	196,875	196,875	196,875	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	148,612.5	148,612.5	148,612.5	148,612.5	
Total	358,612.5	148,612.5	313,612.5	148,612.5	
Cash Flows:					
Without land clearing	-116,737.5	48,262.5	-116,737.5	48,262.5	34.3 percent
With clearing	-161,737.5	48,262.5	-116,737.5	48,262.5	22.0 percent
		LS 400/TON			
Inflows:					
Gross sales	225,000	225,000	225,000	225,000	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	148,612.5	148,612.5	148,612.5	148,612.5	
Total	358,612.5	148,612.5	313,612.5	148,612.5	
Cash Flows:					
Without land clearing	-88,612.5	76,387.5	-88,612.5	76,387.5	84.0 percent
With land clearing	-133,612.5	76,387.5	-88,612.5	76,387.5	53.7 percent

Table 3F. Cash Flows for 1500 Feddan Farm, One-fourth Placed into Fallow and Remainder to Sorghum, 600 Kg/feddan Yield (High Efficiency)

Item	Years 1	2-7	8	9-14	FIRR
		LS 300/TON			
Inflows:					
Gross sales	202,500	202,500	202,500	202,500	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	141,548	141,548	141,548	141,548	
Total	351,548	141,548	306,548	141,548	
Cash Flows:					
Without land clearing	-104,048	60,952	-104,048	60,952	54.2 percent
With clearing	-149,048	60,952	-104,048	60,952	35.4 percent
		LS 350/TON			
Inflows:					
Gross sales	236,875	236,250	236,250	236,250	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	141,548	141,548	141,548	141,548	
Total	351,548	141,548	306,548	141,548	
Cash Flows:					
Without land clearing	-70,298	94,702	-70,298	94,702	133.9 percent
With clearing	-115,298	94,702	-70,298	94,702	80.2 percent
		LS 400/TON			
Inflows:					
Gross sales	270,000	270,000	270,000	270,000	
Outflows:					
Clearing land	45,000				
Investment	165,000		165,000		
Cash costs	141,548	141,548	141,548	141,548	
Total	351,548	141,548	306,548	141,548	
Cash Flows:					
Without land clearing	-36,548	128,452	-36,548	128,452	351.4 percent
With land clearing	-81,548	128,452	-36,548	128,452	157.1 percent

ATTACHMENT 4

COMPLEMENTARY PROJECTS SUPPORTIVE OF THE MECHANIZED RAINFED AGRICULTURE RESEARCH PROJECT

There are several voids in the infrastructure of the mechanized agriculture subsector that need attention and concurrent development if the subsector is to assume its fully productive role in the national economy. In addition to research and its subsequent extension, the obvious voids in the subsector are roads, rural water supplies, and the provision of a multitude of agricultural inputs and a mechanism for storing and marketing the expanding production.

FARM TO MARKET ROADS

The possibilities for construction and improvement of roads in the subsector are unlimited. Essentially, there is an urgent need for three roads for the subsector. These would be (1) Simsim-Gedaref road, (2) Damazin-Singa road, and (3) the Habila-Dilling road.

Simsim-Gedaref road is 130 km or 87 miles and is presently an unimproved road serving the area having the highest percentage of total sorghum production (735,000 tons). Between 300,000-500,000 tons of sorghum is presently being transported over this road during the first five months of 1986.

The lorries carrying this grain are largely tractors with semi-trailers moving 30 tons per trip. Consequently, between 10-15,000 trips will be made during this five-month period for sorghum grain alone. In addition, there is a considerable number of smaller lorries carrying charcoal, labor consumable supplies, and fuels both into and out of the area. Roughly 100-150 round trips are made on this bush track daily at speeds of 10-20 mph. The condition of the road has increased hauling costs to 5.00 per bag or over LS 1500 per 30 ton load for a 260 km round trip. Lorries of the same capacity charge only LS 4.50 per bag to transport grain from Port Sudan to Khartoum, a distance of over 800 km.

The high hauling charges of a bag of grain to the Gedaref market both raises the price to the local consumer and essentially takes the Sudanese sorghum from the international market by making the price non-competitive for traditional markets, unless the GOS subsidizes sorghum exports in some fashion. The March 1986 devaluation could alter this, but GOS would have to export at the devalued rate of LS 4.30 and not the official rate of LS 2.47 = US$ 1.00.

Truckers have said that if a paved road were available for the Simsim-Gedaref route, they would only charge between LS 1.50 and LS 1.00 per bag. In addition, the GOS would save the additional foreign exchange expended in extra fuel, spare parts, and shortened lifespan of lorries

that the bush road exacts. Presently, LS 400,000 is annually expended on maintaining the road from Simsim to Gedaref. The paving of this road would not eliminate the entire maintenance cost, but would greatly reduce this amount and provide a year-around access through the heart of the principal mechanized rainfed farming district.

Cost recovery could be exacted by making this a toll road or charging an annual fee for a lorry to use the improved road. Estimated cost for constructing such a road would be $280,000/km or $36,842,000 for the 130 km of which $22 million would be foreign exchange and about $15 million would be local currency equivalents. If 500,000 tons were moved over the road and an LS 2.00 were charged for each bag, then roughly LS 10 million or $5 million could be recovered each year.

Canadian Aid (CIDA) is greatly interested in improving the Gedaref-Simsim road, as they have a farming demonstration project at Simsim and have agreed to another five-year extension of support for this project. CIDA has expressed some interest in improving this road but does not have sufficient funds for building the entire road and, consequently, is looking for co-financing with another donor and GOS support.

The Singa-Damazin road is an integral part of the Sennar-Damazin road which is presently paved from Sennar to Singa. The Kuwait and Arab funds contributed substantially to the total $57 million cost. Contractor squabbles have delayed completion and, hopefully, this can be resolved and the road can be completed in the next two to three years.

The Dilling-Habila road of 46 km is programmed to be constructed as an all-weather gravel road. West Germany was negotiating contributing DM 70 million toward the total $70 million for a total road package of 285 km that would also include New Halfa-Khashm el Girba (96 km) and the Zalengei-Geneina road (143 km).

WATER YARD DEVELOPMENT IN GEDAREF

The paucity of water supplies in the vertisols that constitute a major portion of the mechanized farming schemes has been limiting development of these areas in three ways. **First**, there is a lack of potable water for domestic use throughout the six or seven months from mid July. This restricts investment in housing and the year-around residence of farmers in many of the mechanized schemes. **Secondly**, there is a lack of water for livestock during the same period. Even though there are surplus supplies, crop residues, and unharvested heads of sorghum throughout the area, animal populations are restricted to only areas having "hafirs" or access to non-permanent rivers or the limited wells. **Thirdly**, there is a lack of clean water for agricultural spraying of herbicides and applications of insecticides. Consequently, this technology cannot be used no matter how cost effective these operations might be.

There have been many searches for groundwater sources that could be used for domestic water supplies. With the recent influx of refugees, such searches have been more numerous and wider ranging. The prospects of finding ground water has been limited to identifying low yielding aquifers around the "jebels" or inselbergs.

Traditionally, the more common method of supplying water is the "hafir". This is, essentially, an excavation of one to two meters depth in a low lying area or adjacent to a "Khor" or drainage way. These can vary in size, but most do not supply water on a year-around schedule. Evaporation will approximate 5 mm/day, and over the 285-day dry season will total nearly 1.5 m. Seepage is low but can approach another 50 cm. Consequently, even if no water is used for domestic, livestock, or agricultural purposes, it is assumed that annual water losses will equal or exceed 2 meters. With convection, the thermal differences in water less than 1 meter deep causes an upwelling of bottom sediment, making such water impossible to use in agricultural sprayers and unfit for human consumption.

It is proposed that a horseshoe shaped dam will hold more water per excavated cubic meter than a hafir. There is topographic relief in these lands and seldom are there more than one to two percent slopes. However, there are sufficient erodible drains that it should be easy to locate a suitable dam site in each area of ten square miles.

A dam with suitable side walls to extend upstream to hold 2.5 m of freeboard and an excavation of 2.5 m to form the basin can provide a 4-5 m depth of water at spillway level. This depth of water should be able to store over 75,000 cubic meters when full if the basin is 5 m deep and the embankment is 3140 m long. With a 5-meter crest and 3:1 upstream and downstream slopes, such an embankment would have 62,800 cubic meters and at L3, 300 per cubic meter would cost about LS 188,400. A simple spillway with concrete surface and stone riprap would cost another LS 20,000 to construct, This amount would provide a modest water supply for 50 farmers, their livestock, and their agricultural needs. Where slopes are less and conditions less favorable, costs could double. For budgetary purposes, a cost of LS 300,000 per dam and spillway will be a conservative estimate.

A siphon; sand filter; two low lift, high capacity pumps (10 L/second); fencing; and stock watering troughs would add another LS 75,000 for a total cost of each watering yard of LS 375,000 or about $100,000. Within each five-mile radius, approximately 50 farmers are now farming about 50,000 feddans. Such farming and associated crop residues could feed 1,000 tropical livestock units1/ TLU for a six-month period.

1/TLU cows = .7, sheep and goats = 0.15, camels = 1.1

Storage of 75,000 cubic meters of water should suffice for the domestic and agricultural use, including the 1,000 TLUs. Thus, in the four million feddans of the mechanized farming system, it will require about 64 such dams and associated water yards.

Water yards management could be similar to that established in Western Sudan, or a modified version thereof. Mechanized farmers and livestock owners should expect to pay for water they consume. Development costs for establishing water yards could be recovered over a period of years.

Domestic and filtered water could be sold for LS 2.00 per filling of a 1,100 liter tank. A 500 liter, two wheeled tank would cost LS 1.00 to fill. Camels would water for 50 piasters, cattle at 25 piasters, and small ruminants for 5 piasters. Herbicide spraying would require 50 cc/m2 or 210 liters per feddan. An annual spraying for the 1000 feddan farm requires 10,000 liters of water at a cost of LS 420. each for water and for the 50 farmers LS 21,000 would be realized. This, coupled with a like amount for livestock, could produce a gross return of LS 40,000 per year. If 20,000 of this could be used for fuels, spares, maintenance, and management, a debt repayment of LS 20,000 per year and 15 years would be required for an interest free payback to supply water inputs for the rainfed farming sector.

FARM SERVICE CENTERS

Availability of inputs such as fuels, lubricants, seeds, fertilizers, tractor spares, herbicides, insecticides, credit, workshops, and market outlets with temporary storage are absent in the countryside. When available, they are concentrated in cities far removed from the farming area itself. The farmers report that the absence of these inputs are their most serious production constraint.

The most basic needs for mechanized agriculture are fuel, spare parts, and repair facilities. The time limits associated with land preparation and planting force farmers to anticipate their needs months in advance and engage in the hoarding of tractor spares that could be needed. Research recommending fertilizer and herbicides is considered irrelevant because such inputs and machinery for their application are not available. It is only in the last three or four years that improved seed has become available, but primarily from private sources.

The Agricultural Development Bank (ADB) loans are available only in Khartoum and other large cities. However, the ADB has recently introduced some pilot schemes for loaning to farmer unions and selected cooperatives in the traditional sector, but such loans serve only a small fraction of the rainfed sector.

There are few opportunities to sell grain in the countryside, and there is essentially no temporary storage in the rural areas. Most grain is sold in bags which are manually loaded and off-loaded on lorries. Essentially, there is no bulk handling of grains and oil seeds. All of these commodities are transported and stored in expensive bags which are imported with scarce foreign exchange.

Workshops and spare parts are frequently hundreds of kilometers from inoperative tractors. There are few, if any, skilled mechanics in the rural areas, and each breakdown requires several days travel to obtain the necessary spare part. There is some custom land preparation, planting, and threshing in the sector, but insufficient to meet the demand. Special farm machinery other than wide level disc and combine harvesters are not available. There are few technicians who can properly mix and apply herbicides and insecticides. Similarly, there are few who can calibrate planters and fertilizer applicators. There are only a few extension offices where farmers can get advice on cropping through the mechanized farming area.

Consequently, if these materials and services were made available to the farmers in the four or five areas that are designated as demarcated lands, they would be greatly utilized. If this facility, hereafter referred to as a Farm Service Center (FSC), were operated by the private sector, it would not be a burden on either the GOS or the donor agencies. However, for the private sector to establish such a facility would require certain incentives and controls. Among the incentives would be a five-year lease on a facility in the mechanized farming area and foreign exchange allowance to import spares, implements, chemicals, and fertilizers. There would need to be a fuel allocation and possibly a license to export surplus production. There would also initially need to be an expatriate manager and the foreign exchange for his salary.

Among the controls would be the monitoring of such services, the auditing of inventories to be assured that materials and services were being purchased and used in the mechanized farming subsector. There would need to be a regulatory function to determine whether materials and services were up to prescribed standards. There would also need to be enforcement of certain safety and pollution controls associated with farm chemicals. Consequently, the first two or three FSC need to be operated as a public sector function to determine operational guidelines. The contracts for the operation and lease of FSC could be made and performance bonds be posted.

The public sector FSC could be used as a training function for management, tractor operators, mechanics, spare parts stockmen, pesticide formulators, grain buyers, and credit specialists. Farmers who use the FSC would have to be registered as demarcated farmers and be current with taxes and rent payments.

Eventually, the FSC would be absorbed entirely into the private sector, become a profit making institution, and not require further GOS or donor support.

ATTACHMENT 5

CLIMATE AND SOILS SUMMARY

The combination of suitable climate and soils are the necessary components of a successful mechanized rainfed agriculture. Rainfall should ideally be from 600 to 850 mm spread out over a five-month growing season with a weekly rainfall not exceeding 100 mm. The soils should be level or with slopes of less than 0.5% to reduce sheet erosion. The texture would ideally be a loam with a depth of at least three feet and having good internal and subsurface drainage. The ph of soil should be 6.5- 7.5 with a cation exchange capacity of 20-40 meq/100 grams. The dominant cation should be calcium and exchangeable sodium should be less than 5%.

Ideally, the organic matter would be 1.5-3.0% and nitrogen content of the soil could be about 0.3-0.6%. Available phosphorus of 8-14 ppm would suffice and exchangeable potassium of 1.2 to 1.8 meq/100 g should satisfy the need for that element. Ideally, soils should remain friable for tillage becoming neither sticky when wet nor hard when dry. The structure should be granular for rapid infiltration and to reduce runoff and surface erosion.

In the Sudan the climate shows diversity in rainfall and is consistently subtropical to tropical with respect to temperature. The isohyets are roughly parallel running ENE to WSW and range from essentially zero in the north to more than 1,400 mm in the southeast. It is in the 500 to 850 mm rainfall belt that most mechanized rainfed farming is located. There are some areas having less than 450 mm where specialty crops are grown under rainfed conditions. Among these are Khartoum, 161 mm; El Fasher, 280 mm; Kassala, 320 mm; Wad Medani, 355 mm; and El Obeid, 372 mm. However, it is such areas as Gedaref, 577 mm; Abu Naama, 613 mm, Kadugli, 671 mm; and Damazin, 711 mm where rainfall is sufficient and reliably distributed through a five-month duration that one finds mechanized rainfed farming.

During the last 50 years the rainfall intensity and distribution has steadily declined and mechanized farms north of Gedaref-Wad Medani highway have had greater frequencies of crop failures due to insufficient rainfall. Consequently, the rainfed mechanized sector is expanding southward.

The growing season is a function of total rainfall, rainfall distribution, and sunlight intensity. The latitude difference between Gedaref and Damazin is only slightly over two degrees or 250 km. However, the growing season at Gedaref averages 3.8 months, and at Damazin it averages 5.7 months. Thus for the normal 105- to 110-day crops the dating tolerance for the optimal sowing is considerably less

with farms to the north and west. The identification of early maturing

varieties for these areas would be specifically relevant.

The soils of the mechanized farming subsector are varied and, consequently, many soil problems will need site specific solutions. However, for the most part, the subsector has concentrated on certain soil characteristics that are easily visible.

The mechanized farming has mainly concentrated on the heavy clay soils that the traditional farmer has been unable to work with hand tools or animal power. These soils are able to store moisture and have an inherent fertility that apparently is slowly released and can be somewhat improved or rejuvinated with a reversion to a fallow.

Most of these dark clays are vertisols or what are locally called the "cracking clays." These tend to dry in massive blocks, leaving 2-3 cm cracks as deep as 1 m. Rainfall intake is initially high, but as soils wet and expand the infiltration rate is rapidly reduced. This rapid swelling has resulted in very little subsurface moisture storage below two meters. The absence of groundwater recharge with these soils has precluded any shallow wells and ground-water development.

The BNIAD had the soils at Damazin analyzed. A summary of that analysis indicates that both nitrogen and phosphorus are deficient. Nitrogen and phosphorus fertilizers must be applied to achieve better yields. As for potassium, it has been mentioned from previous studies that potassium levels decrease with the increasing use of the land. At present, the levels of potassium in the Damazin research farm, at best, can be considered moderate and there is no need for immediate application of potassium fertilizers except for sections A, B, and C which have low levels of mobile potassium reserve. In Abu Gemai there is need for potassium application, as the level of potassium in the soil is low. In Karen Karen and Abu Sheniena the level of exchangeable potassium is moderate but the mobile potassium reserve is low. Therefore, potassium fertilization if necessary.

The physical constraints to fertility are mainly the high clay content with the concomitant low permeability, high plasticity, stickiness, and the extremely hard consistency when dry. The presence of montmorillonitic clay accents these adverse effects with the incidence of cracking which seems to be the only means of having water penetration into these heavy clays.

Due to the high intensity of rainfall and slow permeability, these soils are subject to flooding in receiving sites and erosion in the shedding sites.

Due to the adverse physical properties of these soils, timely tillage is

the main constraint. Cultivation during the rainy season necessarily means that the farmer is forced to take his tractor drawn implements to the field for crop sowing when the moisture content in the soil is optimum for seed germination. However, the soil at this moisture content is also susceptible to soil compaction. Hence, minimum tillage is recommended. Post harvest tillage operations are recommended but require large horsepower and only chiseling should be done to encourage development of penetration and inhibit the drying of subsurface moisture. Contour cultivation should always be adopted to control soil erosion on sites with pronounced variation in topography. Crop rotation with the introduction of leguminous crops in sequence or as intercropping is advisable. Incorporation of crop residue should always be encouraged.

ATTACHMENT 6

IMPLICATIONS OF MECHANIZED AGRICULTURE ON LIVESTOCK FARMING IN THE SUDAN

IMPLICATIONS OF MECHANIZED AGRICULTURE ON LIVESTOCK FARMING IN THE SUDAN

Increases in livestock production in Sudan in the traditional sector, i.e., transhumance, nomadic, and smallholder sedentary are likely to be small, if any, in the next 10 to 15 years. Lack of land tenure, communal use of grazing lands, traditions of keeping maximum numbers of livestock, and inadequate infrastructure including roads, communications, and markets are primary constraints to efficiency of livestock production. They are also either directly or indirectly the cause of grazing land degradation.

The emphasis in Sudan on increasing agricultural production of the mechanized rainfed farming areas provides a surplus of crop residues that could be used to increase the feedbase for livestock. In addition, as better farming methods are introduced and practiced such as crop rotations and intercropping with legumes and potential forage crops, the feed base will be further expanded. With these generalizations in mind, it can be presumed that if substantial increases in animal production are to be made, most of the increase would have to come from an integrated mechanized farming/livestock production effort.

Because of mechanized farming development in Sudan, there has been a dislocation of traditional livestock production patterns. Grazing areas have been turned into large blocks of land for mechanized farms. In some cases, these blocks have been established in areas which were climatically marginal (less than 350 mm precipitation) for crop production. An example is in the Gadambali area east of Gedaref. History has shown that only one out of four or five years is the moisture great enough to produce a sorghum crop in this area.

The MFC has recognized that some of this area in particular should probably be put back into grazing lands. Methods and technology for reestablishing these areas into range and forest need to be considered in an adaptive research program. Considerable technology has already been developed in other countries, especially Australia and the United States, but adaptive research is required to determine which methods would be most appropriate.

A definite limitation for livestock production in some of the marginal lands in Sudan is the lack of ground water for livestock and human consumption. At present, livestock herds and flocks have to be trekked long distances for watering, and water has to be carried to camps for human use. This is particularly true in the Gadambalya area. Methods of water harvesting and conservation need to be studied, and methods used in other countries should be tested for their applicability in Sudan.

ATTACHMENT 7

RAINFED FARMING RESEARCH IN SUDAN

FROM THE SUDANESE VIEWPOINT

by
Professor Mahmoud O. Mahmoud

THE RAINFED SECTOR

Prior to the advent of modern methods of irrigation during the present century, Sudanese agriculture was virtually all rainfed. Irrigation was confined to the small areas that could be managed by the primitive animal-driven water wheels and still more primitive man-driven "shadoufs." Such areas were restricted to a very narrow strip along river banks, especially in the present North Region. In addition, some areas of comparable magnitude were cultivated by the flood system.

Introduction of modern irrigation systems, especially dams, greatly increased the proportion of irrigation in the country's cropped area. Rainfed agriculture still dominates. At present it accounts for more than 85% of the total cropped area, 90% of its livestock population, and virtually all of its forestry products. It contributes 64% of the country's earnings from agriculture and is the main occupation of a similar percentage of the population. Thus, it is the single most important economic sector in the Sudan.

This sector comprises the following three main segments:

1. Arable crops, mainly field and some horticultural
2. Livestock, range, and pastures
3. Forestry

This report concentrates on the first segment.

History of Research on Rainfed Agriculture.

The real beginning of agricultural research in Sudan occurred in 1904 when the Shambat Research Farm was founded. It was preceded by some experimental fields and by the Wellcome Tropical Laboratories in 1902 and 1903. The establishment of the Gezira Research Farm at Wad Medani in 1918 was a big milestone, though it was intended to concentrate research effort on irrigated cotton.

The year 1935 can be considered the beginning of research on rainfed crops. In that year the Kadugli substation was established. However, being a branch of the Cotton Breeding Section at Wad Medani, its primary mandate was rainfed cotton. In this and the two preceding stations (Shambat and Gezira) there was, however, some "spill-over" research effort on crops other than cotton by the cotton scientists. These were crops associated with cotton in the cropping rotation, especially sorghum.

The Yambio Research Station, founded in 1948, was a major departure from agricultural research's orientation up to that date. The station was more concerned with food and tropical plantation crops than with cotton. It was concerned with farming on lateritic soils under fully rainfed conditions. However, because of political disturbances in the South, this station remained inactive for most of its history.

The Central Rainlands Research Station at Tozi was opened in 1952. Its founding was prompted by the failures and problems that faced the Mechanized Crop Production Schemes (MCPS) in northern Gedaref District. It was realized that such a major development effort should have been preceded by adequate research. So, mechanization underlined all the research efforts at Tozi. Sorghum, sesame, cotton, and later, groundnuts were considered the primary crops. Maize, sunflower, and safflower were secondary crops. Many other crops were investigated at varying degrees of intensity. The mechanization section had a large amount of tractors, tillage, and crop cultivation and harvesting equipment. Before it was closed down, the station established most of the essential technologies needed for successful mechanized rainfed farming on the heavy vertical soils of the Central Clay Plains.

In anticipation of the establishment of the Kenana (a Gezira--size and type) irrigated scheme in the area between Roseiris, Sennar, and Kosti, it was decided to transfer the Tozi station to another site on the Blue Nile river bank. This would serve the needs of irrigated as well as rainfed farming. Abu Naama, some 35 kilometers northwest of Tozi, was chosen for this site. The transfer was completed and Abu Naama's Kenana Research Station started operation in the 1963/64 season on the rainfed fields. Research on irrigated crops followed in 1964/65. The station was established with a generous contribution from USAID.

It was envisaged for the station to do fully integrated and comprehensive research on agricultural production in the area. For the first time, the proposed staffing list of any station in Sudan included researchers on forestry, animal production, dairy, and agricultural economics besides the usual complement of crop and soil scientists. However, this plan for integrated research could never be implemented. It was a failure to be lamented.

Progress of the station's rainfed research was hampered by being confined to its own farm, especially when it was found that its soils were severely depleted and infested with Striga hermonthica. Progress in sorghum breeding could only be achieved after three off-station testing sites were established between 1969 and 1971 at Simsim, Agadi, and Tozi. The Mechanized Farming Corporation (MFC) contributed funds to the operation cost of work at the first two sites. This research was conducted on the MFC state farms. Work at these sites was dominated by varietal evaluation of sorghum and sesame from the start. Investigations on herbicides, crop husbandry, tillage, and variety testing of cotton, soybeans, maize, and sunflower were conducted in later years, especially at Agadi.

Since the opening of Abu Naama, rainfed crop research witnessed no expansion other than the major effort of the Western Sudan Agricultural Research Project (WSARP). This project was a great achievement in more than one way. For the first time, research was planned to serve the traditional rainfed farmer and to investigate problems of the sandy soils. Equally as important was the concept of an integrated farming systems approach bringing crops, soils, livestock, and forestry, as well as social and economic factors, under one research umbrella. Yet, it is too early to fairly evaluate WSARP's research achievements. Most of its time up to now has been spent on building its four stations and training its staff. Two of its stations are yet to operate and the third has only three seasons work (two of them drought-stricken). Kadugli, which has been under WSARP for several seasons, does not represent a great departure from Abu Naama, either environmentally or agriculturally.

Research on animal production, range, and forestry has been very weak, if not altogether lacking. The most prominent efforts were those on the animal production stations at Ghazala Gawzat and Um Benain and the Gum Arabic Research Station at El Obeid. However, none of these three stations ever had more than two scientists at any time and only one scientist most of the time.

Institutions Engaged in Rainfed Research.

ARC is Sudan's official agency for agricultural research, except for animal health and production and research undertaken by universities. Its contribution to rainfed research has already been discussed. In spite of shortcomings, its efforts outweigh any other research undertakings in this field. However, other institutions have at one time or another conducted or are still conducting or sponsoring some sort of research. These include the following:

1. Animal Health Laboratories
2. The Animal Production Agency
3. Various universities
4. Mechanized Farming Corporation
5. Western Savannah Development Program
6. Jebel Marra Development Project
7. Blue Nile Integrated Rural Development Project
8. FAO and UNDP
9. USAID
10. German aid (GTZ)
11. British ODA
12. Canada's CIDA
13. Other foreign aid agencies (Dutch, Swedish, Norwegian, etc.)
14. ICRISAT
15. Private aid and philanthropic agencies

16. Some big companies in the mechanized sector such as the Arab-Sudanese Blue Nile (Agadi), Egyptian-Sudanese Integrated Agricultural Company, and Blue Nile Agriculture and Animal Production Company (DAAPCO)

17. Arab Organization for Agricultural Development

Various international research and development companies have conducted research on behalf of some of the above-mentioned institutions. Prominent among these are Doxiades Associates, Hunting Technical Services, Agrodev and Interimco.

Share of rainfed sector in ARC's research. ARC's research programs still strongly favour research on irrigated crops, especially cotton. That is in spite of the greater contribution of the rainfed sector to the country's economy and life.

Out of 13 research stations and substations run by ARC (before WSARP), only Yambio and Kadugli were exclusively devoted to rainfed crops. Abu Naama is shared between irrigated and rainfed farming. That is to say, less than 20% of these stations serve the rainfed sector.

In mid-1983, 93 scientists worked on ARC's research stations other than Kadugli and El Obeid. Only 11-12% of them were at Abu Naama and Yambio (Table 1). Even with the ten scientists then working at the two WSARP stations, the total on rainfed stations was only 54% of those working at Gezira Research Station alone.

It is not only a matter of quantity, but also of quality, reflected by the type of scientists manning these stations (Table 1). At present, not a single scientist of a professor or assistant professor level serves on the rainfed stations, and never has a professor served on any of them. Some of these specialists presently at the stations are senior

Table 1. Distribution of ARC's Qualified[1] Research Scientists as of July, 1983 (excluding WSARP).

	Professors	Others	Total
ARC Headquarters[2]	1	2	3
Irrigated Research Stations			
1. Gezira (W. Medani)	18	21	39
2. Hudeiba	0	12	12
3. Guneid	0	5	5
4. Shambat	2	5	7
5. Sennar	0	4	4
6. Shendi	0	2	2
7. Rahad	0	5	5
8. New Halfa	0	7	7
9. Maatug	0	1	1
TOTAL IRRIGATED	20	62	82
Rainfed Research Stations			
1. Kenana (Abu Naama)[3]	0	8	8
2. Yambio	0	3	3
TOTAL RAINFED	0	11	11
Research Centres			
1. Food Research	1	31	32
2. Silviculture	3	1	4
3. Fisheries	0	10	10
4. Wildlife	0	3	3
TOTAL CENTRES	4	45	49
TOTAL ARC[4]	25	120	145

[1]Assistant scientists (B.Sc.) not included.

[2]Director General and his two deputies not included in headquarters, but in their respective sections at Gezira. Included in the headquarters are workers from Training and Publication and Statistics and Ag. Econ. sections.

[3]Abu Naama does both rainfed and irrigated research.

[4]Scientists on study or cn secondment not included.

scientists, but most are scientists assigned to these stations immediately after obtaining their doctorates or master degrees. There are no incentives for experienced scientists to stay and work at these stations. Working and living facilities and conditions are much poorer than they are on the irrigated stations. At present, almost all of ARC's professors and assistant professors work at the stations and centres located at Wad Medani, Khartoum, and Hudeiba.

Budgets and facilities show an even stronger bias toward irrigated crops. The following table shows percent distribution of ARC's (excluding WSARP) approved Chapter II (operating expenses) budget.

Headquarters	36.6%
Irrigated Stations	37.9%
Abu Naama and Yambio	7.2%
Research Centres	18.3%
TOTAL (L.S. 1,250,000)	100.0%

Of the total research stations' share, rainfed stations have only 16%. All this goes to reveal the very unfair deal the rainfed sector has been getting from ARC, and the need for drastic changes in ARC's objectives and strategies. Such changes shall be in line with the present general tendencies of Sudan's economists, planners, and policy makers.

With the coming of WSARP, rainfed agricultural research within ARC has been strongly tipped in favour of the traditional subsector. Beside WSARP, all the regional development projects, the international organizations, foreign governmental, and philanthropic aid is pouring into this subsector. Now with the World Bank's MFC III project over, this will leave the needs of mechanized rainfed farming research very poorly served.

Problems and Challenges of Rainfed as Compared to Irrigated Agricultural Research.

For proper planning of research needs, it is important to understand the differences between different agricultural sectors, as well as activities and problems in each, and the challenges and opportunities they provide for research.

In the Sudan the following differences between the irrigated and rainfed sectors should be noted.

1. Rainfed agriculture covers a much wider range of environments. These are created by the interaction of different soils and varying rainfall. While irrigation alone cancels differences in moisture availability, most of the country's irrigated lands are confined to

the heavy cracking clays of the Central and Eastern Regions. There are limited areas of silty soils along the Nile banks. There is no irrigation on other major soil types. Rainfed agriculture, on the other hand, covers all types of arable soil within the country. Superimposed on these soils are rainfalls ranging from 200 to 1,500 mm from north to south, creating a multitude of agro-climatic zones.

2. The crops, livestock, and forestry products of the rainfed sector are much more varied than those found on the irrigated counterpart. The people practicing rainfed farming are a cross-section of Sudanese ethnic, tribal, religious, and cultural groups. All this resulted in a greater number of farming systems than are found on irrigated areas.

3. Farmers in rainfed areas are generally less enlightened and more conservative than in the irrigated sector, especially the traditional rainfed area farmers.

4. Infrastructures and services are much poorer in the rainfed than in the irrigated areas.

All these differences between the two sectors make the problems of the rainfed sector greater in quantity and in quality. This calls for greater attention and facilities being allocated to the rainfed sector, both in research and in services.

On the other hand, these differences provide researchers in the rainfed sector with greater challenges. The very greatness of the challenges and the many unsolved problems of rainfed agriculture make it easier and more gratifying for researchers to arrive at interventions that can cause rapid advances. This depends greatly on an understanding and evaluation of the problems and establishment of correct priorities before formulation of research programs.

Problems of the Mechanized Rainfed Subsector and Their Causes

The problems faced in mechanized farming production which can be solved or eased by research can be classified under two main headings: (1) low and declining yields , and (2) degradation of soils and environment. This does not take into consideration non-research related problems of infrastructures and services.

The average yields attained in mechanized farming are much lower than the potential established by research or that realized by good farmers. By using improved cultivars and agronomic practices, multi-location and multi-season tests of ARC have shown sorghum to yield more than 1,250 kg/feddan, without fertilizer. Good farmers are consistently getting yields of about 750 kg/fd, yet average farmers' yields hardly ever exceed 350 kg/fd. Their low yields can be attributed to the following

practices and circumstances.

Poor utilization of soil moisture due to:

1. **Late sowing.** Farmers tend to sow much later than the optimal date in an effort to give weeds enough time to germinate and be destroyed by discing. This minimizes cost of hand weeding. More than 50% of the total annual rains fall before most farmers sow their sorghum. It has been estimated that every day's delay from the optimal sowing date causes a loss of 2% of potential yield. This results not only from wasted soil moisture, but also from poor seedbed preparation and seed placement in wet soil. The subjection of young seedlings to excessive moisture during the peak of rains also decreases yield potential.

   Farmers delay 15-60 days from the optimal planting date, but the average seems to be in the range of 20-30 days. Thus, it seems that 40-60% of potential yield is lost on the average, which makes such delays the single most important cause of low yields.

   Research leading to early and efficient or cheaper weed control will induce early sowing. Herbicides, tied to a crop rotation, is one solution. Row planting to enable inter-row cultivation or make hand weeding cheaper and more thorough is another answer. Timely cultivation of fallow areas is a third consideration. All deserve further research.

   It should be noted here that farmers try to minimize weeding expense because they cannot afford to finance good weeding. Very often, that is because they cultivate an area much greater than is specified by MFC's rotation program or that is financed by the Agricultural Bank.

2. **Poor infiltration of water into the soil.** This can be attributed to improper and untimely tillage. Continuous harrowing at the same depth causes hard pans (plow soles). Delayed tillage that seals the natural cracks reduces the amount of rain water that infiltrates through these cracks.

   Use of tined implements, post harvest tillage, occasional deep plowing, and minimum tillage need to be investigated in search of solutions for these problems.

3. **Use of moisture-inefficient traditional sorghum cultivars.** Their inefficiency is caused by their comparative late maturity and their excessive height. The increased height results in the production of much unwanted and moisture-depleting stover. In addition to lateness and height, sorghum landraces may be physiologically moisture-inefficient.

   The development and promotion of dwarf, earlier maturing and drought tolerant cultivars enchance the opportunity to meet the need for moisture-efficient crops.

Use of inherently low-yielding cultivars and of poor quality seed. Beside their moisture-efficiency defects, the popular landraces in mechanized farming are inherently low yielding. Even under adequate soil moisture, they are consistently out-yielded by improved, research-produced varieties and hybrids. Yet there is a wide scope for still more improvement in yield and quality of grain. The latter has been a cause of the low acceptability of most improved varieties.

Yielding ability can be increased by a backcrossing program to reduce stalk height of the present preferred landraces of sorghum. Earlier maturing can be achieved without changing their grain quality. The yield increase will be brought about by a higher yield index and an optimal crop density.

In addition to the inferior cultivars themselves, the seeds used to produce them are usually of low quality. They are taken from the lots of commercial grain without any grading to eliminate shrivelled seeds. They are most often contaminated with weed or other crop seeds. The abundance of wild sorghums contributes to outcrossing and genetic contamination of the seed source. On the average for the whole subsector, yield losses because of poor seed seem to be in the range of 5-10% for sorghum. For sesame, it is less due to its self pollinating habit and the absence of compatible wild relatives.

Low crop densities cause low yields. In fact, crop densities are usually much lower than recommended by research. However, they are the logical result of the forementioned practices and conditions. If farmers use higher densities with late sowing, late maturing, and tall cultivars, they are apt to lose all or a good part of the already low yields that they are getting. Low crop densities are further justified by the declining soil fertility.

Degradation of soils and environment. Soils have been degraded chemically, physically, and biologically. Environmental degradation was caused by indiscriminate tree removal with subsequent enhancement of water and wind soil erosion.

1. Chemical soil degradation or loss of fertility is a result of continuous monocropping with sorghum without any added fertilizers. This is attested to by the decline in yields over time. The farmer is forced to either abandon his farm or leave it under a long resting period to regain fertility.

   These clay soils, inherently deficient in nitrogen and sorghum, usually responded positively to nitrogen fertilization. Response to phosphorous has been very erratic with most crops, and response to potassium was mostly negative. Other macro- and micro-nutrients

were hardly ever tested, except for zinc which gave positive results on maize. Sorghum crops have often shown clear signs of zinc deficiency, though application of zinc to sorghum has not been adequately tested.

Whatever the case, it seems logical to assume that fertilizers have to be added to the soil to replace the nutrients removed by crops. Yet, even with nitrogen, farmers cannot be advised to use fertilizers with their present practices of late sowing and poor cultivars. The plant vigour caused by fertilizers may exacerbate moisture deficiency causing still lower yields. At such low yields, increases due to fertilizer application may not be profitable. So it is only to the better farmers who are now getting high yields that nitrogen application to sorghum can be recommended.

Application of all fertilizers on all other crops need further in-depth investigations. Sesame in particular has shown no positive response to NPK. A claim was made that it gave a strong positive response to molybdenum at Tozi, which might be true. This or other micro- or macro-nutrient deficiencies may be the cause of the negative results of fertilizer trials with most rainfed crops on clay soils.

Decline in soil fertility can be slowed greatly by proper crop rotations. Such rotations have been developed and recommended by ARC. However, they could not be adopted due to the difficulty of harvesting all crops recommended other than sorghum. Hence, mechanization of sesame harvest and introduction of other mechanizable and economically viable crops is of paramount importance for adopting sound rotations. Such rotations are not needed just for fertility maintenance, but are equally important for the successful adoption of herbicides and weed control and for the stabilization of farm incomes.

2. Physical soil degradation is reflected in the already mentioned soil compaction and erosion. Shelter belts, proper tillage, contour plowing, and planting after proper disposal of crop residues are techniques to be investigated to protect soils against physical degradation.

3. Biological soil degradation refers to the excessive contamination of soils by weed species. These dominant weeds include wild sorghum and other sorghum related grass species and, more importantly, the parasitic and hard to control Striga hermonthica. It also refers to the presence of soil borne diseases and pests and their adverse effects on crop production and on beneficial micro-organisms. Again, crop rotations should be considered for solutions.

The solution to environmental degradation seems obviously to be the planting and maintenance of shelter belts and windbreaks. However, the selection of tree species, spacing within and between rows, and the geographic orientation of the shelter belt justifies some research.

Research Priorities for the Mechanized Subsector

The above discussion, though not complete, shows the many problems requiring investigation. However, it does not seem feasible to handle all problems at the same time. In establishing priorities, the following criteria need to be considered:

1. The relative importance of the problem to be solved and the impact of its solution.

2. The probability and ease of finding a solution.

3. The acceptability and affordability of solutions by the farmer and by the country.

Thus, priorities should be given to problems of high impact or which can be solved with little effort and time. In that the improved technologies must be economically feasible, highest priorities should be given to solutions that will require a minimum investment by the farmer and a minimum of added foreign exchange commitments by the nation.

Taking into consideration that solutions already exist for many problems, it seems that the following deserve highest priority ratings.

1. **Mechanization of sesame harvest to make it possible to grow larger areas of this crop** This leads to a sounder crop rotation. Beside the higher comparative economic value of sesame itself, such a rotation is essential for maintenance of soil fertility and for effective use of herbicides.

   As envisaged in a former project, this problem should be attacked on two fronts. For the shorter term, combine harvesting of the present shattering sesame types should be tried, as well as partial mechanization of their harvest, with the use of reaper/binders. For the longer term the breeding of agronomically acceptable non-shattering types should be the objective.

   Introduction of new legume and oilseed crops (soybeans, cowpeas, sunflowers, etc.) will meet the same ends as sesame. However, the problems facing their introduction gives them a little lower priority than sesame.

2. **Weed control problems.** Weed competition causes serious yield losses. In the mechanized sector, delaying sowing to get good week control results in even greater yield losses. Finding weed control methods that enable early sowing should cause a very favourable impact on yield. For this the following may be investigated:

   a. Alternating between herbicides of different selectivities,

together with changing of crops in rotations.

b. Using effective post-emergence herbicides. This allows more exacting selection of herbicides.

c. Planting in rows and inter-row cultivating with on-row band application of herbicides.

d. Plowing of fallow areas before their weeds set seeds or spraying them with herbicides at that time.

3. Production of high-yielding, dwarf, early-maturing, and drought-tolerant sorghum cultivars. Conversion of popular landraces to early and dwarf counterparts is an easy task with expected high impacts on yields and soil fertility.

4. Use of fertilizers to replace the depleted nutrients of the soil. Fertilizers involve higher investments by the farmer and require considerable foreign currency to import, yet they need to be given a high priority in research. In the past, work has concentrated on N, P and K and was not adequately tied to factors affecting their availability and uptake. No attention has been given to other nutrients, especially micronutrients, an omission that has to be corrected. In particular, the fertilization of sesame needs to be investigated.