Report No. 3

Farming Systems Research Along the Senegal River Valley

Agricultural Research Alternatives

Senegal Agricultural
Research Project II

College of Agriculture
The Office of Arid Lands Studies
The University of Arizona
March 1987

Supported by USAID/Dakar

FARMING SYSTEMS RESEARCH ALONG THE SENEGAL RIVER VALLEY

AGRICULTURAL RESEARCH ALTERNATIVES

by

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Executive Summary

This report presents a number of agricultural research alternatives that could be pursued by the Institut Senegalese de Recherche Agricoles (ISRA) and the West African Rice Development Association (WARDA) to increase agricultural production in the Senegal River Valley. These research alternatives are derived from a rainy season farming systems reconnaissance survey that was conducted in Senegal in the Middle Valley Region between Podor and Matam. The study was carried out under the auspices of the Senegal Agricultural Research Project II and was supported by USAID/Dakar. The University of Arizona, Office of Arid Lands Studies had responsibility for directing the survey. The survey provided an assessment of the current agricultural practices, constraints and needs of farmers so that research programs could be devised accordingly. A summary of the possible research alternatives is provided below.

Summary of Research Alternatives

A. Irrigated Agricultural Research

- Seed multiplication programs could receive more support to provide farmers sufficient quantities of improved varieties of rice. maize, sorghum and tomatoes.
- Coordinate multiplication efforts with ISRA, WARDA and SAED.
- Multiply varieties that have already been tested.
- Identify improved seed which is adapted to different soils and climatic factors.
- Test hybrid seeds developed in other regions of the Sahel.
- Emphasize the diversification of cereal crops in seed programs.
- Conduct research on labor-saving technologies and improved cultivation techniques for small perimeters.
- Conduct research on puddling.
- Investigate the feasibility of using animal traction to level and prepare fields.
- Continue to explore the feasibility of introducing small machinery, mechanical transplanters and hand threshers to farmers.
- Continue research on alternatives for improving and maintaining soil fertility.
- Focus on appropriate doses of chemical fertilizers in terms of timing, soil types, crop, and number of applications.
- Continue research on organic fertilizers (green manure).
- Continue research on Matam rock phosphate as a substitute for triple super phosphate and ammonia phosphate (i.e., appropriate application rates, costs/benefits, etc.).
- Continue research on Azolla and Sesbania as potential nitrogen supplements and weed suppressants.
- Establish a number of producing centers for Azolla and Sesbania.
- Conduct research on minimal seasonal water requirements for different crops on different soil types to develop scheduling criteria.
- Identify alternative crops to rice and corn which are more water efficient.
- Investigate the possibility of minimal soil preparation between cropping seasons.
- Continue research on alternative crops which could be used in rotation on perimeters which promote the best utilization of parcels (i.e., high value cash crops and forage crops).

- Conduct research on alternative crop associations as a way to control pests and use limited land resources more effectively.
- Determine the impact of various cultural practices on water use (i.e., fertilizer use, mulching, weed control, etc.).
- Determine what is the optimum size of an irrigated holding for a farm family.
- Conduct research on farmers' practices regarding competing cropping activities.
- Collect information on the critical labor bottlenecks and the adjustments farmers make to deal with them.
- Identify crops and varieties that can be grown which reduce labor conflicts.
- Adjust crop calendars to take seasonal food shortages into account.
- Develop different crop calendars for the different subzones along the river.
- Continue research on ways to minimize insect damage to irrigated crops.
- Continue entomology research on the life cycle of serious insect pests to devise effective treatment programs.
- Conduct a study on traditional techniques of insect control used by farmers.
- Establish links with other pest control programs to coordinate research on a regional basis.
- Continue to strengthen the collaborative links among ISRA, WARDA, SAED and CER.
- Continue conducting seminars and training courses for SAED field agents periodically.
- Continue to involve SAED agents in surveys, on-farm trials and monitoring experiments.
- Encourage SAED and CER agents to provide feedback regarding farmers' problems and needs.

B. Rainfed Agricultural Research

- Pursue an integrated approach to dieri cultivation which focuses on depression farming.
- Introduce water conservation and harvesting techniques to take advantage of water runoff.
- Conduct research on drought resistant, water efficient, short cycle varieties of millet, sorghum, cowpeas, and watermelon.
- Conduct research on the appropriateness of animal traction for dieri cultivation.
- Develop and integrate pest management program for dieri fields.
- Conduct research on appropriate crop rotation and crop scheduling for dieri cultivation.
- Conduct research on staggered cropping and different intercropping strategies to identify the best crop combinations.
- Test whether Matam rock phosphate has potential for improving dieri fields.
- Determine the timing and rate of application of rock phosphate for dieri soils.
- Investigate the potential of sesame as an oil seed crop for dieri cultivation.

C. **Livestock Research**

- Continue research on ways to improve forage and fodder resources for livestock.
- Conduct an inventory of existing rangeland resources.
- Develop a flexible code of forage utilization with herders to prevent over-grazing.
- Initiate agroforestry projects which re-establish beneficial plant species which are important fodder sources.
- Introduce exotic drought resistant fodder grasses.
- Conduct palatability studies to identify a number of potential wild plant species that could serve as acceptable fodder during the dry season.
- Continue research on crop by-products as potential fodder supplements.
- Continue research on evaluating the feasibility of incorporating forage crops into cropping systems.
- Investigate the economic viability of introducing sprinkler irrigation systems in association with bore holes to grow forage crops.
- Conduct research on the existing marketing system for livestock in the Middle Valley.
- Continue research on cross-breeding and animal health studies.

D. **Vegetable Crop Research**

- Continue research efforts on testing and multiplying improved vegetable varieties.
- Give emphasis to varieties which are adapted to different seasons and which have different maturation periods.
- Identify vegetable varieties that have minimal water requirements.
- Conduct research on better water management, cultural practices and input use to improve vegetable cultivation.
- Conduct a vegetable marketing study in the Middle Valley.
- Conduct research on vegetable preservation and storage techniques.

E. **Agroforestry Research**

- Conduct agroforestry experiments to see if trees can more effectively be integrated into agricultural production.
- Identify appropriate trees for shelterbelts and live fences to be planted around irrigated perimeters and dieri depressions.
- Identify nitrogen fixing trees for alley cropping and tree mosaics.
- Identify bird resistant varieties of millet and sorghum that can be planted in association with trees.
- Conduct village trials to determine if farmers are receptive to woodlots.
- Investigate alternative ways to ease the pressure on forest resources (i.e., fuel efficient stoves, alternative energy sources).

F. **Other Research**

- Conduct research on fonio or paguiri to develop a food crop which supplements the other domestic grains.
- Investigate the impact of domestic labor-saving technologies on women's labor (i.e., grain mills, fuel efficient stoves, etc.)
- Set up an aquaculture research program at the Fanaye research station to help develop fresh water fishing along the river.

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I. INTRODUCTION

This report presents a number of agricultural research alternatives that could be pursued by the Institut Senegalais de Recherches Agricoles (ISRA) and the West African Rice Development Association (WARDA) to help increase agricultural production in the Senegal River Valley. These research alternatives are derived from a rainy season farming systems reconnaissance survey that was conducted in Senegal in the Middle Valley Region between Podor and Matam (See Report 1). Twenty-seven villages were surveyed over a two week period in October 1986. The survey team was multidisciplinary, and involved 16 persons drawn from ISRA, WARDA, the Societe Nationale pour le Developpement du Terre du Delta du Fleuve Senegal (SAED), the Centre National de Recherche Agronomique et de Developpement Agricole (CNRADA) in Mauritania, the Organisation pour la Mise en Valeur du Fleuve Senegal (OMVS) and the University of Arizona. The study was carried out under the auspices of the Senegal Agricultural Research Project II and was supported by USAID/Dakar. The University of Arizona, Office of Arid Lands Studies had responsibility for directing the survey. The primary objective of this study was to provide information on the farming systems found in the Middle River Valley. Rainy season data were collected on cropping patterns (irrigated and rainfed), animal husbandry, off-farm economic activities, marketing and consumption.

This survey allowed the researchers to assess the current agricultural practices, constraints and needs of farmers so that research programs could be devised accordingly. This report draws upon this information and outlines a number of possible research alternatives for ISRA's consideration. Before discussing these research alternatives, a brief description of ISRA will be provided as well as its goals and objectives. This will be followed by a general description of the agricultural research programs which currently exist along the Senegal River Valley.

II. ISRA

The Institute Senegalais de Recherches Agricoles (ISRA) was created in 1975 to take over all phases of agricultural research which had previously been undertaken by specialized French research agencies (i.e., IRAT and IEMVT). While commodity research programs have been a priority, since 1979 there has been an emphasis on regional research, training of national scientists, the development of socioeconomic research, and on-farm research (See ISRA Master Plan 1980). The current organizational structure of ISRA is presented in Charts 1 and 2. In recent years, ISRA has undergone a number of organizational changes. One of the key elements of this reorganization is to reinforce the research departments by turning them into autonomous departments with both scientific and management responsibilities, and by placing the research centers under their direct control (Faye and Bingen 1986).[1] Under the auspices of the World Bank and a USAID funded Agricultural Research Project, two important new orientations were added. The office of Macro-economic Analysis (BAME) was created as well as the farming systems research (FSR) program (Production Systems Research).

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[1] Because of recent financial and administrative difficulties, ISRA has been pressured by donor agencies to reduce its staff at the administrative level considerably and grant greater authority to researchers. ISRA is presently implementing these reforms.

CHART 1.
ISRA SIMPLIFIED ORGANIZATION CHART 1982 - 1985

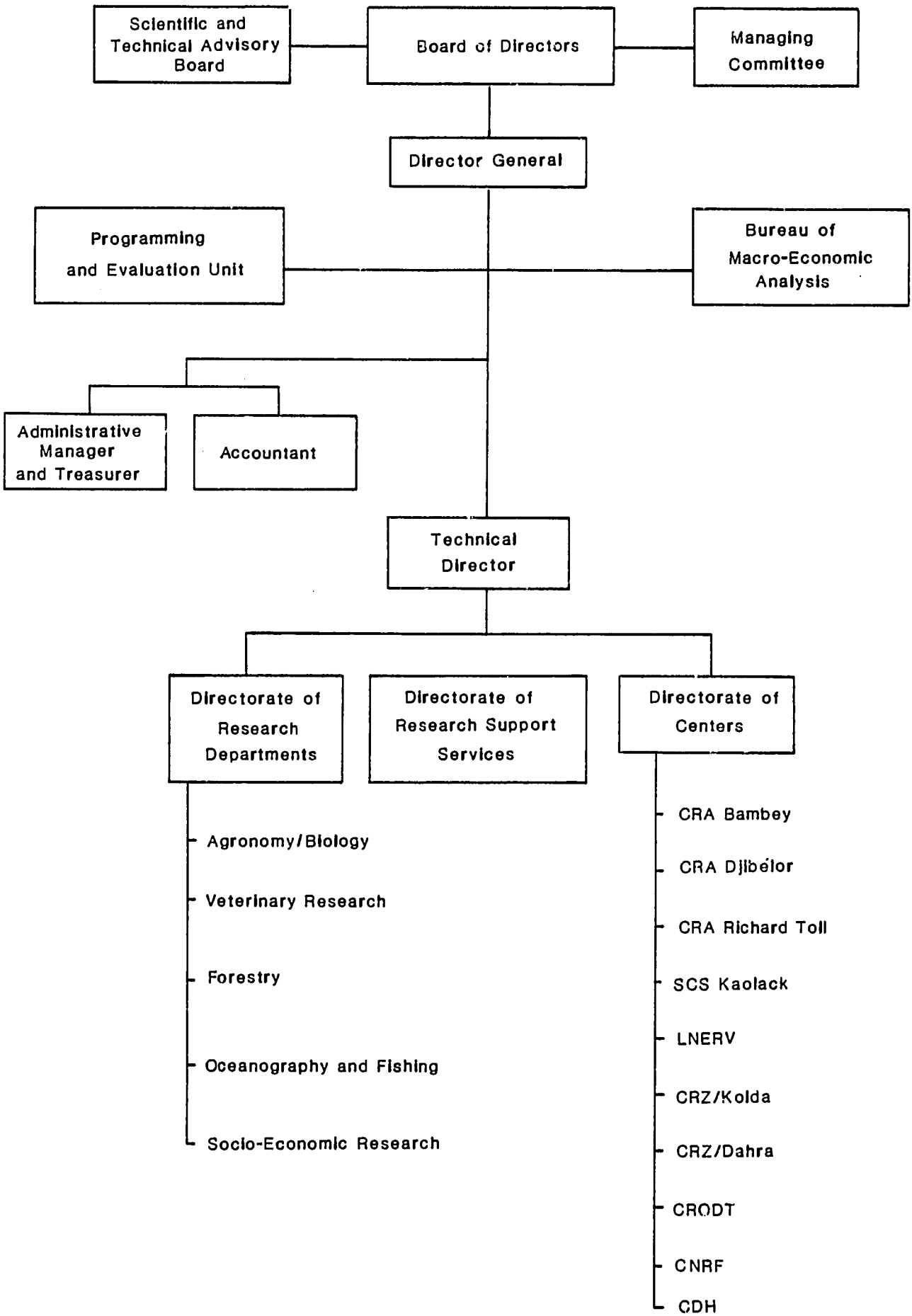
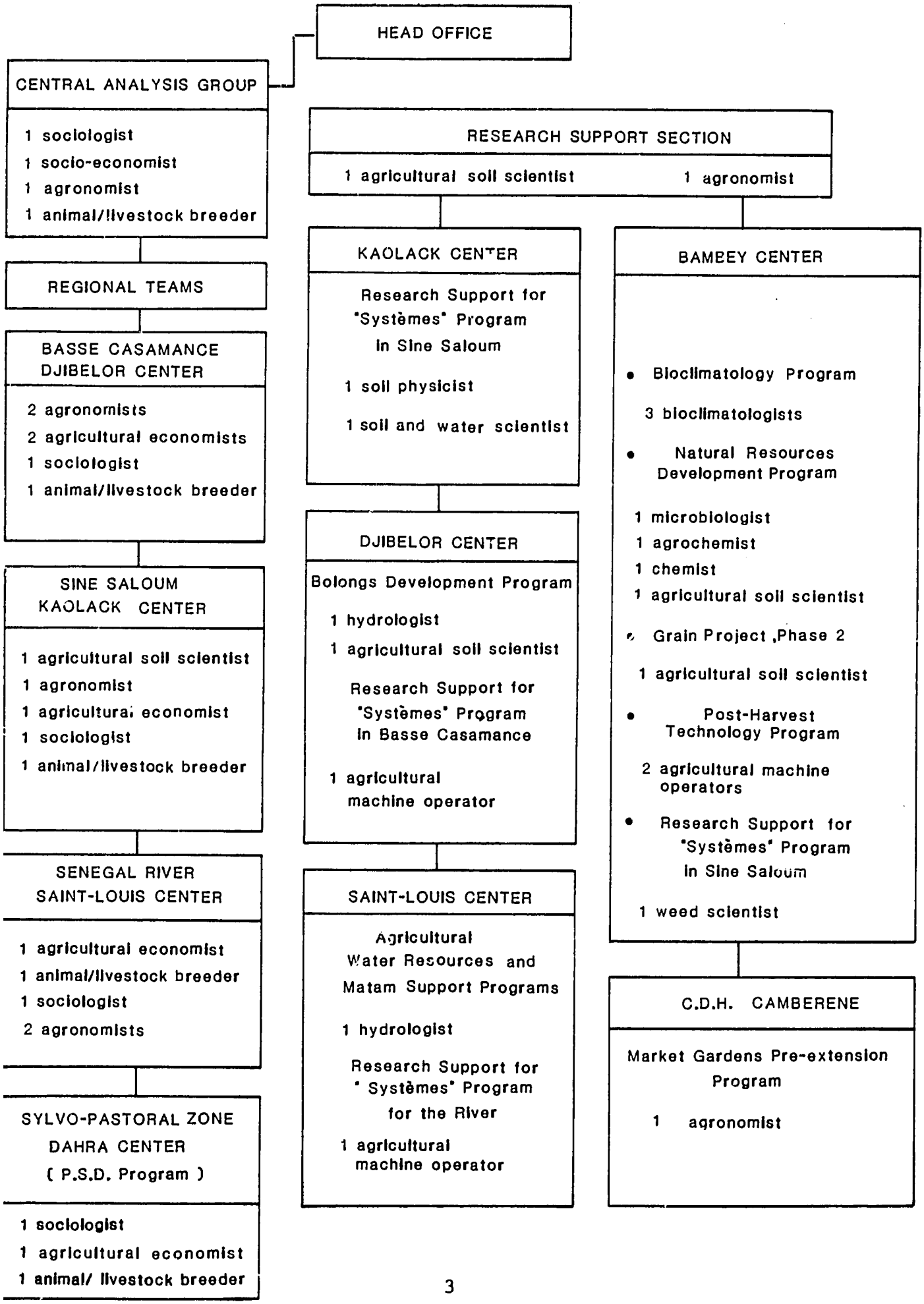


CHART 2.
DEPARTMENT ORGANIZATION CHART (1985)



ISRA has had five years of in-depth experience in FSR in the Basse Cassamance, and several years experience in the Delta Region of the Senegal River. ISRA also has an FSR team based in Kaolack. Although communication with commodity focused researchers has not always been ideal, the FSR program has made important strides in promoting FSR methodology through the use of micro-computers, through agronomic research focused on the peasant context, and through livestock research (Faye and Bingen 1986). The FSR teams have also attempted to collaborate with development agencies by developing a memorandum of understanding between the two groups. Acknowledging this progress, ISRA staff feel that more work needs to be done to integrate extension agents and farmers more effectively in the research/development process. In addition, ISRA researchers feel that FSR in Senegal must expand its scope beyond the level of the farm household to take into account problems associated with natural resource degradation, watersheds, village territory and micro-agricultural regions. Furthermore, FSR results should play a more important role in helping define national agricultural policy.

III. ISRA'S RESPONSE TO THE NEW AGRICULTURAL POLICY

The Government of Senegal (GOS) has recently outlined a number of goals in a New Agricultural Policy which should guide agricultural research conducted by ISRA. These include: 1) striving for food self-sufficiency; 2) the development of industrial agriculture; 3) increases in agricultural exports; 4) improving the organization of agricultural production by commodity and by channels of production; 5) protection of endangered national ecosystems; and 6) reinforcement of the linkages among research, training and extension (DIOP, 1984).

To accomplish the goals of the New Agricultural Policy, ISRA will: 1) conduct sectoral analyses; 2) contribute data on production and marketing constraints; 3) provide technical and cost data to help formulate national agricultural policy; 4) test technologies proposed by or for regional and local development projects; and 5) provide technical assistance to sectoral studies and sectoral analysis conducted by projects on an as needed basis (ISRA 1986).

In addition to these general activities, ISRA has outlined a number of specific research objectives in response to the goals of the New Agricultural Policy which are particularly relevant to the Middle River Valley. In the area of crop production, ISRA proposes to: 1) increase the production of millet, sorghum and maize; 2) maintain the present yield levels of recession sorghum and maize; 3) intensify the production on irrigated perimeters through systematic double cropping, thereby permitting an increase of paddy rice and maize yields; 4) develop selective technologies for different levels of agricultural intensification as a function of the type of farm; and 5) reduce post-harvest losses through better crop protection (ISRA, 1986). With regard to livestock production, ISRA proposes to: 1) develop typologies of pastoral zones and production units; 2) help develop solutions to problems associated with herder organization and pastoral research management; 3) continue research on animal pathologies; and 4) improve beef and small ruminant meat production. Forestry research objectives proposed by ISRA to help combat desertifiction and improve access to firewood include: 1) integrating forestry into existing farming systems to rehabilitate degraded zones and maintain the ecological equilibrium of newly opened areas for agriculture; 2) increasing rural forestry projects at the village level and supporting popular initiatives in this area; 3) rational management of forests through conservation of biotic communities and protection against bush fires; and 4) developing new agroforestry systems. As for

fisheries, there is presently no explicit government policy for guiding research on inland fishing resources. ISRA proposes that improvements can be made in this area by a more rational exploitation of available fish resources.

The ability of ISRA to implement these goals and objectives along the Senegal River Valley will depend upon access to resources such as adequate research facilities, trained personnel, financial support and research-development linkages. The current status of agricultural research along the river valley is presented below.

IV. GENERAL STATUS OF AGRICULTURAL RESEARCH ALONG THE SENEGAL RIVER

The three major organizations conducting agricultural research along the Senegal River are ISRA, WARDA and OMVS. A brief description of the research activities of each of these organizations is presented below.

A. ISRA

ISRA is presently understaffed in the Senegal River Basin and relies heavily on expatriates to conduct research activities (LeBeau and Eriksen, 1986). Based at the recently built office/laboratory complex at St. Louis, ISRA has 12 researchers and 28 technician positions designated for this regional center. Seven of the 12 research staff positions are filled by expatriates, 3 by Senegalese and 2 are vacant. Thirteen of the 28 technician positions were also not filled as of late 1985 (LeBeau and Eriksen, 1986).

ISRA has laboratories in St. Louis and shares a research station with WARDA at Fanaye, 160 kilometers from St. Louis. The Fanaye station has limited research infrastructure and housing, so researchers and senior staff are reluctant to live and work full- time at the station.[2] Researchers travel back and forth from St. Louis and technicians live in a village 5 kilometers away. Another substation in close proximity to St. Louis can be found at N'Diol, but it is underutilized. Presently the N'Diol substation is being used for onion seed production (Belgian support), limited vegetable variety trials and fruit tree research (British support). ISRA is also conducting fieldwork in several perimeters in conjunction with WARDA. Five technicians are posted at 5 perimeters, and 8 observers/enumerators are posted at 4 villages in the Delta to carry out surveys, tests and demonstrations (LeBeau and Eriksen, 1986).

ISRA's research program is primarily concentrated in the Delta Region. The major focus of this research is the Production Systems Research (PSR) activity which is part of a broader program entitled "Research on Agrarian Systems and Agricultural Economics." Seven researchers are involved (4 expatriates and 3 Senegalese) and the principal research activities include: 1) socioeconomic surveys; 2) testing technologies on farmers' fields; and 3) demonstrations on farmers' fields (LeBeau and Eriksen, 1986). Beginning in 1984, an extensive exploratory survey was conducted in 3 zones of the Delta among 500 households in 18 villages. Village level information was collected on history, demography, social organization,

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[2] USAID is attempting to remedy this situation by improving the infrastructrure and housing at Fanaye.

infrastructure, upland cropping patterns, irrigated cropping patterns, flood recession, agricultural machinery, livestock, and off-farm activities. From this study 69 households were selected for long-term monitoring with regard to inputs, outputs, land- based activities, off-farm activities and animal husbandry. Other surveys planned or conducted include a fertilizer distribution study, vegetable marketing study, meat marketing study, and an agricultural by-products survey (MSU, 1986). An aerial inventory of livestock, gardens and immigration camps was also conducted. The Macro-economic Analysis Bureau of ISRA provides technical support to the PSR field team and has also conducted a cereals marketing study in the river valley (Morris, 1986). This study focused on the organization and performance of the official and unofficial marketing channels.

On-station and off-station agronomic trials have also been conducted by ISRA in the Delta Region. On-station trials have been conducted at Fanaye on seed multiplication, cultivation techniques, double cropping, and forage crops (MSU, 1986). On-farm trials on rice have focused on varieties, fertilizer application and land preparation (St. Louis et al., 1985). On-farm trials have also been conducted on tomatoes (varieties, transplanting dates, ridge cultivation and plant protection) and fodder crops (grass fodders, crop by-products). Other on-station and on-farm trials planned include livestock feeding trials using crop residues, maize improvement trials, improved water management, fruit trials, and vegetable seed production and trials (LeBeau and Eriksen, 1986).

In conducting the on-farm trials, the ISRA PSR team is working with SAED. Other efforts ISRA has made to improve research/development linkages with SAED include: 1) training SAED extension agents; 2) assisting in conducting seminars and field trials; 3) reviewing SAED technical documents and analyzing the results of on-farm tests; and 4) helping to update the bibliography for all technical publications used to train extension agents (St. Louis et al., 1985). SAED is particularly interested in ISRA's work on no-fill land preparation techniques for rice, forage crops and the utilization of crop by-products for livestock feed (St. Louis et al, 1985).

B. WARDA

The West African Rice Development Association (WARDA) has been assigned the major responsibility of developing irrigated rice along the Senegal River Valley by ISRA. WARDA has been conducting rice research along the Senegal River since 1976. Presently, WARDA has a staff of 13 researchers (5 detached from ISRA), all being posted at the ISRA headquarters in St. Louis (LeBeau and Eriksen, 1986). WARDA conducts most of its on-station trials at Fanaye, although some work is also carried out at the OMVS station at Guede. In addition, WARDA conducts field research on several perimeters.

WARDA's research program is being carried out throughout the river valley up to Bakel. Some of the major research activities include: 1) rice varietal testing (short and medium cycle, cold tolerance); 2) entomology studies and pest control (rice stem bores, mites); 3) rice disease studies (inventory of bacteria and fungus); 4) study of rice weeds (wild rice, sedges) and weed control methods (mechanical, herbicides, Azolla); 5) soil fertility studies (tailoring NKP doses to different soil types, use of rock phosphate, nitrogen fixation of Sesbania and Azolla); 6) testing mechanical transplanters (developed by IRRI); 7) water management studies (in collaboration with the University of Wagenhagen); and 8) seedbed improvement

(Dapog method) (WARDA, 1986).

In addition, WARDA was asked by Senegal in 1983 to conduct Production Systems Research in the Middle Valley to avoid duplication of ISRA's work in the Delta. Prior to this time, WARDA was only carrying out multi-location trials on farmers' fields. Since 1983, rice based farming systems research has been carried out by WARDA under the Evaluation and Technology Transfer Program (ETT). For several years, socioeconomic data were collected to determine farmers' constraints and needs and to help accent research programs to meet these needs. Promising technologies have been tested in on-farm trials (i.e., improved seedbeds, short cycle varieties, Azolla, etc.) and are ready to be extended. In addition, information from farmers has been fed back to the research station for technology design (i.e., fertilizer doses).

WARDA has attempted to establish close collaboration with SAED in its farming systems efforts. In addition to working with SAED agents in conducting on-farm trials, WARDA has tried to elicit SAED's participation in the identification of constraints, conducting surveys and establishing dialogue with farmers (Cunard, 1986). WARDA personnel believe that an effective extension structure cannot be established without the extension agents doing the trials themselves. For this reason, WARDA staff are teaching SAED extension agents trial techniques at N'Diaye (SAED headquarters). The ETT program also holds seminars for extension agents and farmers. Good results have come out of this collaboration (i.e., Nianga/Matam).

Despite its positive attributes, one problem associated with WARDA's PSR approach is that it is quite different from ISRA's approach on the Delta. In addition, the research activities of WARDA and ISRA are not well coordinated. This situation can promote friction between the two institutions and may hinder effective collaboration. To facilitate collaboration, more formal coordination of research may be required.

C. OMVS

OMVS conducts limited agricultural research at the Guede station, 180 kilometers from St. Louis. Agricultural research in the past was funded by UNDP, USAID, FAC, UK and FAO (OMVS, 1985). Research activities have focused on varietal trials on rice (cold tolerance), wheat, maize, and sorghum (recession and irrigated), as well as weed control and fodder crops (OMVS, 1985). Presently, only one researcher directs research at Guede and he has been seconded to OMVS by ISRA (LeBeau and Eriksen, 1986). Although the research facilities at Guede are adequate, financial support of research operations and station personnel is limited. Under present conditions, an effective research program is difficult to maintain. In addition, collaborative links between OMVS and ISRA are poor. To avoid duplicating the ongoing efforts of ISRA and WARDA, OMVS and donor groups should seriously consider the utility of maintaining this facility unless research conducted at Guede is complimentary.

Given ISRA's limited number of research personnel, it will be difficult for ISRA to achieve its research objectives for the Senegal River Valley without better collaboration with the other research and development institutions operating in the basin. Even with improved collaboration, expansion of research activities into the Middle Valley could put considerable strain on the existing research staff. Thus,

more staff with field experience will be required to implement many of the research activities proposed in this report.

V. RESEARCH ALTERNATIVES

To assist ISRA in achieving the research objectives relevant to the Middle River Valley, which it has proposed in response to the New Agricultural Policy, a number of research alternatives have been identified. These research alternatives were derived from a rainy season farming systems reconnaissance survey that was conducted in the Middle Valley Region between Podor and Matam in October 1986. These alternatives are based on the current agricultural practices, constraints and needs of farmers in this region. Although the list is comprehensive, it is assumed that only a few of these alternatives can be implemented at any one time due to resource limitations. No attempt has been made to prioritize these research alternatives. This task has been left to ISRA and the Ministry of Rural Development.

Each of the research alternatives listed responds to one or more of the research objectives proposed by ISRA. In addition, many of these alternatives may be applicable to several Directions and Departments in ISRA, and should not be viewed as mutually exclusive. The presentation of each research alternative will be followed by a statement regarding the current status of research in this area at ISRA, and/or other institutions working along the river.

A. Irrigated Agricultural Research

- **Seed multiplication programs could receive more support to provide farmers sufficient quantities of improved varieties of rice, maize, sorghum and tomatoes (p. 53).**[3]

  a. **Coordinate this effort with ISRA, WARDA and SAED.**

  b. **Begin with varieties that have already been tested.**

  c. **Improved seed should be adapted to different climatic constraints and soil types.**

  d. **Hybrid seeds developed in other regions of the Sahel could be tested to determine their appropriateness for Senegal. If hybrids are introduced, care must be taken to ensure that ample supplies of seed are made available each year in a timely fashion.**

  e. **Diversification of cereal crops could be emphasized in seed programs. Farmers should be given alternatives so they can select the cereal crops and varieties that best fit their preferences and circumstances. The crops that receive first priority should be those that are the most widely grown and have the greatest potential for improvement.**

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[3] All page numbers cited refer to the discussion of this issue in Report 1.

Current Status: In terms of access to improved seed adapted to the local conditions, considerable varietal testing has been carried out over the years by various research organizations working along the river. The status of this work can be addressed on a crop by crop basis:

Rice – Varietal testing on rice has been conducted by FAO in the Richard Toll area since 1945 (FAO, 1985). Double cropping studies were initiated in 1971. FAO researchers identified a number of varieties well suited for the rainy season (i.e., I Kong Pao, Taichung Native No. 1, IR8, etc.) as well as a number of varieties appropriate for the dry season (i.e., Jaya, TNI, KSS, IKP, IR8). In addition, FAO identified a number of long panicle varieties that were adapted to the dry season wind (IR 2061, 214-3, 3-12, 1R 3941).

WARDA has also been conducting varietal trials since 1976. Every year WARDA conducts a series of trials on international (i.e., IRRI and the International Rice Testing Program) and regional (IITA) varieties (LeBeau and Eriksen, 1986). More than 3000 varieties have been evaluated; 500 in 1985 alone (WARDA, 1986). WARDA's varietal selection program focuses on high yielding varieties with variable growth cycles (short and medium).[4] Cold tolerance is also an important selection criteria (Japonica varieties suitable for the cool, dry season). In this selection process, WARDA takes local acceptability of rice characteristics into account. A number of rice varieties have been identified which have good potential for extension. Some potential short cycle varieties include Sri Malaysia[5], BG90-2, FH-190 and IET 1996. Two potential cold tolerant varieties are Tatsumi Mochi and KH 998. WARDA's rice testing is coordinated with research being conducted in the Casamance as well as with the Gambia and Guinea Bissau. WARDA also started its own rice breeding program in 1984.

ISRA has also been testing some of the rice varieties in the Delta recommended by ISRA and WARDA. Since rotational systems will determine varietal selection, on-station trials have focused on varieties suitable to the cool dry season and hot dry season (Jamin, et al., 1986). On-farm trials have also been conducted on short cycle (IET 1996) and cold tolerant varieties (KH 998). ISRA's program on irrigated rice is entitled, "Multidiscipline Research Program on Irrigated Rice," under Agricultural Sciences ISR.29.

Although varietal testing of rice has been extensive, seed multiplication of new varieties has not kept pace with demand. For instance, WARDA has experienced some difficulties in seed multiplication control in terms of quantity and quality (Andrews, 1985). In compliance with the New Agricultural Policy, development agencies such as SAED have taken on this role, but shortfalls in seed supply still persist. Thus, a coordinated effort among ISRA, WARDA and SAED will be necessary to meet the

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[4] Past surveys have indicated that farmers consider as desirable short cycle high yielding varieties of rice with lower water requirements.

[5] On-farm trials conducted on Sri Malaysia have shown favorable results when compared with IKP (Podor) and Jaya (Matam) (WARDA, 1986).

demand.

Maize – Varietal testing on maize was also carried out by FAO and OMVS in the past (FAO, 1985). This work focused on testing introduced hybrids and composites. One hundred forty cultivars were tested since 1974 for all three seasons. The hybrids gave poor results while several composites were found to be appropriate (i.e., CPJ Bouake, Early Thai and Diara). Early Thai was found to be the best composite, yielding approximately 5 tons/hectare (October planting). Unfortunately, many of the maize varieties previously tested and recommended by FAO/OMVS degenerated over the last several years (LeBeau and Eriksen, 1986).

Recently ISRA has reactivated the maize improvement program. A French agronomist has been brought in to reestablish this program. Technical support is being provided by CIRAD and financial support is provided by the French government. In addition, maize research (i.e., breeding, agronomy, pathology, etc.) is also being carried out by ISRA at SCS/Kaolack (Andrews, 1985). Recent research conducted at Matam showed that maize yields are mainly affected by date of planting (St. Louis et al, 1985). The ISRA maize improvement program is entitled, "Multidiscipline Research Program on Improvement of Maize," under Agricultural Sciences IRS.30.

It is evident to ISRA that irrigated maize will not become important to cropping systems along the river until higher yields can be obtained. Work on maize improvement should begin with a thorough evaluation of existing varieties in Senegal (LeBeau and Eriksen, 1986). In addition, although the current ISRA maize selection program is back on track, seed multiplication capability is inadequate. Again, a collaborative effort will be needed between ISRA and SAED to improve this situation.

Sorghum– FAO/OMVS also conducted varietal trials on sorghum in the past (FAO, 1985). Over 80 introduced composite and hybrid cultivars and 22 local cultivars were tested over a 6-year period at Guede and Fanaye (OMVS 1985). A number of varieties were identified as suitable for the rainy season (i.e., 73-13, 77-11, ISRA-IRAT 202, 312A x 68-29), as well as the cool dry season (73-13, 75-14, ISRA-IRAT 204, 612A x 7-314, 612 x 68-29) (FAO, 1985). Improved varieties for flood recession were also identified (RT 13) (OMVS, 1985).

ISRA also has conducted varietal trials on sorghum. Seventeen cultivars from the basin and other areas of Senegal along with 34 hybrids were tested. Trials conducted in the cool dry season yielded 5 tons/hectare. The recommended varieties included sambossoki, 2450, 74-14, IRAT 202, 77-11, IRAT 13, 73-13, and 612 x 75-14. Sorghum research is also being carried out by ISRA at SCS Kaolack (Andrews, 1985). Varietal improvement work has identified a number of varieties and hybrids which may be appropriate to the Senegal River. The ISRA sorghum improvement program is entitled, "Multidiscipline Research on Improvement of Sorghum," under Agricultural Sciences ISR.27.

Despite this past and ongoing research, ISRA is currently placing little emphasis on sorghum in the Senegal River Valley. Little consideration is given to sorghum as an irrigated crop despite indications that yields of 5

to 7 tons/hectare can be obtained (LeBeau and Eriksen, 1986). Sorghum could be an excellent second season crop in perimeters (see below). In addition, improved sorghum varieties for recession cultivation could be very important after the Manantali dam is completed and controlled flooding is put into effect. In view of this potential, ISRA should work with SAED to ensure that improved sorghum varieties are multiplied and made available to farmers.

- Research could be conducted on **labor-saving technologies and improved cultivation techniques** available for small perimeters to determine which are the most appropriate to promote given farmers' current access to resources, inputs, spare parts and training (p. 54).

  a. Conduct experiments on the **advantages of puddling**. This involves flooding a parcel before plowing and using the water as a transport vehicle for moving soil (especially the heavy soils found in the Fonde areas).

  b. Investigate the feasibility of using **animal traction to level and prepare fields.**

  c. Continue to explore the feasibility of introducing **small machinery, mechanical transplanters and hand threshers** to farmers. On-farm trials could be conducted in collaboration with WARDA, SAED and CER (Centre d'Expansion Rurale Polyvalent). Such studies should consider cost, availability of spare parts, training requirements and labor displacement in their assessments.

Current Status: A study was conducted in the late 1970's by PNUD/OMVS/FAO on the use of agricultural machinery at the Guede and Dagana CUMA-PILOTES (Constantinov, 1980). This study suggested that medium sized tractors (i.e., 65 HP tractors) were superior to lighter weight or manually operated machinery because they lasted longer. The major problems identified for agricultural machinery were maintenance and parts availability. Recommendations were made regarding the optimum technical package (tractors and accessories) associated with a given size of land distributed among a set number of parcel holders. In addition, the study recommended against the use of animal traction because of the heavy soils and lack of sufficient fodder supplies. [6]

WARDA and SAED have also conducted on-farm experiments with mechanical transplanters developed by IRRI (WARDA, 1986). Although the use of transplanters did not increase yields, they did appear to save on labor time (WARDA, 1986). However, three major constraints were identified regarding their use. First, the transplanters are costly to import from IRRI. Second, local manufacturers have not succeeded in building a working model. Third, the machine has too many delicate parts that can break down. WARDA is presently testing another less complicated model obtained from IRRI. IRRI has agreed to provide the plans and manufacturing rights to local businesses.

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[6] Animal traction may still be appropriate for irrigation on lighter, sandy soils and where adequate forage supplies are available.

- Research could continue on **cost-effective alternatives for improving or maintaining soil fertility** (p. 55)

  a. Continue research on **chemical fertilizers, focusing on appropriate doses in terms of timing, soil types, crop and number of applications.**

  b. Continue conducting research **on organic fertilizers (green manure).** This would include determining the beneficial effects of **combining organic fertilizers with chemical fertilizers.**

  c. Continue conducting research on **rock phosphate as a substitute for triple super phosphate and ammonia phosphate.** Research could focus on the **appropriate application rates** for different soils and different crops. Research could also focus on the **economic costs and benefits of rock phosphate production** and application. This work could be coordinated with BRGM (France), IFDC in Togo and Muscle Schoals, Alabama.

  d. Continue conducting research on the benefits of Azolla **as an organic fertilizer and weed suppressant.** Similarly, work could continue on the legume Sesbania **as a potential nitrogen fixing agent.** In conjunction with this work, explore the possibilities of establishing a number of **producing centers for** Azolla **and** Sesbania to make these plants available to farmers.

Current Status: Chemical fertilizer studies in the Senegal River Valley have been conducted by FAO on rice, sorghum and maize for a number of years (FAO, 1985). ISRA has also collected good baseline data in other regions on fertilizer application, phosphate use and the value of incorporating crop residues and manure for different crops (Andrews, 1985). Recently, both ISRA and WARDA have been conducting fertilizer studies in the river basin. For example, ISRA conducted a fertilizer distribution study in the river valley (MSU, 1986). ISRA's on-farm work in the Delta Region has focused on the effects of timing, condition of the parcel and type of crop with regard to recommended fertilizer mix and dosage (Jamin, 1986). WARDA's research has involved farmer surveys on fertilizer use, on-station trials and on-farm trials (WARDA, 1986). A recently conducted survey determined that farmers were not applying fertilizer in the proper quantities (too much) or in a timely fashion (Cunard, 1986). Some of the research topics WARDA is presently pursuing include: 1) evaluating the response to NKP on different soils with different timing of application; 2) fractioning nitrogen doses into three applications; 3) introducing super granules of urea to farmers; 4) determining the beneficial effects of green manuring rice stalks and/or Sesbania and Azolla (see below); and 5) testing the value of combining organic composts (i.e., rice stalks, Sesbania, Azolla) with chemical nitrogen.

Research has been conducted on Matam rock phosphate since 1981 (Pascal et al., 1986). Supported by BRGM (France), ISRA in collaboration with GERDAT, carried out this research at Fanaye, as well as in Oriental and Basse Casamance from 1981 to 1984. The objectives of this research were to: 1) study the response of rice, maize, cotton and groundnuts to rock phosphate; 2) define recommended doses; 3) define the best method of application; and 4) compare rock phosphate efficiency to other phosphate fertilizers (Pascal et al, 1986). Three years of on-farm trials demonstrated the beneficial and residual effects on cotton, rice and maize (Pascal et al, 1986). WARDA took over the rock phosphate trials along the Senegal River in 1983 (Pascal, et al, 1986).

WARDA's research determined that Matam rock phosphate produced comparable results as triple super phosphate in the third year after application. The best rate of return for Matam phosphate was found to be 90 kg/hectare. WARDA also determined that the amount of phosphorous absorption is affected by the amount of water applied and its duration (Cunard, 1986). Matam rock phosphate is easily accessible (5 to 15 meters below the surface), and highly soluble. This resource has great potential and can be easily utilized by local farmers as well as by local industry.

WARDA has also been conducting on-station and on-farm trials on Azolla for several years. Azolla is a type of aquatic fern native to the tropical parts of Asia and the Americas which fixes nitrogen, suppresses weeds and conserves water[7]. Beginning with a large number of varieties, WARDA has come up with a suitable selection of Azolla to meet varying conditions of irrigation. The three best varieties are Azolla pinnata imbrieata, Azolla carolinana, and Azolla microphylia. One variety of Azolla can even survive in the mud, making it suitable for perimeters with irregular water supplies. WARDA has found that the use of Azolla can reduce the need for chemical nitrogen by half (60 kg/hectare). However, to establish Azolla in a perimeter so that it acts as a nitrogen supplement, it must receive water one month before rice planting at a time when water supplies are poor. This is a constraint at the farmer level. Thus, Azolla is presently being incorporated into the perimeter after the rice is transplanted, so that it still acts as a weed suppressant. On-farm trials are currently being conducted with 60 farmers (WARDA, 1986). WARDA is also looking at the value of Azolla as a green manure/compost, as well as a possible fodder source for livestock and fish (WARDA, 1986). WARDA's future work on Azolla will focus on: the association between Azolla nitrogen fixing and crop seasons; phosphorous needs; capacity to grow in humid soils; and compost dosages in relation to soil type (WARDA, 1986). Farmers have expressed an interest in Azolla, although access is limited due to a shortage of production centers. Presently, Guede is the only center of production of Azolla for distribution to farmers. More supply centers are needed to meet demand.

WARDA is also working with a legume called Sesbania rastrata which provides an organic complement to nitrogen fertilizer (WARDA, 1985). Trials indicate that the legume provides 90 kg/hectare of N for a 120 kg/hectare N requirement (WARDA, 1985). Rice should be transplanted one week after Sesbania is worked into the soil. Research results indicate that later seeding brings about better results than early seeding in terms of nitrogen fixation and reduced nematode activity (WARDA, 1985). Sesbania needs to be irrigated intermittently every 10 days. WARDA is also assessing Sesbania's potential as a green manure. In terms of farmer access, Sesbania supply problems are similar to Azolla.

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[7] ISRA has two research programs focusing on nitrogen fixation. One is entitled, "Nitrogen Fixation in Flooded Rice Fields," under Agricultural Research ORS.09, and the other is "Symbiotic Nitrogen Fixation", under Agricultural Research ORS.13.

- Research could focus on ways of **improving the utilization of perimeters** taking into account perimeter construction and maintenance, as well as access to soil, water, diesel and other inputs (p. 56).

  a. Research could be conducted on **minimal seasonal water requirements for optimum production of different crops on different soil types** (LeBeau and Eriksen, 1986). From this information, **scheduling criteria could be developed for each type of crop.**

  b. **Water efficient crops that use less water than rice or corn could be proposed.** Sorghum is one possible alternative.

  c. Investigate the possibility of **minimal soil preparation between cropping seasons to reduce costs** (LeBeau and Eriksen, 1986).

  d. Research could continue on **alternative crops that could be used in rotation on perimeters**, promoting the best utilization of parcels. Seasonal requirements should be taken into account in the selection of crops. **High valued crops** (i.e., sesame) **and forage could be considered in such rotation schemes.** An economic analysis could be conducted to determine the net return of alternative irrigated crops.

  e. Research could focus on **alternative crop associations as a way to control pests and utilize limited land resources** more effectively. Aside from Azolla and Sesbania, possible associations can be derived from previous work done by IRRI and IITA.

  f. Research could determine the **impact of various cultural practices** (i.e., **fertilizer use, mulching, weed control, etc.) on water use** (LeBeau and Eriksen, 1986).

Current Status: ISRA plans to initiate a research program for improved water management on SAED irrigated perimeters in the near future (LeBeau and Eriksen, 1986). Presently, this program does not have the trained personnel to carry out this research. WARDA, in collaboration with the University of Wageningen, has conducted a water management study of several perimeters in the Middle and Upper portions of the River Valley (i.e., Dagana to Bakel) (LeBeau and Eriksen, 1986) Surveys were conducted in several villages in both Senegal and Mauritania among three different ethnic groups. The surveys were descriptive, identifying current water management practices and constraints. The study identified numerous problems in the design and construction of small perimeters resulting in water losses and poor distribution. Drainage is also a significant problem in many perimeters. The study outlined a number of areas for further research for improving the efficiency of water use.

Previous research has also identified some alternative irrigated crops that are water efficient or can be used in rotation. As stated previously, a number of sorghum varieties have been identified which are suitable for the rainy season and cool dry season. Sorghum is a very water efficient crop in comparison to rice and corn. Despite this trait, little emphasis has been given to sorghum in ISRA's research activities along the river. As for other alternatives, ISRA is conducting trials on forage crops to determine their potential in rotation schemes. Both annuals and perennials were tested on-station, and some on-farm trials were conducted as well (Jamin et al., 1986). Although some good

on-farm results were obtained with sorghum harvested green (10 tons of green in 2-1/2 months), farmers felt that the trials were too labor intensive. In addition, farmers lost interest in the idea of fodder crops once the rains proved to be adequate for generating natural forage (Jamin et al., 1986). ISRA has also begun looking at ways to reduce land preparation in on-station trials conducted at Fanaye (Jamin et al., 1986). Much more work is needed in this area of research.

- A socioeconomic study could be conducted to determine the optimum size of an irrigated holding for a farm family, taking yield and economic returns into account (p. 57). Other factors to take into account in this study would be environmental conditions, access to resources, family circumstances and optimum size of perimeters for a given pump.

  Current Status: Previous studies conducted by PNUD/OMVS/FAO determined that the optimum size of an irrigated holding for a farm family should be 1.5 hectares (Constantinov, 1980). This finding needs to be verified. The current long-term monitoring study being carried out by the ISRA PSR team in the Delta among 69 farm families could provide this information. Similarly, this research should build upon the information collected by WARDA's ETT team in the Middle Valley.

- Research could focus on farmers' practices regarding competing cropping activities (p. 58).

  a. Information could be collected on the critical labor bottlenecks and the adjustments farmers make to deal with them.

  b. Identify crops and varieties that can be grown which would reduce labor conflicts.

  c. Adjust crop calendars to take seasonal food shortages into account (i.e., combining short cycle and long cycle varieties to fill food gaps).

  d. Develop crop calendars which take into account the variability that exists in climate and access to resources along the Senegal River.

  Current Status: This work could build upon the PSR studies conducted by ISRA in the Delta and WARDA's work in the Middle Valley. ISRA and WARDA have also identified a number of rice varieties which are short and medium cycle varieties and can possibly be used to help adjust for labor conflicts and food gaps. Sorghum varieties have also been identified which could help meet this need.

- Research could continue on ways to minimize insect damage to irrigated crops (p. 59).

  a. Entomology research could continue on the life-cycle of serious insect pests so that effective treatment programs can be devised.

  b. A study could be conducted on traditional techniques of insect control used by farmers. Aside from identifying effective traditional control measures, this information will indicate ways to incorporate new control measures into existing practices.

c. **Establish links with other pest control programs** to coordinate research efforts on a regional basis. Stronger links could be established with CILSS, OCLALAV, IPM programs in Mali, Niger and Mauritania as well as the Senegalese Crop Protection Service.

Current Status: Most of the research dealing with insect pests has been conducted by WARDA in recent years. This research has focused on the life cycles of major insects such as grasshoppers, stem borers and mites. The mite is a newly introduced pest in the area, and WARDA is studying its biology to develop control measures (LeBeau and Eriksen, 1986). Population studies are also being conducted on rice stem borers and mites through the use of traps. These traps may provide a means for identifying potential insect outbreaks. WARDA is also looking at the relation between the severity of insect attacks and the date of planting, variety used and spacing. Tests are being conducted by WARDA on the effectiveness of insecticides such as Furadan and Azadrin as well. In addition, WARDA researchers have begun efforts to breed rice varieties that are resistant to mites and white fly (WARDA, 1985).

- Efforts to strengthen the collaborative links among ISRA, WARDA and SAED could continue in order to improve extension. In addition, stronger links could be established between these organizations and CER (Centre d'Expansion Rurale Polyvalent).

a. **ISRA and WARDA could continue conducting seminars and training courses for SAED field agents periodically.** This would keep the field agents up-to-date on the latest trials, improved seeds and improved techniques.

b. **SAED agents could continue to help ISRA and WARDA conduct surveys and on-farm trials and to monitor experiments.**

c. **SAED and CER agents could provide feedback to ISRA and WARDA regarding farmers' problems and needs.** This could be done through periodically scheduled meetings.

Current Status: As stated previously, ISRA and WARDA have begun to establish a working relationship with SAED. ISRA and WARDA have put on seminars and training courses, and involved SAED agents in surveys and on-farm trials. In addition, ISRA reviews some of SAED's technical documents, helps analyze the results of on-farm tests, and helps update the bibliography of all technical publications used to train extension agents. As for CER, very little collaboration has been established with ISRA and WARDA in the river basin. Although CER focuses on all aspects of development, some agricultural extension services are provided by this organization. ISRA and WARDA could collaborate more effectively with CER.

Staff Requirements: To pursue many of the research alternatives outlined under irrigated agricultural research, additional researchers will be needed. To support varietal testing, seed multiplication and soil fertility studies, at least one or two more agronomists will be required. To conduct the economic analysis proposed, an agricultural economist will be needed. An agricultural engineer may also be required if research on appropriate irrigation technology is to be conducted.

B. Rainfed Agricultural Research

- An integrated approach to dieri cultivation could be pursued which focuses on depression farming. ISRA could coordinate this effort with SAED and CER (p. 60).

  a. Water conservation and harvesting techniques could be introduced to take advantage of water runoff. Studies and on-farm trials could be conducted to determine the most appropriate techniques for a given area (i.e., contour plowing, terracing, diversion dikes, etc.). On-farm trials could also help determine the best combinations of crop type and cultivar, spacing, type of fertilizer and rates of application, and spacing of water catchments for different soils and rainfall conditions.

  b. Research could focus on drought resistant, water efficient, short cycle varieties of millet, sorghum, cowpeas, watermelon and other crops (e.g. maize)[8]. This effort would begin with varieties farmers are already using in conjunction with varieties developed elsewhere in the Sahel (i.e., ICRISAT, SAFGRAD, CILSS, etc.). To facilitate this effort, local seed germ plasm could be collected (i.e., diortani).

  c. Research could focus on the appropriateness of animal traction for dieri cultivation. Trials could be conducted to determine which types of equipment and traction animals are suitable for different soil types and cropping situations.

  d. Develop an integrated pest management program for dieri fields to deal with crop damage caused by insects. On-station and on-farm trials could be conducted on proper insecticide use, crop associations and other biological controls.

  e. Research could focus on appropriate crop rotation and crop scheduling for dieri cultivation. Further research could be conducted on staggered cropping and different intercropping strategies to identify the best crop combinations.

  f. On-farm trials could be conducted to test whether Matam rock phosphate has potential for improving dieri soils. These trials could help determine the timing and rate of application of rock phosphate for these soils.

  g. Researchers could investigate the potential of sesame as an oilseed crop for dieri cultivation. Sesame is a drought tolerant oilseed crop grown in other regions of the Sahel which does well on sandy soils and minimum amounts of rainfall (e.g. 250-300 mm). It should first be tested on-station to determine its potential for the region. Seed varieties can be obtained from Sudan, Cameroon, and possibly international centers like

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[8] Caution must be exercised in placing too much emphasis on early maturing varieties. Although such varieties may be adapted to minimal rainfall conditions, they may be susceptible to drought periods occurring within the rainy season. In addition, in years of normal rainfall, early maturing varieties may suffer from mold damage. Thus, a range of alternative varieties with different maturation lengths should be made available to farmers.

ICRISAT or ICARDA. An essential component in these trials will be farmers' receptivity to the taste of sesame oil. In addition, low technology processing techniques for sesame could be tested to see if farmers are interested in adopting such technology. Current processing techniques used in the Sudan may be suitable for this region as well.

Current Status: Very little research has been conducted by ISRA on dieri cultivation in the Senegal River Valley in recent years. However, research activities carried out by ISRA in other regions of Senegal could be applicable and transferable to this region. For example, ISRA has been conducting variety improvement research at Bambey on millet and cowpeas[9], selecting for resistance to drought and major pests and diseases (Andrews, 1985). This work is done in collaboration with ICRISAT, CILSS, and SAFGRAD. Research on sorghum at SCS Kaolack has identified a number of varieties that might be suitable for rainfed cultivation along the Fleuve (Andrews, 1985). The ISRA research program at Bambey entitled, "Programme Valorisation de Resources Naturelles," has shown through on-farm trials the usefulness of Matam rock phosphate on rainfed cotton, maize and millet. This research program has collected good baseline data on crop rotations, the value of incorporating crop residues and organic fertilizer, and the integration of animals on the farm. ISRA could build upon this information in its research activities in the rainfed zones of the river valley.

ISRA has not focused on the potential of water harvesting techniques along the river. Some work in this area has been conducted by French researchers in the Bakel region, and should be reviewed. Previous research conducted in Niger could also provide a series of useful models which could be implemented in Senegal (Tabor, 1986). Should this research be implemented, water rights must be taken into account to avoid future conflicts.

ISRA has done little work on animal traction in dieri cultivation along the river although animal traction has been studied by ISRA in other regions of Senegal. Many farmers along the Senegal River have animal traction equipment although much of it is in need of repair or the traction animals are not available.

Although insect studies and control measures are being conducted on rice in the river valley, little work is focusing on pests associated with dieri cultivation. ISRA could begin this effort by drawing upon the research on pest control being conducted in Bambey on millet and cowpeas and SCS Kaolack on sorghum. As stated previously, this work could be coordinated with CILSS, OCLALAV, IPM programs in Mali, Niger and Mauritania as well as the Senegalese Crop Protection Service.

As stated previously, considerable work has been conducted by ISRA and WARDA on the potential of Matam rock phosphate. Past research done by ISRA has demonstrated that dieri and walo soils are deficient in rock phosphate. Building upon the work of ISRA and WARDA, as well as phosphate

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[9] The ISRA research program on millet is entitled, "Multidiscipline Program on Improvement of Millet," under Agricultural Sciences, ISR.26. The cowpea research program is entitled, "Multidiscipline Research on Cowpeas," under Agricultural Sciences ISR.31.

research conducted in Mali, models for application can be devised to be tested in dieri fields.

No research has been conducted on sesame by ISRA in the past. Currently, on-station and on-farm variety trials are being conducted on sesame in Mauritania under both irrigated and rainfed conditions (N'Gaide et.al., 1986). This research should be reviewed in order to identify possible varieties which might be appropriate for Senegal.

Staff Requirements: To pursue many of the research alternatives outlined under rainfed agricultural research, an additional agronomist and possibly an agricultural engineer trained in water harvesting techniques will be needed. In addition, one researcher trained in entomology may be required to conduct research on dieri insect pests.

C. LIVESTOCK RESEARCH

- **Research should continue on ways to improve forage and fodder resources for livestock in the Senegal River Valley** (p. 62).

  a. **An inventory of existing rangeland resources could be conducted**, focusing on forage utilization and availability, seasonal grazing patterns, soil potential and water availability. This information could be used to determine optimum stocking rates for different ecological subzones.

  b. **Develop a flexible code of forage utilization with herders which takes into consideration the complexities of land tenure issues and the traditional communal grazing patterns.** By placing limits on exploitation of forage biomass, this code could help prevent overgrazing.

  c. **Agro-forestry projects could be initiated to reestablish beneficial plant species that are important fodder sources, as well as to introduce exotic drought tolerant fodder grasses.** Priority could be given to the preferred species that disappeared.

  d. **Palatability studies could be conducted to identify a number of potential wild plant species that could serve as acceptable fodder during the dry season** if harvested during flowering and stored properly. These studies could also determine at what stage of growth these plants should be harvested to maximize nutritional value. One potential plant worth studying is Cassia tora.

  e. **Research could continue on crop by-products as potential fodder supplements.** Cost efficient additives should be identified to improve the nutritional value of crop by-products. For instance, rice stocks can be treated with NH_3 to improve the nutritional content of the residue.

  f. **Research could continue on evaluating the feasibility of incorporating forage crops more directly into the cropping systems followed by farmers.** Forage crops could be grown as dry season crops in irrigated perimeters.

Current Status: Although little livestock research has been conducted in the Middle Valley, ISRA has carried out a number of surveys in the Delta region

which have included a livestock component. An aerial survey was conducted to get some estimate of livestock numbers in the Delta (Jamin et al., 1986). The numbers obtained by ISRA (22,000) were much lower than the previous SAED estimates (120,000). Data on livestock were also collected in the large exploratory survey which sampled 500 households (MSU, 1986). From this large sample, 69 households were chosen for in-depth study, and livestock information is being obtained. Topics of investigation include the purchase and sale of animals, births, deaths, live weight gain and milk production (Cunard, 1986). Aside from this information, ISRA also conducted an agricultural by-product survey. Data were collected from farmers on the use of rice by-products (straw, bran, broken rice), vegetable by-products (tomato wastes), peanut cake, as well as the production, sale and purchase of chaff (Cunard, 1986). Data were also collected on the purchase of industrial feed and other animal feeds used by farmers. In addition, ISRA is evaluating the potential of crop by-products as animal feed in cattle fattening trials. Cattle in enclosures are fed rice straw, molasses and urea or by-products from other regions (i.e., peanut cake) mixed with urea (Jamin et al., 1986).

Research on forage crops was carried out by OMVS in the past (OMVS, 1985). Forage trials were conducted on both annuals and perennials, and a number of potential varieties were identified. Recently, ISRA has been conducting research on forage crops in the Delta region.[10] These research activities have included the maintenance of a nursery of potential forage crops at Fanaye, a bibliographic inventory on livestock and forage cropping possibilities, as well as on-station and on-farm trials. In addition, ISRA is investigating improved methods of fodder conservation. On-station trials have involved varietal testing of both annuals and perennial forage crops under irrigated conditions (Jamin et al., 1986). Research focused on different planting densities, water applications, fertilizer doses and crop rotation. Tests were also conducted on pregermination of seed and broadcasting. The major crops tested were sorghum and cowpea varieties although some work was also done on ratoon rice, alfalfa, clover and different gramineous plants. It appears that several local varieties of sorghum have good forage potential (i.e., Nebari and Ndanere), although yields were twice as good with an imported hybrid (Sweet Sioux) (Jamin et. al., 1986) Neibe did not do well in the forage trials. The perennial grasses which also appear to have good forage potential are Panicum maximum, Brachiara mutica, and Pennisetum purpureum. Three cuts of fodder appear to be possible over a two year period. On-farm trials conducted by ISRA have focused primarily on varietal tests. Good results were obtained with some varieties of sorghum (10 tons/hectare), but neibe did not perform well. Critical factors influencing these trials were water management and salt buildup in the soil (Jamin et. al., 1986). Despite the positive results with sorghum, farmers were not very receptive to these forage trials. Farmers felt that the trials were too labor intensive and that forage crops are not important under good rainfall conditions. Farmers will not pay for forage crops if natural forage is available. This practice could pose a serious constraint to the adoption of forage crops.

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[10] ISRA's research program on forage crops is entitled, "Study and Improvement of Forage Production," under Animal Health and Production ISR.02 and ISR.02A.

Although ISRA has not conducted an inventory of rangeland resources in the Middle Valley, a research program does exist under which a study of this kind could be carried out. This research program is entitled, "Study of Pastoral Environment: Cartography of the Changing Environment and Improvement of Natural Pasture," under Animal Health and Production ISR.01 and ISR.01A.

- Research could **investigate the economic viability of introducing sprinkler irrigation systems in association with bore hole wells to grow forage crops** as well as irrigated grain crops.

  Current Status: No research on sprinkler irrigation systems has been conducted by ISRA or any other organization in the Senegal River Valley in the past. Sprinkler irrigation systems have been tested in Mali and Morrocco with some success. ISRA could review these systems to determine whether they are appropriate for Senegal.

- **Research could be conducted on the existing marketing system for livestock in the Middle Valley** focusing on the major constraints (p. 64).

  a. Identify differences that may exist among Toucouleur, Peuhl and Maures in the commercialization of livestock.

  b. Improved marketing strategies could be identified which have higher price incentives for producers.

  c. Researchers could outline policy changes which could be considered to bring about improvements in livestock production.

  Current Status: No livestock marketing studies have been conducted by ISRA in the Middle Valley. In the Delta region, ISRA has been collecting information from 69 farm families regarding the sale and purchase of livestock. In addition, a meat marketing survey has been proposed for the area (MSU, 1986).

- Research could continue to be directed toward improving livestock potential through **cross-breeding and animal health studies.**

  Current Status: Although ISRA is not conducting breeding trials or animal health research along the Senegal River, relevant research is being carried out at other research centers (i.e., Dara). Findings are applicable to the Senegal River area. ISRA presently has research programs oriented toward improvements in beef, sheep and goat production as well as health research programs for domestic animals dealing with viral, bacterial and parasitic pathologies.

  Staff Requirements: ISRA might consider bringing in additional researchers to address the research alternatives proposed for livestock research. At a minimum, one animal scientist should be brought in to coordinate the research. This researcher could work closely with the other crop researchers, especially with regard to forage crops. An additional agronomist may also be necessary to oversee the research on forage crops.

D. Vegetable Crop Research

- **Research efforts could continue on testing and multiplying improved vegetable varieties** (p. 66).

  a. Emphasis should be given to **varieties that are adapted to different seasons and that have different maturation periods.** Such varieties would enable farmers to have access to vegetables for home consumption through most of the year, as well as help spread out marketing. Varieties may be obtained from other regions in Senegal, IITA, and the Asian Vegetable Research and Development Center in Taiwan.

  b. Research could attempt to **identify vegetable varieties that have minimum water requirements.** This could help cut down on the frequency of watering.

  Current Status: FAO/OMVS conducted vegetable trials in the past, mainly on tomatoes and onions (FAO, 1985). Recently, ISRA has initiated research activities oriented toward improving vegetable production in the Delta. The Belgian government is funding some of the work on vegetables, especially the onion varietal trials and seed multiplication at Fanaye (LeBeau and Eriksen, 1986). ISRA has also started conducting a number of on-farm tomato trials in the Delta region. These trials are focusing on varietal testing, transplanting dates, ridge cultivation, plant protection and fertilizer application (Jamin et al., 1986). Two new cultivars proposed by CDH (Centre de Developpement Horticole) named Romitel and Roteller performed well. Both varieties tolerated slightly salty soils. The on-farm trials also showed that tomatoes did not respond to potassium fertilizing. As for grain legumes, very little research is being conducted in the river basin (LeBeau and Eriksen, 1986). The ISRA research programs under which vegetable crop research is conducted are entitled, "Development of Market Gardens" (Agricultural Sciences ISR.35) and "Development of Natural Agricultural Resources for Vegetable Production" (Production Systems Transfer ISR.39, ISR. 39A, and ISR.39B).

- Research could **focus on improving vegetable cultivation through better water management, cultural practices and input use** (p. 67).

  Current Status: Presently, SAED provides some horticulture extension to farmers along the river, especially on tomatoes. In the past, CDH worked with FAO to distribute inputs and knowledge on vegetable production (FAO, 1985). CDH prepared information sheets on various vegetables and varieties and provided planting directions to follow. ISRA could continue this effort to distribute up-to-date information to farmers on horticultural practices.

- **A vegetable marketing study could be conducted in the Middle Valley** to determine the major constraints and potential for such activities (p. 68).

  Current Status: Although the Middle Valley was not included, ISRA has been conducting a vegetable marketing study in the Delta region. This survey collected information on a weekly basis on vegetable price fluctuations, the availability and origin of vegetables in the market, and the quantities of vegetables marketed in major towns like St. Louis and Richard Toll (MSU, 1986). This study attempted to assess the value of early or late harvests with regard to market prices, so that planting dates could be adjusted in varietal

trials. A similar study is needed for the Middle Valley region.

- Research could focus on vegetable preservation and storage techniques (p. 67). Forms of storage and preservation techniques appropriate to the resource base of farm families should be emphasized. Such practices could give farmers access to vegetables during other seasons and food deficit periods.

  Current Status: To effectively deal with the research needs presented under vegetable crop research, more vegetable specialists could be brought in to the ISRA regional center. At least one horticulturalist is needed. In addition, serious consideration should be given to bringing in a food technologist to work on appropriate storage and preservation techniques.

E. Agro-forestry Research

- Agro-forestry experiments could be conducted to see if trees can more effectively be integrated into agricultural production (p. 51).

  a. Researchers could identify appropriate trees for shelterbelts and live fences to be planted around irrigated perimeters and dieri depression fields. These trees could help cut down on wind erosion, sand encroachment and evapotranspiration as well as help maintain soil moisture. In addition, these trees could serve as a source of firewood, building material and fodder. Trees that might be used for this purpose include Eucalyptus, Prosopis spp. or Cajanus cajun.

  b. Nitrogen fixing trees could be identified to promote alley cropping and tree mosaics. Such trees might include Acacia albida, Acacia senegalensis, Neem, Parkonsonia spp., and Prosopis spp. Researchers could determine the proper spacing pattern between trees to allow for intercropping of other crops.

  c. Researchers could identify or develop bird resistant varieties of millet and sorghum that can be planted in association with trees. Alternatively, researchers could introduce a drought tolerant cash crop like sesame that birds will not attack.

  d. Village trials could be conducted to determine if farmers are receptive to woodlots to help overcome firewood shortages. Proper management will ensure continuous access and natural vegetation will not have to be used. Tree species which produce human food should be considered in the selection of trees.

  e. Researchers could investigate alternative ways to ease the pressure on forest resources. For example, fuel efficient wood burning stoves could be developed and tested to determine the most appropriate type for a given region. In addition, other alternative energy sources might be explored such as peat, manure, solar energy and wind power.

  Current Status: Since 1976, research has been conducted by CRDI (Centre de Recherche pour le Developpement International) on forestry plantations in irrigated zones in Mali (FAO, 1985). A number of trees appropriate for this purpose were identified, including Eucalyptus (Camald d'Australie), Gonelina

arborea, Khaye senegalensis, Eucalyptus brassiora, and Acacia nilotica. the ISRA's research efforts in agro-forestry in the Middle Valley of the Senegal River Valley have been minimal.[11] However, a number of agro-forestry projects have been initiated. FAO started a wood lot project near Nianga in 1980. Problems identified by FAO in its initial attempts to introduce trees in villages included high project costs, damage caused by termites, and the need to protect young seedlings from animals. Villagers also appeared to favor individual plantations over collective ones (FAO, 1985). Shelterbelts have also been planted by farmers around perimeters in Thoubalel and Donaye. The types of trees being used include Eucalyptus spp., Prosopis spp. and Cajanus cajun. In Bakel, bananas have been planted around a perimeter as a wind break. The forestry service has also begun introducing woodlots. Gum arabic stands have been introduced in Loumbal Baladgi and Goudoude Ndouetbe. Another woodlot has been proposed by the Forest Service for Abdallah Walo. Food-for-work programs are being used to ensure the maintenance of these woodlots. In addition, alley cropping trials have been initiated in Mafre Decore by OFADEC (Office Africain pour le Developpement et la Cooperation). Acacia halo is being planted with melons and cowpeas (see Report 1).

To reduce the pressure on forestry resources, improved cooking stoves have been introduced in other parts of Senegal with some success. Peace Corps Volunteers have been promoting such stoves for several years in Mauritania. In addition, a recent study just completed by USGS indicates that there are considerable quantities of peat available in the river basin. Peat could be substituted for wood as a cooking fuel.

Staff Requirements: ISRA could bring in a researcher to coordinate agro-forestry experiments. This researcher should have a background in forestry.

F. Other Research

- **Research could be conducted on fonio or paguiri to develop a food crop which supplements the other domestic grains** (p. 69).

  Current Status: No research is presently being conducted by ISRA in this area. If research is to be initiated on fonio, links might be established with agricultural research organizations in Mali where fonio is cultivated by some farmers.

  Staff Requirements: No additional staff would be required to conduct research on fonio or paguiri.

- Researchers could **investigate the impact of domestic labor saving technologies on women's labor** (p. 69). For example, cooperative grain mills, improved water lifting technologies and fuel efficient stoves could significantly reduce the labor inputs of women.

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[11] The ISRA research program under which the agro-forestry research would be conducted is entitled, "Study of Resources and Natural (tree) Planting of the River Valley and Sahel Basin" (Forestry Research IRS.13).

Current Status: No research is presently being conducted by ISRA in this area.

Staff Requirements: No additional staff would be required to conduct this research.

An aquaculture research program could be set up at the ISRA research station at Fanaye to help develop freshwater fishing along the river. Fish ponds could be established at the station to begin breeding programs for fish fingerlings. This program could provide technical guidance and fingerlings to farmers.

Current Status: No work in this area is presently being conducted by ISRA along the Senegal River Valley. To initiate work in this area, collaborative links could be established with the Peace Corps. The Peace Corps has had extensive experience in setting up fish ponds throughout Africa, and is presently establishing some ponds in the river basin. Collaboration could also be set up with the Central Agricultural Research Institute (CARI) in Liberia and GTZ, both of which have had years of experience in these types of research programs. In addition, a model upon which to base this work is the Niger FAO/USAID river fisherman program. Before proceeding with these activities, efforts should be made to review past failures in aquaculture development (i.e., Bakel) so that lessons learned can be integrated into the new research program.

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