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FARMING SYSTEMS RESEARCH IN SOUTHERN SENEGAL: THE DJIBELOR EXPERIENCE (1982-1986)

by

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SPECIAL NOTE FOR
ISRA-MSU REPRINTS

In 1982 the faculty and staff of the Department of Agricultural Economics at Michigan State University (MSU) began the first phase of a planned 10- to 15-year project to collaborate with the Senegal Agricultural Research Institute (ISRA, Institut Sénégalais de Recherches Agricoles) in the reorganization and reorientation of its research programs. The Senegal Agricultural Research and Planning Project (Contract No. 685-0223-C-00-1064-00), has been financed by the U.S. Agency for International Development, Dakar, Senegal.*

As part of this project MSU managed the Master's degree programs for 21 ISRA scientists at 10 U.S. universities in 10 different fields, including agricultural economics, agricultural engineering, soil science, animal science, rural sociology, biometrics and computer science. Ten MSU researchers, on long-term assignment with ISRA's Department of Production Systems Research (PSR, Département de Recherches sur les Systèmes de Production et le Transfert de Technologies en Milieu Rural) or with the Macro-Economic Analysis Bureau (BAME, Bureau d'Analyses Macro-Economiques) have undertaken research in collaboration with ISRA scientists on the distribution of agricultural inputs, cereals marketing, food security, and farm-level production strategies. MSU faculty have also advised junior ISRA scientists on research in the areas of animal traction, livestock systems and farmer groups.

Additional MSU faculty members from the Department of Agricultural Economics, Sociology, Animal Science and the College of Veterinary Medicine have served as short-term consultants and scientific advisors to several ISRA research programs.

The project has organized several short-term, in-country training programs in farming systems research, farm-level agronomic research, and field-level livestock research. Special training and assistance has also been provided to expand the use of micro-computers in agricultural research, to improve English language skills, and to establish a documentation and publications program for PSR Department and BAME researchers.

Research conducted under this collaborative project was originally published only in French. Consequently, the distribution of results has been limited principally to West Africa.

In order to make relevant information available to a broader international audience, MSU and ISRA agreed in 1986 to publish selected reports as joint ISRA-MSU International Development Paper Reprints. These reports provide data and insights on critical issues in agricultural development which are common through Africa and the Third World. Most of the reprints in this series have been professionally edited for clarity; maps, figures and tables have been redrawn according to a standard format. Most reprints are available in both French and English. A list of available reprints is provided at the end of this report. Readers interested in topics covered in the reports are encouraged to submit comments directly to the respective authors, or to Dr. Eric W. Crawford, Director, Senegal Agricultural Research II Project, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039.

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*In December 1987 MSU, ISRA and USAID/Dakar negotiated a 2 1/2 year contract (Contract No. 685-0957-C-00-8004-00) to extend MSU's program of research support and training in the social sciences, agronomy, forestry and research planning.

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Foreward

The "Djibelor Experience" is a product of joint efforts of the members of the Farming Systems and Technology Transfer team at the Institute of Agricultural Research (ISRA) station in Southern Senegal during a five year period (1982-1986). In addition to the authors, the other members were S. Sall, M. Diouf, F. N'Diame, A. Fall, M. Sonko and M. Lo.

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I. INTRODUCTION

Senegal has a rich tradition of agricultural research, spanning over sixty years. During this period, the research strategy has evolved in response to both political changes--dating back to the colonial period--and the introduction of new methodologies from abroad. This paper briefly reviews the history of agricultural research in Senegal and describes the evolution of the current farming systems research (FSR) program, with emphasis on lessons learned that have implications for other researchers conducting farming systems research in national research programs in developing countries.

1.1 Adaptive Research in Senegal

From the turn of the century until the mid-1970s, agricultural research in Senegal and throughout Francophone West Africa was implemented under the auspices of the French overseas research institutes--most notably IRAT (crops research), IEMVT (livestock), IRHO (oil plant), IRCT (cotton) and ORSTOM (overseas scientific and technical research).

In 1975, the Government of Senegal (GOS) established the Senegalese Agricultural Research Institute (ISRA) as part of its policy to nationalize agricultural research. Under ISRA, crops research was concentrated at the *Centre National de Recherches Agricoles* (CNRA) at Bambey and carried out through a network of regional stations. This research focused on variety improvement and plant protection. Animal production and veterinary research was carried out at the *Laboratoire National d'Elevage et de Recherches Vétérinaires* (LNERV) in Dakar and at two substations (Dahra and Kolda).

Since Senegal served as the headquarters for agricultural research in Francophone West Africa until the 1960s, today the country has one of the most extensive research infrastructures in Sahelian Africa (Bingen and Faye, 1987). Since 1975, ISRA has conducted extensive research on groundnuts, cereals, cotton, cowpeas and soybean at CNRA/Bambey and has generated many research results relevant for improving agriculture in the Sudano-Sahelian zone.

In spite of these successes, in the 1960s many observers pointed out several weaknesses in the research system. For example, crops research had few links with extension and was concentrated on stations, with little research conducted at the farm level. Similarly, livestock research, which focused on veterinary research and breed improvement, neglected the production constraints faced by pastoralists (World Bank, 1981).

In response to these criticisms, in the early 1960s ISRA established outreach (off-station) sites called *Point d'Appui et d'Expérimentation Multilocale* (PAPEM) where researchers implemented multi-locational experiments on soil fertility, crop rotations and variety evaluation (Bingen and Faye, 1987). A major objective of PAPEM was to develop simple extension themes--mainly on fertilization and improved varieties (millet, sorghum, groundnuts)--that collaborating farmers could verify in their own fields; and which would serve both demonstration and training purposes.

In the late 1960s, ISRA realized that (1) farmers were not widely adopting research results, despite the contacts and opportunities provided through PAPEM, (2) it was possible to develop coherent extension packages and improved cropping systems models from many available research results, and (3) it was necessary to conduct on-farm adaptive research on a wide enough scale to take into account differences in farmers' socio-economic constraints.

In response to these realizations, ISRA initiated the *Unités Expérimentales* (UE) project in 1969 to assess the relevancy to farmers of technologies developed on research stations. At the time, this project represented a unique attempt in West Africa to apply a systems approach, with a farm-level focus, to agricultural research (Gilbert *et al.*, 1980; Norman *et al.*, 1981).

The UE project generated considerable knowledge about the technical and economic feasibility of intensifying agriculture and the process of transferring technology from research stations to farmers[1] (Faye, 1978; Benoit-Cattin, 1982). Researchers and extension personnel also gained a better understanding of the structure and the functioning of the farm family. However, following a major review the UE project was terminated in 1981, due to its high cost (Norman *et al.*, 1981).

In 1981, the World Bank-funded Agricultural Research Project (ARP) was initiated to decentralize agricultural research at ISRA, develop interdisciplinary programs to address commodity improvement constraints, and implement production systems research[2] (PSR) in the country's major agro-ecological zones (Figure 1). Under the umbrella of the ARP, USAID/Dakar

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[1] Details of the scientific output from the UE project can be found in ISRA publications, including ISRA/CNRA- Bambey (1977), Faye (1978) and Benoit-Cattin (1982).

[2] Production systems research is a literal translation of the French concept, *Recherches sur les Systèmes de Production*, which has a different connotation than the English term, farming systems research. The latter is roughly equivalent to the French concept, *Recherches sur les Systèmes d'Exploitation*, focusing on the farm as the unit of production. To conform with the terminology in vogue in Senegal, this paper uses production systems research as equivalent to farming systems research.

subcontracted Michigan State University (MSU) to assist ISRA in implementing the Senegal Agricultural Research and Planning Project (SARPP)--designed to organize and carry out PSR, as well as macroeconomic research (Eicher, 1982). As part of the reorganization, ISRA established the Production Systems Department[3] in 1982. This department was responsible for establishing five PSR teams (one in each agro-ecological zone) and managing several research support programs (Bioclimatology, Weed Control, Post-Harvest Technology and Soil Fertility). By 1986 the department had three operating PSR teams, stationed at Djibelor (Lower Casamance), Kaolack (Peanut Basin) and St Louis (Fleuve region), and an interdisciplinary Central Analysis Group (GCAS) based in Dakar. Members of the MSU technical assistance staff joined the PSR teams in the Lower Casamance in 1982 and the Fleuve region in 1983.

1.2 Objectives

National research systems throughout the developing world attempt to develop appropriate strategies to increase agricultural productivity. The objective of this paper is to share Senegal's considerable experience in conducting farming systems research; and contribute to the growing body of methodological literature on FSR and technology evaluation in West Africa. To achieve these objectives, this paper documents the farming systems research conducted over the 1982-86 period, by (1) chronicling the "Djibelor Experience", including the methodology used by the PSR team, (2) summarizing the empirical findings for the Lower Casamance, in order to make them available in one place, and (3) discussing major problems in program implementation and their policy implications.

II. THE LOWER CASAMANCE REGION: THE SETTING IN 1982

The study area is the maritime (Western) zone of the Casamance region, lying between the Gambia and Guinea-Bissau (Figure 2)[4]. The total population is 362,000, of whom more than 70% live in rural areas (Harza, 1984). The major ethnic groups are the Diola (85%) and the Manding (6%). Although numerically fewer, the Manding historically have had a strong cultural and religious influence north of the Casamance River.

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[3] In 1986, the name was changed to Department of Agrarian Systems Research and Agricultural Economics to reflect the focus on agrarian systems (beyond the farm level) and the inclusion of macro-economic research.

[4] In 1984, the Casamance was split into two separate administrative regions: the Ziguinchor region (Lower Casamance) and the Kolda region (Middle and Upper Casamance).

Low-lying inundatable valleys dominate the landscape of the Lower Casamance (Table 1). An estimated 28% of the total area (734,200 ha) is cultivated, located along a typical toposequence (Figure 3), ranging from sandy ferrallitic upland soils to mangrove swamp, where lowland rice is transplanted. Between these two extremes are small inland depressions (*talwegs*), where accumulations of clay, organic matter and water permit freshwater rice cultivation (Posner *et al.*, 1983). The Casamance River is a tidal estuary whose highly saline waters have to be diverted from farmers' fields, rather than used for irrigation.

As a result of several continuous years of drought, the rainy season has been reduced from five and one-half to four months. Rainfall data for Ziguinchor (Figure 4) shows that total rainfall for the region declined by 25% from its long-term average of 1000-1100 mm in the early 1980s.

Total cereal production in the Lower Casamance region was relatively constant between 1970 and 1983. However, production of rice, the primary staple food, declined drastically from a ten-year average of 31,000 mt to 6,300 mt in 1983. With population increasing, rice imports rose from 2,000-3,000 mt in 1962 to nearly 30,000 mt in 1983 (Jolly, Kamuanga *et al.*, 1988).

In response to the region's prolonged drought, the *Projet Intégré pour le Développement Agricole de la Casamance* (PIDAC)--an extension branch of the regional development agency, *Société de Mise en Valeur de la Casamance* (SOMIVAC)--began to promote direct seeding of rice and planting maize as a field crop rather than as only a compound crop. The objective was to increase the availability of cereals for farmers by capitalizing on the shorter growing season. Other themes extended by PIDAC personnel in the early 1980s included flat cultivation of upland crops and animal traction to increase family labor productivity.

During the 1970s, most farmers acquired farm equipment and fertilizer through the GOS's credit program (*Programme Agricole*). When it was discontinued in 1979, many farmers stopped using fertilizer due to a lack of cash for purchasing inputs. Those with animal traction confronted serious difficulties in maintaining their equipment and purchasing spare parts.

The ISRA station at Djibelor (five kilometers west of Ziguinchor) was established in 1967 to conduct research on aquatic rice, as a complement to research on groundnut and upland food crops that had been conducted at the Sefa station in the Middle Casamance since 1947. In addition, the Djibelor and Sefa stations managed a network of PAPEM set up by IRAT in 1962, and located in the villages of Enampore, Maniora II and Diana Ba. Other research activities already being carried out as the PSR work began included multi-locational trials run from either CNRA/Bambey or other ISRA stations, and forestry research managed by a station at Djibelor.

However, rice research has remained the main activity at Djibelor, with several subprograms in soil fertility and plant breeding (since 1967); agricultural mechanization and cultural practices for aquatic rice (1970-1976); entomology (1970); phytopathology and weed control (1981) (Posner, 1988). Available rice technology included high-yielding varieties developed under shallow-flood and phreatic[5] conditions (DJ12-519, IRAT 112, IRAT 113, IKP and 144B/9), and other cultivars (Rok 5, DJ-684) which exhibited a high potential under deeper flood conditions (Sall, Kamuanga and Posner, 1983; Posner, 1988).

Traditionally, rice in the Lower Casamance is grown in low-lying inundated plains, a large portion of which are influenced by river tides originating from the Atlantic Ocean. These areas can be cultivated only after heavy August rains have leached accumulated salts. Declining rainfall in the last two decades has made the mangrove swamps unsuitable for rice. None of the available improved varieties performed well under saline soil conditions.

With no research on upland food crops being conducted at Djibelor, the available packages for maize, sorghum, millet and groundnuts appropriate for the Middle Casamance ecology were those developed at the Sefa station. These packages were promoted by PIDAC and accepted in those villages with cropping systems similar to the Middle Casamance. On this basis, PIDAC/SOMIVAC had classified villages as open or closed to progress--depending on the rate of adoption of the major themes.

III. PROGRAM IMPLEMENTATION STRATEGY

The PSR program at Djibelor evolved in two main phases. During the first phase (1982-83), the PSR team conducted exploratory surveys, delineated the region into farming systems zones, defined research themes and implemented on-farm exploratory trials. The second phase (1983-86) included a combination of testing/screening and testing/pre-extension activities involving on-farm and on-station agronomic trials, verification and problem-focused socio-economic surveys. The methodological instruments, objectives and expected output from each subphase are presented in

[5]The fields are saturated due to capillary action.

Table 2. An internal review of the program, initiated in 1985, guided the implementation of the third and on-going phase which began during the 1986-87 agricultural season[6].

3.1 Exploratory Surveys (February-June 1982)

The PSR team initiated the exploratory surveys by visiting 35 of the approximately 330 villages in the Lower Casamance--the PIDAC mandate region. ISRA and SOMIVAC authorities agreed to restrict research activities to this region in order to strengthen ties and interaction with PIDAC and to increase cost-effectiveness. Past research results and socio-economic studies were also reviewed during this period.

Informal discussions with farmers and extension personnel concentrated on the need to understand and characterize various farming systems in the region and to identify major constraints to increasing farm production. Visits with farmers often involved walking to their fields in order to understand how they organized and managed the village landscape. Interviews were also conducted with key informants with a variety of backgrounds and rural experiences. Often, one or two thematic researchers were invited to participate in the interviews, if it was expected that an interdisciplinary technical problem would be discussed. Most field trips lasted three to four hours, which included one to one and one-half hours of actual interviews with farmers--thus, permitting the team to visit two villages per day. Although the discussions were informal, a guideline was prepared prior to each visit, as suggested by Collinson (1982). Field notes were prepared for discussion and later consolidated as short reports that emphasized both farmers' constraints and their perceived alternative solutions[7]. The information collected during this phase--and from secondary sources--confirmed that ISRA had conducted very little applied research, especially with regard to upland food crops.

3.2 Characterizing Farming Systems

The agro-ecological and socio-cultural heterogeneity of the Lower Casamance was a major "discovery" of the exploratory and informal survey phase of the program. Due to this variation, the

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[6]The program has since undergone yet another major review, which resulted in curtailing activities to accommodate budget cuts. Since June 1986, the PSR team has focused on collaborative work with farmers' groups, led by non-governmental organizations. This approach is viewed as a cost-effective means of advancing the improved technologies tested over the 1982-86 period to the pre-extension phase. The current phase (1986 to present) awaits evaluation.

[7]By the end of June 1982, some 30 field reports of 2-3 pages had been written by each team member. Initially, these documents proved very valuable in formulating research hypotheses; and later in defining research themes.

research team decided it was important to subdivide the region into more homogeneous agricultural subzones.

The zoning work combined several approaches in order to adapt to local conditions. First, a rapid appraisal--the Sondeo (see Hilderbrand, 1981)--was initiated to identify major farming systems and assess technology needs prior to agricultural research. Second, the PSR team sought appropriate ways to regroup natural and administrative boundaries into "agricultural situations" (*Situations Agricoles*). This concept is more encompassing than recommendation domain, which is used to identify target groups of farmers in similar circumstances (Byerlee, Collinson *et al.*, 1980; Harrington and Tripp, 1982)[8].

Third, in delineating zones, dynamic criteria concerning farmers' management of their environment were given precedence over more passive criteria such as morphopedology, or agro-climatology. The three major criteria were gender division of labor, the importance of animal traction in land preparation and the importance of aquatic rice in the cropping system. They are explained in detail below. The five agricultural zones are depicted in Figure 5, and their characteristics given in Table 3.

According to the first criterion, gender division of labor, the Lower Casamance was divided into two areas: the prototypical (original) Diola system in which men prepare the land while women plant, weed and harvest (Zones I, II, and V), and the Manding system practiced in the northeast in which the roles of men and women are separated by crop--with women cultivating rice and men cultivating upland crops, groundnuts as a cash crop and coarse cereals for home consumption (Zones III and IV).

The use of animal traction in land preparation resulted in a further characterization of the Diola/Manding divide. North shore villages close to the Gambia and Middle Casamance had used animal traction for years (Zones IV and V). Adoption of trained oxen, a moldboard plow and occasionally a seeder made it possible for these farmers to cultivate twice the amount of land as those without animal traction south of the Casamance River.

[8]In the Francophone research-development terminology, a *situation agricole* represents a set of spatial units with comparable agro-ecological potential and confronting similar constraints, for which a unique development strategy could be designed (*ISRA/Département Systèmes et Transfert de Technologies*, 1984). In this context, we believe that the notion of a recommendation domain is a subset of *situation agricole*. From each domain, a sample of farmers can be drawn to conduct experiments under conditions representative of their farms in order to develop technologies applicable to the entire group.

The third criterion was the role of aquatic rice in the cropping system. The gradual rising of the landscape as one moves from the southwest to the northeast is associated with a decreasing rainfall gradient (1300 mm to 800 mm). This favors a greater emphasis on upland crops in Zones II, III, IV and V. The effect of this transition on the cropping calendar is quite marked. In the northeast (Zone IV) major agricultural activities take place in June/July when farmers plant maize, groundnuts, millet and direct-seeded rice. In contrast, peak labor demand in the southwest (Zone I) does not occur until late August or early September when farmers plow and transplant rice. Traditional Diola villages, such as Seleky in the south, plant no upland crops at all.

3.3 Defining Research Themes

Although the Lower Casamance was divided into five agricultural situations, or zones, four unifying agronomic themes were identified and used to define the PSR program's research strategy. Each theme focused on opportunities to alleviate observed constraints in helping farmers adapt to a drought-prone environment.

The first theme was intensification of production on good lands. This refers to increasing rice yields in low-lying inland valleys and maize yields in compound fields. The inland valleys accumulate more water than the sandy uplands and are sufficiently upstream so that salt encroachment from the mangrove swamps is not a problem. For maize, the high level of organic matter from kitchen refuse near compounds made intensification easier to propose. In both cases, improved seeds and fertilizer were to be used.

The second theme was diversification of the cropping system by introducing late-seeded crops (sweet potatoes, cowpeas, sorghum) that would not compete for family labor during the peak growing season. Increasing the options for late planting was emphasized--given the absence of mechanization, the changing rainfall patterns and the expectation that these crops would serve as catch-crop alternatives should the first seedings fail.

The third research theme was rehabilitation of abandoned land (Zones I, II, IV, and V). Farmers had abandoned higher rice fields near the villages--normally fed partially from underground water--due to falling water tables. Also, salt intrusion made low-lying, potentially fertile rice lands no longer suitable for cultivation. The fourth theme involved harvesting residual moisture by planting a relay crop such as sweet potatoes (Zone III). This was envisaged as an option for farmers who cultivated short cycle rice varieties.

3.4 Chronology and Activity Highlights

This study reports on PSR activities that were implemented during the period, 1982 through 1986.

3.4.1 Site Selection and Sampling

By June 1982, two villages had been selected in each zone to capture intrazone variability. All ten villages chosen (Figure 5) were located within 120 km of the Djibelor station to minimize supervision costs. The factors and village characteristics that influenced the selection process are reviewed below for each zone[9]:

Zone I (Oussouye):

- Boukitingo village represented the traditional Kasa-Diola production system, which emphasized on aquatic rice cultivation.
- Loudia-Ouoloff village had limited access to good low-lying rice land, motivating farmers (Ouoloff migrants) to vigorously reclaim upland fields. This gave the PSR team an opportunity to experiment with improved upland practices in a zone where, traditionally, transplanted rice was the mainstay.

Zone II (Blouf):

- Mangagoulak[10] represented the traditional Blouf-Diola country.
- Mahamouda, south of the River, was an example of the transition toward a "plateau" cropping system.

Zone III (Niaguis):

- Households in the villages of Maoua and Boulom had similar Manding-type social organization of production, but represented two different experiments in terms of contacts with extension services.

Zone IV (Sindian-Kalounayes):

- Households in Boulandor and Medieg both used animal traction and represented typical Manding production systems. Although only 30 km apart, the two villages had marked differences in soil composition and fertility.

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[9]The traditional name given to each zone is shown in parentheses.

[10]The site was later abandoned due to a lack of plateau land.

Zone V (Fogny-Combo):

o Bandjikaki and Tendimane were located at two extreme positions in the zone characterized by Diola-type organization of production and wide use of animal traction. However, since animal traction was not very common in Tendimane, this site was reassigned to Zone II and replaced with the village of Suel in 1983.

A list of compounds in each village was updated in June 1982 and used as a sampling frame. A random sample of 10-15 compounds was drawn without prior stratification. This approach was justified by the time constraint and the preliminary nature of the data to be collected during the first season, but was later criticized by colleagues who favored a stratified or purposive sample[11]. Table 4 shows the relationship between the population and sample size in each village. The team visited each site every two weeks to supervise surveys and trials, discuss the objectives and expected results of the trials with farmers and obtain feedback.

3.4.2 Fieldwork

During the 1982-86 period, many different activities took place as a result of the research findings of previous years and the widening scope of the research agenda following expansion and changes in the PSR team's composition[12]. The highlights of each year are given in the following sections and in Table 2.

3.4.2.1 **1982 Season**

After completing the exploratory surveys and the delineation of the region into zones, two major activities took place in the summer of 1982. First, a verification survey was conducted in order to obtain quantitative data about farmers' cultural practices and constraints by crop and field operation. Secondly, exploratory (orientation) on-farm trials were initiated with participation by farmers. The master sample included 125 compounds made up of 235 independent households (farms) who cultivated 1300 plots. Data collection was organized at the plot level.

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[11]For example, the animal scientist justified purposive sampling on the grounds that it permitted inclusion of farmers with large herds of cattle. These farmers might otherwise have been considered to be outliers.

[12]The initial PSR team included two expatriates (an agronomist, PhD, under the SECID Lower Casamance Project, an economist, PhD, under the MSU/USAID project), and a Senegalese agricultural economist (Ms). A sociologist (Ms equivalent) joined the team in 1983, followed by an animal scientist and an agricultural engineer (Ms). A counterpart was assigned to the senior agronomist in 1983. By June 1986, the team included seven scientists representing five disciplines.

A major finding of the 1982 survey--contrary to the conventional view that lowland rice was the dominant crop--was that upland (rainfed) cropping across the region accounted for 50-85% of the total cultivated land per farm. These results greatly influenced the research design in subsequent years.

3.4.2.2 **1983 and 1984 Seasons**

The importance of upland crops confirmed the need for more research on groundnuts and maize (intensification theme) and also justified the attempt to introduce sorghum and cowpeas as late-planted crops (diversification theme). Identification of weeding as a major labor bottleneck led the PSR team to envisage cultivation experiments for upland crops and herbicide trials for direct-seeded rice fields.

The composition and type of experiments changed as the number of on-farm trials increased from 72 in 1982 to 114 in 1984. On the basis of results from the 1982 exploratory trials, more verification trials were conducted--including an increased number of large-scale experiments (*essais en vraie grandeur*). By the end of the 1984 season, eight crops were being tested. Rice (upland, phreatic and aquatic) accounted for 37% of the trials, sorghum (19%), sweet potatoes (17%), cowpeas (15%), maize (10%), groundnuts (7%), cassava (3%), and millet (2%). The majority of the experiments were variety tests (62%), followed by fertilizer trials (20%), and weed control and other treatments (18%). The emphasis on upland crops was reflected in the distribution of experiments along the toposequence with 55% on strictly rainfed crops; 29% on phreatic rice and 15% on aquatic rice. Twenty-five percent of the experiments were conducted in the controlled environment of the Djibelor station to generate referral results.

In planning the second and third year research program, the team decided to separate agronomic and socio-economic surveys and reduce the master sample to 80 compounds, 147 farms and 1100 plots. This was done primarily to facilitate greater field supervision and monitoring of data collection on farmers' agricultural practices. Using weekly recall methods, on-farm resource monitoring was conducted on a subsample of 30 purposively-selected farms in the five zones.

In addition, problem-focused studies were conducted. For example, income differences between animal traction farmers north of the Casamance River and hoe (*cajendo*, *daba*, *donkonton*) farmers in the south led to further inquiries about the potential benefits of animal traction. The contribution of off-farm activities to family incomes was also assessed in 1983 and 1984.

Sociological studies were initiated in 1983-84 to improve the team's understanding of how the farmer and his family function as a complex production and consumption unit. Greater knowledge of the social organization of production among various Diola groups was also judged important for explaining the adoption or non- adoption of proposed improved technologies. In response to new program objectives livestock system research was initiated in 1984, further widening the team's scope of activities. This subprogram began with exploratory surveys which resulted in the elaboration of an operational typology of livestock systems in the Lower Casamance.

3.4.2.3 **1985 and 1986 Seasons**

The main feature of this period was the team's implementation of an internal review of the PSR program, actually in progress since November 1984. The review, which benefited from colleagues' input and outside consulting missions, assessed the adequacy of the existing data base, the need for additional data collection and ways to improve research links with both on-station programs and the PIDAC (Kamuanga, 1986). Zoning and sampling procedures were reexamined with regard to their efficacy in testing improved technologies. Subsequently, the number of research sites was reduced from ten to nine, the master sample from 147 to 135 farms and detailed input/output studies were halted. Activities at each site were reoriented to focus on testing selected interventions in order to develop recommendations. In fact, as shown in Table 5, each retained site represented a combination of the principal characteristics of the two major farming systems (Diola vs. Manding) and the availability of suitable low-lying land and plateau fields.

On-farm surveys were reoriented to include evaluation of prototype technology and farmers' attitudes toward these improved practices. Researcher-managed trials were drastically reduced. Those technologies which proved successful were moved into pre-extension trials with an increased number of replications (4 to 5), sometimes involving the extension agents (ISRA, 1986).

Livestock production system studies continued with in-depth investigations of village-level herd and rangeland management practices. The village itself became a subject of investigation, instead of simply an aggregation level for data analysis. Village institutions were examined as a vehicle for adopting improved technologies. Finally, the team initiated studies to evaluate the returns to infrastructural investments in small anti-salt dams, which were being promoted by SOMIVAC/PIDAC in selected villages.

IV. RESULTS OF TECHNOLOGY EVALUATION AND SOCIO-ECONOMIC STUDIES

The research identified several major farm-level constraints in the Lower Casamance. Due to continuing drought, farmers had lost access to many traditional rice fields (to salt intrusion or drought stress). The gradual shift to direct-seeded rice on remaining fields created new problems for variety selection, weed control, fertility management and family labor allocation. To compensate for lost paddy production, farmers put greater emphasis on upland cereals (maize, millet) and cash crops (peanuts). Here, problems of soil fertility, diversification of crops and mechanization were key constraints. Findings from the field trials and socio-economic studies are summarized below.

4.1 Rainfall Analysis[13]

A clear picture of the variability of rainfall during the 1982-86 period is given in Figure 6, which compares two representative sites--Boulandor, north of the Casamance River (Zone IV) and Loudia-Ouoloff in the southwest (Zone I).

Total annual rainfall varied enormously at Boulandor--between 580 mm in 1983 and 1048 in 1985. Interannual variation at Loudia-Ouoloff was less marked, with precipitation above 1000 mm in four out of the five years. However, between 1982 and 1985 rainfall at both sites was below the long term regional average. The 1983 season was particularly dry, resulting in the failure of the rice crop in most villages. By contrast, although rains in 1984 began very well across the region--encouraging farmers to plant rice--drought in August reduced yields of both upland and inundated crops.

In summary, rainfall was variable throughout the study area; and below the historical average, which had ensured successful and stable crop production in the past. South of the Casamance River, where aquatic rice is the agricultural mainstay, heavy rainfall is needed in September and October to ensure proper inundation of low-lying plains. To the north where upland cropping systems predominate, rains must begin promptly in June, without dry spells so that groundnuts, cereals and direct-seeded rice will produce good harvests.

4.2 Results of Experiments

Research focused on developing technologies that would enable farmers to intensify production (increase yields), diversify their cropping pattern, rehabilitate abandoned land, and harvest residual moisture (Table 6).

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[13]Detailed analysis and interpretation of the evolution of rainfall over the 1982-1986 period are found in Posner, Kamuanga and Lo (1991): "Lowland Cropping Systems in the Lower Casamance of Senegal: Results of Four Years of Agronomic Research (1982-1985)." MSU International Development Paper No. 30. Department of Agricultural Economics, Michigan State University, East Lansing.

4.2.1 Intensifying Production on Fertile Lands

The fertile land category includes (1) newly cleared bush fallow, (2) compound fields and land near villages that receive animal manure, and (3) humid, low-lying rice zones where salt intrusion was not a problem. The intensification theme primarily refers to increasing yields of maize, groundnuts and phreatic rice--especially north of the Casamance River (Zones IV and V).

About 7% of the total cultivated land in the region was planted to maize. Fertilizer trials indicated that in compound fields yields of 1.5 to 3.0 mt/ha were possible, although on poorer outlying fields the range was 0.5 to 1.5 mt/ha. Field trials indicated that heavily cultivated, low organic matter, acidic soils responded poorly to chemical fertilizer. Mechanized weeding of maize was also studied. Flat-plowing followed by combined ridging-weeding with a moldboard plow was three times as fast as initial ridge-plowing followed by hand planting and weeding. In Boulandor, this technique was adopted once farmers overcame their initial reluctance to use oxen in standing corn.

For groundnuts (about 55% of total cultivated area), fertilizer trials showed adequate returns in 1983 and 1985, but in 1984 aphid attacks markedly reduced yields[14]. The overall results of the on-farm trials indicated that application of 150 kg/ha of 8:18:27 increased yields by 57%--from 1,120 kg/ha to 1,760 kg/ha.

Weed control trials for maize and upland rice indicated the importance of weeding frequency on yield. Researcher-managed trials at Djibelor indicated that weeding at 2, 4 and 6 weeks after line seeding reduced the labor requirement to 23 person-days/ha--compared to the 39 person-days required for farmers' usual practice of a single weeding 6 weeks after planting. Average labor productivity, as measured by the ratio of output to total weeding labor (a limiting factor), was highest (180 kg of paddy per person-day) for multiple weeding (Lo, 1984).

Rice is the most important food crop in the Lower Casamance. The intensification theme focused on phreatic rice (10% of cultivated area) since the team felt that the topographic position somewhat mitigated the effects of low rainfall. Variety tests were conducted and fertilizer application and weed control practices were investigated in order to increase rice yields. Improved varieties suited to phreatic conditions (DJ 12-519, IRAT 133, IRAT 112 and 144B/9) were compared to local varieties at several sites in large-scale (500 m^2) farmer-managed trials. These

[14]The following regression equations of yield (y=kg/ha groundnuts) on fertilizer (x=kg/ha NPK, 8:18:27) were estimated: 1983 : $y = 1129 + 5.2x$ $r = 0.61^{*}$ $n = 15$; 1984 : $y = 1095 + 2.9x$ $r = 0.43^{**}$ $n = 42$; 1985 : $y = 1353 + 5.5x$ $r = 0.59^{*}$ $n = 9$

varieties were well-adapted to local conditions (in terms of height, growing cycle, type of panicle) under low levels of management and performed as well as, or better, than local varieties--as shown in Table 7 (Posner *et al.*, 1991). At higher input levels, DJ 12-519, yielded 2.2 mt/ha, compared to 1.6 mt/ha without fertilizer and using farmers' practices. Because of location-specific problems for rice under aquatic conditions (iron toxicity, salt, moisture stress), no improved cultivar outyielded local varieties. However, under good conditions, improved varieties such as Rok 5 and DJ-684 sustained yields of 1.9 to 2.3 mt/ha over many years (Table 7).

The response of phreatic rice to fertilizer largely depends on the texture and initial acidity status of fields under cultivation. On the better rice fields (pH> 4.5, heavier textured) the benefit-cost ratio of applying 200 kg/ha 8:18:27 and 150 kg/ha urea was 3.5 in 14 out of 26 tests. The experiments pointed out the need to classify rice fields according to their fertilizer response aptitudes prior to conducting optimal-dose experiments, in order to generate recommendations appropriate to each type of field.

To evaluate weed control options for phreatic rice, two types of on-farm experiments were conducted. The first, in which herbicide (Ronstar 250 CE) was applied with a backpack sprayer, proved to be popular with women since it reduced their weeding time on treated plots to one-third that of non-treated plots. The benefit-cost ratio was estimated at 1.9 across all 26 tests. Herbicide use was highly profitable (benefit-cost ratio >2) in half the tests. These were sites that had been flat-plowed, planted to short-stature varieties on heavier soils, and were late-weeded due to labor shortages. Generally, to pay for the herbicide (14,000 CFA/ha[15]), women had to either realize a 20% yield increase from timely weeding or use time-savings to expand their rice holdings.

The second weeding experiment entailed using an ox-drawn groundnut seeder to row plant rice. This permitted subsequent hoe-weeding, rather than hand-pulling of weeds--which was the only possible technique when rice seed is broadcast. This technique was widely adopted in Boulandor, where many farmers owned oxen-drawn seeders. A third approach involved using a two-row, hand-pulled Casamance seeder (Fall, 1987). Preliminary results indicate labor time savings of about 30%.

4.2.2 Diversifying Production

The diversification experiments were oriented toward late- seeded crops that would permit farmers to increase cropping intensity--and use their land, equipment and time more efficiently.

[15] 1 US$ at 350 CFA.

In the north, experiments included short-cycle, improved cowpeas and sorghum varieties, while cowpeas and sweet potatoes were the target crops south of the River.

Over three years (1983-85), the sorghum varieties V6 and V2 planted in mid-August averaged 950 kg/ha of grain--three times higher than the average yield of 315 kg/ha for local varieties. Late-seeded sorghum raised a great deal of interest among participating farmers, who began to appreciate it as a catch-crop. Cowpeas, less known to northern farmers, were a riskier proposition because of their susceptibility to aphid attacks. Yields were often below 300 kg/ha. Variety trials (without fertilizer) were conducted at eight sites involving six varieties. Large-scale, on-farm trials (with the participation of nine farmers) indicated that the improved variety 58-57, sown between August 15th and September 1st, produced an average yield of 775 kg/ha--compared to 248 kg/ha for local varieties.

In the south, relay cropping was intended to reduce the risk of crop failure under conditions of low rainfall when lowland rice fields are not sufficiently inundated. Over the 1982-85 period, cowpea variety 58-57 significantly outyielded local varieties (496 kg/ha vs. 103 kg/ha). Large-scale sweet potato trials showed that the improved variety N'Dargu, planted between August 15th and September 15th on plateau fields, maintained an average yield of 5 mt/ha--compared to 1.9 mt/ha for the local variety.

4.2.3 Rehabilitating Abandoned Land

This research theme addressed two situations. First, emphasis was placed on sandy fields well above the high tide mark that farmers had abandoned because of drought susceptibility. The second emphasis was on sites located on the flood plain where annual resalinization that occurred during the dry season was rarely leached free of salts--to permit transplanting of rice--in the wet season. An estimated 1/3 to 2/3 of previously inundatable rice lands had been lost to various causes (Sall, Kamuanga and Posner, 1983).

On-farm trials revealed that maize, sorghum and sweet potatoes could be grown with some success on the abandoned upper rice fields--which were generally sandy and low in organic matter. Whereas rice yields ranged between 0.8-1.2 mt/ha, maize yields approached 2 mt/ha and sweet potatoes 6 mt/ha. In contrast, sorghum yielded only 1 mt/ha because of heavy losses due to bird attacks. In addition to their higher yield potential, these new crops were more competitive against weeds and more drought tolerant than rice.

On the lowest rice fields, much of the research was conducted at the Djibelor station in collaboration with the watershed management team. The objective was to enhance the leaching of salt through use of drains, different plowing techniques and anti-salt dams. The rehabilitation theme was transferred to the watershed management (Bolong) program in 1984. It has had relatively little success since farmers continued to hope that a return to normal rainfall would once again flood the abandoned rice fields (Barry and Posner, 1987).

4.2.4 Harvesting Residual Moisture

In certain rice fields, the soil remains moist after harvest due to upward capillary movement from the water table and heavy dew in November. Farmers preferred fields in the vicinity of urban centers (Bignona, Ziguinchor, Oussouye) since they could sell their produce during the long dry seasons.

By planting a sweet potato crop after rice on this residual moisture, farmers could increase cropping intensity. Twenty-seven on-farm tests with sweet potatoes were conducted between 1983 and 1985 using the improved variety N'Dargu and the local white skin variety "Chinese" which was preferred by farmers. The results shown in Table 8 indicate that yields of 2.5 to 5 mt/ha were common. Although these were lower than yields obtained at the Djibelor station, the gross returns (cash) earned by farmers were significant, ranging from 8,000 to 12,000 CFA on 500 m^2 plots. These plots received no fertilizer and were not weeded. Fertilizer trials (100 kg/ha 8:18:27; 75 kg/ha urea) at the station indicated that on well watered fields, yields of up to 8.5 mt/ha were possible. This theme has been the most successful to-date as many farmers wanted to plant sweet potatoes following their rice crop[16].

4.3. Results of Socio-Economic Studies

Various socio-economic surveys were conducted to (1) better understand the objectives and constraints facing the farm family, as well as the dynamics of the farming system, and (2) study the factors likely to affect wide-scale adoption of proposed improved technologies. A detailed list of the studies implemented between 1982 and 1986 is provided in Table 9. The major findings and implications are discussed in the following sections.

4.3.1 The Social Organization of Production

There exist significant differences in the social organization of production and land tenure systems in the Lower Casamance, which have important implications for technology adoption. South of the Casamance River (Zone I), the Kasa-Diola live in households (*butong*) composed of conjugal units with autonomy in economic matters. Villages are organized in groups of individual

[16]PIDAC has successfully promoted this technology since 1986.

residential units (*eluf*). Households follow an intensive aquatic rice production system with a marked division of labor by task--the heavy work of dike building and ridging is done by men, while women transplant and harvest rice. Land is nominally owned by patrifilial groups (Linares, 1981; Diouf, 1984), but usufruct rights to land lie with the conjugal unit under the direct responsibility of the head of the compound. Women, as a rule, do not own land. However, there are indications that the roles of men and women are reversing in the villages where direct-seeded rice has been adopted (Maoua, Boulom, Boulandor).

Northeast of the River, the Diola of Sindian-Kalounayes (Zone IV) have adopted many aspects of their Manding neighbors' culture, including the Islamic religion. Division of labor in agriculture is by crop along the toposequence. In the lowlands, women grow rice for subsistence; on upland fields men produce groundnuts for cash and coarse cereals for home consumption. Residential units are large; and are often comprised of polygamous households--which are all responsible to the head of the compound who allocates land use. Rice land is owned by patrilineal groups, but unlike in the south, resident female agnates can gain access to rice land through the lending of land by close relatives (Linares, 1981).

Female access to rice land and the existing division of labor in Zones III and IV have facilitated the adoption of both direct and row seeded rice. However, this has slowed intensification of production (use of animal traction, improved seeds and fertilizer) as men give priority to upland fields at the beginning of the season and women do not have access to seasonal credit (Posner *et al*, 1988).

The social organization of production of the Diola in Fogny-Combo to the northwest (Zone V) is an intermediate case between the first two types. As in the southwest, division of labor between men and women is by task. Residential units are large and have the same internal structure as in Zone IV. However, the majority of households within the compound are economically independent (Diouf, 1984). In addition to providing a better understanding of the implications for adoption of improved technologies by men and women, the study of social organization also sought to clarify the concept of a farm. This helped relate farm characteristics (sizes, labor stock and use, incomes, etc) to their real context in each zone.

4.3.2 Labor Profile on Farms

As shown in Figure 7, labor peaks vary as one moves from the southwest (Oussouye, Zone I) to the northeast (Sindian-Kalounayes, Zone IV). These seasonal labor bottlenecks are not only a function of the rainfall distribution, but are also partially determined by existing cropping patterns and the type of technology employed.

Farmers in Oussouye primarily devote their labor to transplanted rice and groundnuts. Peak labor demand is determined by the timing and amount of weeding required by groundnuts in August, as well as ridging and transplanting of rice from late August through September. In Sindian-Kalounayes, maize, millet, sorghum and phreatic rice are cultivated in addition to groundnuts and, to a lesser extent, aquatic rice. This represents the most labor-demanding cropping system in the Lower Casamance (Table 10). Land preparation and planting (direct-seeding rice in the lowlands and plowing upland crops) cause labor bottlenecks, primarily because the timing of these operations is increasingly critical as the growing season becomes shorter as one moves northeast. Although a narrower range of crops are cultivated in Zone V (Fogny-Combo) than in Zone IV, land preparation, planting, and weeding of upland crops (rice and groundnuts in particular) create bottlenecks in June/July and September, respectively. Labor profiles in Zones II and III are similar to those of Zones I and IV, respectively.

Depending on the type of technology introduced, the following labor bottlenecks are likely to arise. First, the adoption of land-saving technology (improved seeds, fertilizer) in Zones IV and V--where animal traction is already used--will shift the labor bottleneck to the time of harvesting. Second, changes in land preparation from hand-plowing to animal traction (labor-saving technology) in Zone I, but retaining other traditional techniques, will shift the labor bottleneck to weeding. Third, although a combination of animal traction (with ridging, planting and weeding equipment) and improved seeds and fertilizer will ease the weeding bottleneck, it may accentuate the harvesting bottleneck. This will create the need to improve post-harvest technology, particularly access to transportation (Norman *et al.*, 1982).

Time allocation between men and women (Table 10) is about equally split in Oussouye (Zone I), but heavily biased toward men (64% vs. 34%) in Sindian-Kalounayes (Zone IV). Any technology likely to alter the time allocation by sex will have significant repercussions on crop output, particularly in Zone IV.

4.3.3 Farm Incomes, Food Grain Balances and Animal Traction Use in Lower Casamance

Differences in farm income are significant between the north and south in the Lower Casamance (Table 11). These differences are primarily attributable to levels of resource endowments. For example, farms are relatively large in Sindian-Kalounayes (Zone IV) and Fogny-Combo (Zone V) because production is organized at the compound level--thus, making it possible to mobilize a much larger work force than in southwestern zones. In addition, animal traction (oxen and moldboard plows) permits farmers to cultivate both larger and more numerous upland fields. In contrast, the majority of farms in Oussouye (Zone I) are organized as nuclear families, which limits manpower availability. Use of traditional manual land preparation techniques also restricts the amount of land farm families can cultivate. Therefore, farms in the Lower Casamance should only be compared on the basis of labor productivity and net incomes per hectare--as shown in Table 11, which compares a dry (1983) and a rainy year (1984). Generally, all income parameters are higher in Zones III, IV and V than in Zone I. Labor productivity ranges from 281 CFA/man-day in Oussouye (1983) to as high as 653 CFA/man-day in Fogny-Combo (1983).

As a direct consequence of the recent drought in the Lower Casamance, households have experienced severe food grain deficits, contrary to the popular view of the region as the grain basket of Senegal. Measured against the FAO standard of 250 kg/per capita/year, grain balances were evaluated in the ten villages monitored by the PSR team between 1982 and 1984. Analysis of the survey data indicated that seven of the ten villages in 1982, all 10 villages in 1983 (dry year) and eight of the ten villages in 1984 experienced cereal deficits at the farm level (Table 12). Furthermore, the average Lower Casamance farmer was a net buyer, rather than a seller of grain (Jolly, Kamuanga *et al.*, 1988).

In villages north of the Casamance River (Zone IV and V) where farmers plant large areas to upland crops and have long used animal traction, farm incomes were highest and food grain deficits lowest. On the other hand, farmers in Oussouye (Zone I) to the southwest, who plant aquatic rice (to the virtual exception of any other crop), earned the lowest incomes and faced the most severe cereals deficits.

Although no in-depth studies were conducted on animal traction, a cross-section comparison of users and non-users in two northern villages showed moderate labor productivity gains by users (Table 13). Cash flow analysis for a sample of users and non-users of animal traction in the same villages indicated positive balances of 93,503 and 65,533 CFA per average farm, respectively, for the two categories (Ndiame, 1986; 1987).

Compared to the Sine Saloum region, animal traction in the Lower Casamance is still in its infancy, with only 17% of farmers owning at least one plowing ox. This distribution is, however, skewed toward the northeast (Zone IV) where more than 60% of the farmers owned oxen and equipment (Fall, 1985). Even within this group, effective traction capacity (measured by the number of traction units, 1 TU = 2 oxen) is still comparatively low. Data indicated that only 6.7% of the oxen users in Zone IV had more than 1.5 TU (Sonko, 1985; 1988). As shown in many studies in West Africa, animal traction is a moderately promising means of improving farm productivity (Barret *et al.*, 1982). To reap its full benefits, the traction package (including fertilizer and improved seeds) must be tailored to meet local farmers' socio-economic conditions. In the Lower Casamance, lack of credit for purchasing oxen and associated equipment has seriously hampered the expansion of animal traction since the national credit program (*Progamme Agricole*) was terminated in 1979.

V. PROGRAM IMPACT, KEY IMPLEMENTATION ISSUES AND IMPLICATIONS

The PSR team interacted with three groups of clients (1) low income farmers, in particular those who collaborated in the experiments, (2) the extension agency--PIDAC, and (3) on-station ISRA researchers at Djibelor. While the program made many positive contributions, the team encountered several methodology and implementation problems in conducting the PSR program. This section reflects on this experience and draws appropriate lessons for the future.

5.1 Contributions of the Djibelor PSR Program

Over the five year period, the team consistently pursued an interactive approach with collaborating farmers. This strategy emphasized adapting improved technologies to farmers' circumstances, while exploiting the system's built-in flexibilities and opportunities to increase production and reduce costs (Posner *et al.*, 1985). The most visible achievement of this approach was the acceptance and adoption of specific technology components by some farmers--as a direct result of their interaction with the PSR team and field assistants.

- o The majority of farmers in Boulandor (Zone IV) began to use mechanical rice seeders for direct seeding of phreatic rice (*riz de nappe*). This operation permitted timely plowing of upland crops by men, freeing time for them to help women in the rice fields.
- o After overcoming their initial reluctance to employ oxen in the standing crop, some collaborating farmers in Medieg (Zone IV) adopted the oxen-drawn moldboard plow for weeding-ridging their maize.
- o Some of the collaborating farmers in Loudia-Ouoloff (Zone I), Maoua (Zone III) and Boulandor (Zone IV) adopted relay cropping of maize/cowpeas and rice/sweet potatoes--as recommended by the PSR team and later extended by PIDAC in 1986.

- Due to the success of the farmer-managed herbicide trials on rice at Maoua, in 1985, members of the women's cooperative agreed to purchase for cash the herbicide that PIDAC has normally supplied through credit.

The PSR's redefining of the zonal classification of the Lower Casamance contributed to increasing the impact of research and extension. There had been previous attempts to delineate the region into homogeneous zones (Kamuanga *et al.*, 1989). For example, SOMIVAC had defined its intervention zones using criteria most relevant to regional development planning, especially with regard to watershed management. The merit of the PSR's zonal classification was that zones were identified as having different potentials and opportunities for research and extension themes--based on knowledge of local production systems. SOMIVAC's later acceptance of the PSR zones represented an important step towards closing the research-extension gap in the Casamance (Bingen and Faye, 1987). It also reflected the importance SOMIVAC had begun to give incorporation of socio-economic criteria in its planning. Furthermore, the PSR team was instrumental in implementing the ISRA/SOMIVAC research-extension protocol[17].

The PSR team contributed to legitimizing interdisciplinary research by working closely with thematic researchers, first during the exploratory phase in 1982 and throughout the project's life. Many factors contributed to this success. First, the team actively initiated open discussions which cleared misperceptions held by on-station researchers about the objectives and methodology of PSR.

Second, clarification of the role that the PSR program could play in the diffusion of improved varieties helped reinforce interaction between programs (Posner *et al.*, 1990). In fact, the PSR network of ten villages across the Lower Casamance were used as pre-extension sites for rice varieties that proved successful in breeder's plots and in multi-locational trials. Rice researchers found the PSR program offered an opportunity to leave the PAPEM for farmers' fields, thus extending the variety evaluation process to its last stage in the station-PAPEM-pre-extension site continuum (*évaluation système*).

Third, thematic researchers agreed to devote some of their time to the problems raised by the PSR team, thereby increasing the impact of adaptive research. For example, the weed control specialist moved from his initial single-focused concern with chemical control of weeds which affect rice to a broad based examination of how the different land preparation techniques practiced by

[17]See Bingen and Faye (1987) for a detailed discussion of issues in the implementation of the ISRA/SOMIVAC protocol of agreement.

farmers can control weed growth more effectively and less expensively. The plant protection program also broadened its scope to include crops other than rice, such as cassava and vegetables.

The rice entomology program was deemphasized after region-wide survey results indicated that insect damage to rice was below economic threshold levels. Traditionally, priority in rice improvement had been given to selecting high-yielding cultivars that performed well under high management. In response to the findings of the PSR program, breeders gave increased attention to developing low-input (i.e. fertilizer) rice varieties. This indicated a recognition of the necessity to minimize farmers' risks (Kamuanga, 1986). In addition to their impact on rice research, the team's efforts also contributed to the establishment of the Bolong (watershed management) program within the PSR Department (ISRA, 1984).

Finally, the most notable impact of the PSR program was its contribution to highlighting the importance of rainfed, upland crops in Lower Casamance production systems (50-85% of cropped area per farm), showing that rice was only a component of the overall system. This sparked subsequent collaboration with the CNRA/Bambey commodity programs (maize, millet, sorghum, groundnuts and vegetables), and motivated several Bambey researchers to initiate collaborative research at Djibelor. The station itself changed its name from the Center for Rice Research (CRR) to the Center for Agricultural Research (CRA) in 1984 in recognition of the important refocusing of research activities from rice to upland crops and livestock. Accompanying this name change was acquisition of a 40 ha upland site near Djibelor for research on rainfed crops.

5.2 Key Issues in the Implementation of PSR in the Lower Casamance

The Djibelor PSR experience provides several lessons that are relevant to researchers implementing on-farm research in national research programs in other developing countries.

5.2.1 On-Farm Research: The PSR Approach and the Franco-Senegalese Tradition

The concern with conducting research in the rural setting has been a key element in Senegal's research strategy for over 20 years (Bingen and Faye, 1987). ISRA's launching of the UE project (1969-1981) marked an important initial phase in the evolution of agricultural research in Senegal. The UE approach represented a slightly modified version of the transfer of technology or diffusion model (Chambers and Ghildyal, 1985) that is based on the premise that improved technology bears the imprint of the research station conditions in which it is generated. If transferred to a local agricultural system where conditions are different, it "stirs" the environment to allow researchers to assess the parameters which govern the direction and the pace of possible change (Reboul, 1972; Faye, 1978).

The Djibelor PSR methodology, on the other hand, was adapted from the approach promoted primarily by some of the International Agricultural Research Centers (IARC), most notably CIMMYT, IRRI and CIP (the so-called Anglophone School) (IARC, 1987). This model asserts that research should begin with an understanding of local farming systems and constraints in order to develop production technologies that are adapted to the conditions and needs of farmers. Research stations have only a referral and consulting role in this process (Byerlee, Collinson *et al*, 1980; Chambers and Ghildyal, 1985).

This shift in the research approach brought criticisms from thematic researchers on two main points. First, the informal survey phase--which represented a fundamental change in orientation from the UE diffusion model--was regarded with "raised eyebrows" by many within ISRA and criticized as an attempt by the PSR team to "rediscover the wheel" in a country with nearly 50 years of research results. However, the team believes that the success of the program was largely due to the role of and method by which exploratory surveys were conducted, since research priorities identified in early 1982 gave consistency and substance to the program throughout its duration.

Second, farmer-managed trials in the first year were initially considered to lack scientific rigor, mainly because the rationale underlying the design and implementation of on-farm trials was not well understood by on-station researchers. It took several years to demonstrate that testing at the farm level provided a realistic environment for evaluating the potential suitability of proposed improved technologies and techniques, and, thus, increased the probability of farmers' adoption (Zandstra, 1979).

To counterbalance the perceived "Anglophone" approach being implemented at Djibelor, the Department's Central Analysis Group (GCAS) influenced the research design and conduct of the PSR teams at Kaolack (Peanut Basin) and St. Louis (Fleuve region). Emphasis was placed on conservation of ecosystems, the trajectory of farmers, use of surveys and cluster analysis.

This long term view, which called for research to focus on the landscape, village and small region (rather than the farm) as appropriate levels of investigations, was logically defensible (Faye and Bingen, 1989). However, acceptance of this view would have overwhelmed the Djibelor team's limited resources and expertise, because it implied implementing a new and large-scale research methodology. Moreover, the CGAS never seriously considered the challenge that the PSR team would face in synthesizing the results of the various studies (to be undertaken at different levels of observation) into a meaningful whole suitable for policy recommendation.

5.2.2 Farmer-Managed Trials, Replications and Timing of Surveys

Both researcher-managed trials (RMT) and farmer-managed trials (FMT) were conducted. The former involved greater management input from agronomists and were conducted at the Djibelor station using standard experimental designs. Indeed, 25% of all the program's trials and tests were RMT. FMTs, on the other hand, involved treatments that were less complex. Emphasis was placed on conducting trials to permit the PSR team to examine the rationale behind farmers' behavior and assess the suitability of the tests to their circumstances. Most tests simply compared local techniques with recommended practices (for instance, ridging vs. flat-plowing). The trials were generally conducted on 500-600 m^2 plots and occasionally on larger plots (1000 m^2) for demonstration purposes.

A critical issue that was continuously debated between agronomists and economists concerned the number of replications per trial/test and the plot size. Although there was agreement that plot size should be large enough (>500 m^2) to collect meaningful labor data, the number of replications had to be decided in accordance with criteria for statistical analysis. As Bernsten (1985) notes, the number of replications required to identify statistically significant differences between farmers' existing and new technology depends on the stability of the technology across environments and the yield increasing potential of the intervention. The team finally settled on two treatments per test and as many as five farmers, replicating the design in each village.

Equally important was the question of the representativeness of collaborating farmers. The choice was between selecting more cooperative farmers to maximize the chance of obtaining accurate data and farmer insights, or a large number of farmers to ensure representativeness. The team decided it was necessary to use both categories of farmers, depending on the stage within the testing phase. Just as on-station researchers control the environment to assess the technical feasibility of a trial, it is appropriate to use cooperativeness as a criterion for selecting farmer participants in FMTs--which are designed to assess the suitability of an intervention to farmers' circumstances and to learn about the pace at which change might take place. Yet later, after suitability is ensured (i.e. testing phase), it is necessary to diversify the sample of collaborating farmers to insure representativeness.

Farming systems research, in its various manifestations, is typically described in terms of sequential stages (Norman, 1978; Shaner *et al.*, 1982). In practice, these steps are iterative and activities associated with each phase can be undertaken simultaneously. Thus, in the Djibelor PSR program, verification surveys and on-farm (exploratory) trials were run concurrently during the first year (1982). This synthetic approach, used in PSR programs throughout West Africa (see Purdue University/IPIA, 1986) had the advantages of simultaneously (1) generating information on farmers' resource base and constraints; and knowledge of the agricultural calendar necessary to examine the potential contribution of proposed improved technologies in a whole farm context, and (2) allowing the team to move rapidly through the screening process, rejecting obviously incompatible technology components.

5.2.3 Interdisciplinary Team Work: Concept and Reality

PSR accepts the premise that a truly interdisciplinary output will emerge through the collaboration of many disciplines. To be successful, the team must establish a "common view" early in the program which permeates and guides the research effort (Rossini *et al.*, 1978; Flinn and Denning, 1982).

Except for the senior agronomist, none of the Djibelor team members had prior interdisciplinary experience. Thus, several problems arose in attempting to forge a team spirit. Initially, the research was managed by one agronomist and two agricultural economists. For a team of three with only two disciplines represented, it was fairly easy to develop a "common view". Although many factors limited agricultural production in the Lower Casamance[18], the team agreed that increasing crop production was the key problem in the region that researchers at ISRA were equipped to tackle. Within two years, following interaction with the GCAS, the scope of the research was expanded in response to the need to better understand farmers' problems, including their social situation. Reinforcements arrived: a sociologist and counterpart agronomist in 1983, an agricultural engineer and animal scientist in 1984, and a second counterpart economist in 1985. As the team grew in size and scope it encountered the dual problems of integrating new disciplines into the research team and orienting the new researchers to the research approach/issues so they could contribute to the program.

In order to resolve these problems, each new member was hired on probation (of up to one year) and required to write a confirmation thesis (*mémoire*) on an issue perceived to be important

[18]The primary constraint was the loss of nearly 2/3 of the arable low-lying rice land due to reduced rainfall. Other constraints included the lack of marketing infrastructure for domestic cereals, low producer prices for cereals and consumption habits. However, production constraints are believed to have caused much of the stagnation of agricultural production in the Lower Casamance.

by senior team members[19]. Subsequent publications by new team members also addressed questions that were developed from the original "common view".

Occasionally, friction and disagreement occurred among team members and at times between the PSR team and the Department's GCAS. First, disciplinary differences of opinion surfaced since each discipline had its own sampling procedures, analytical tools and philosophical attitudes towards research[20]. Second, as the research agenda widened to include livestock systems, off-farm activities and farmers' organizations, the project fell into the trap of overinvesting in data collection--a problem that many survey-based research projects have faced (Byerlee and Tripp, 1981; Purdue University/IPIA, 1986). To reduce data collection, the project attempted to create a permanent panel of farmers for multi-year data collection (Faye, 1984; Vincent, 1984). This option did not work for several reasons; including the inherent difficulty of handling a large data file since each discipline believed that its choice of what variables to include was non-negotiable. Nevertheless, the Djibelor team was able to avoid some of the problems inherent in interdisciplinary work through constant effort such as frequently exchanging views, discussing research strategy and revising the program as necessary. Working in the same villages, addressing similar questions and learning each other's disciplinary jargon and concepts not only led to improved problem definition, but also helped to forge team spirit.

Over time, each team member began to realize the limitation of his discipline in solving farmers' problems and appreciate the need to generate a truly interdisciplinary research output. Despite the problems noted above, research integration was achieved, especially in interpreting research results--as shown by the team report on farmers' strategies in response to drought (Posner et al., 1985). The Djibelor experience suggests that effective interdisciplinary research results mainly from longevity in the field, rather than through formal training--provided there is a willingness to overcome problems.

5.2.4 Running PSR in Casamance: Costs and Logistics

Few studies accurately document the cost of conducting farming systems research. McIntire's (1984) comparison of extensive and intensive survey costs did not include the cost of

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[19] All the *mémoires* produced under the program are included in the list of references.

[20] For example, to include farms with special characteristics, the animal scientist and the agricultural machinery specialist consistently favored purposive sampling over the random sampling favored by economists.

running experiments. Rapid appraisal procedures for diagnosing farmers' constraints prior to technology development (see Collinson, 1980; 1982) have sometimes been misinterpreted as a cost effective way of implementing all sequences of PSR.

Table 14 estimates the total cost of the Djibelor program, based on the 1984 season, which was a normal year of operation[21]. Annual capital costs represented only 7% of total cost. The recurrent costs of the international staff (salaries and fringe benefits) represented one-half of the total cost of operation. Research costs per household, including both surveys and on-farm experiments, amounted to $1,769--compared to the $1,060 per household estimated by McIntire (1984) for survey research in Burkina Faso and Niger. Research expenditures of these magnitudes should dispel the notion that farming systems research is cheaper than earlier "transfer of technology" approaches or thematic research in general. When the focus goes beyond one or two leading crops--as with the CIMMYT approach--and complex improvements requiring simultaneous changes in several parts of the system are investigated, the total cost per household of conducting PSR may turn out to be unexpectedly expensive.

Greater cost effectiveness can be achieved by (1) reducing the number of international staff in PSR projects through increased participation of national scientists, (2) increasing the size of the target population, and (3) sharing research expenditures with the development agency in charge of extension. The success of the Djibelor experience can be measured by either the number of farmer-managed trials which led to effective adoption of improved technologies or the number of successful research themes taken over and extended by PIDAC after 1986 (see Section IV).

The Djibelor PSR program was not without administrative and logistical problems. Although the program received substantial on-campus support from Michigan State University that helped alleviate many bottlenecks (gasoline, office supplies and access to an imprest fund), administrative hurdles at the station often made it difficult to carry out surveys and experiments. These difficulties partly arose from legal structures that limited the station director's jurisdiction and constrained the PSR Department's ability to control and allocate financial resources, even when funds were available. Procedures in the disbursement of Title III funds complicated matters even further. In some years, the program was able to spend only 40-50% of its allocated budget. Field assistants and contractual laborers sometimes were not paid for several months, though this was in part alleviated

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[21]In 1984, the PSR program was able to spend 82% of the ear-marked annual budget and the research staff was the largest of any year.

by withdrawals from the MSU imprest account. In 1987 Senegal's structural adjustment program required ISRA to dismiss all contractual agents in the PSR program.

5.3 Policy Issues

Relevant policy issues with regard to PSR development in Senegal (i.e., research-development interface, conceptualization and implementation of PSR in Senegal, manpower development) have been discussed in some detail elsewhere (Bingen and Faye, 1987; ISRA, 1984; Faye et al., 1986; Faye and Bingen, 1989). This section raises three issues that had a major impact on the Djibelor experience in order to guide future PSR development in the Casamance.

5.3.1 Need for a Long Term Research Strategy Planning

At the end of the exploratory survey phase that defined research priorities, the Djibelor team failed to develop a three to five year program. Instead, research activities were planned at the beginning of each season, building on the previous year's results which--very often--were not fully analyzed. Developing a three to five year research agenda, with specific yearly objectives and means to achieve them, would have helped the team to measure its own accomplishments against planned objectives. In addition, this would have ensured the gradual integration of the livestock and agro-forestry subprograms that were not initially envisaged in early 1982; but which, nevertheless, were expected to be included in the future. Research on agro-forestry began in 1983 and evolved into a separate program under ISRA's Center for Forestry Research (CNRF), despite the close proximity of the PSR and CNRF research offices in Djibelor.

5.3.2 The Composition of PSR Teams

As a corollary to the establishment of a long term research agenda from the start, the composition of the PSR team should have been decided taking the agro-ecological setting, the major problems faced by farmers and environmental constraints into account. In the case of the Lower Casamance, a core team comprised of an agronomist, economist, and animal scientist was necessary to tackle the key problems of increasing crop and animal production. To gain an in-depth understanding, the social dimension of these problems needed to be explored. Indeed, sociological studies contributed a great deal to the team's understanding of the social organization of production and the varying capacities of different family members to both gain access to resources and assimilate improved technologies. However, creation of a full-time sociologist position led to an imbalance in team composition in favor of social scientists. The pursuit of disciplinary investigations were of little relevance to the research goal as initially planned.

By the end of 1985, with a full team of seven researchers representing five disciplines (agronomy, economics, sociology, animal science and agricultural mechanization), the PSR work in the Casamance was running the risk of being a mile long and an inch deep.

5.3.3 Training of Counterparts

Long and short term training of nationals was both a key component and an important success of the Senegal Agricultural Research and Planning Project (SARPP). By 1985, more than 20 ISRA researchers in several fields were preparing Master's degrees at ten different U.S. universities.

The Djibelor experience is instructive in that Senegalese counterparts were assigned to the program from its beginning. Others joined the team as they returned from training in time to be included in on-going program activities. The required writing of confirmation *mémoires* on topical issues relevant to the program was an interesting example of on-the-job training. When the contracts of expatriates terminated, there was a competent national team ready to take over project activities--despite a reduction in the operations budget.

IV. CONCLUSION

The organization and implementation of Production Systems Research at the ISRA/Djibelor Center since 1982 has presented an opportunity to reinforce the linkages between on-farm and thematic/disciplinary research, as well as between research workers and development agents in the Lower Casamance.

The research focus on farming households increased the probability of developing improved systems that address the constraints faced by households. At the same time, the study of the social organization of production identified the key interlocutors (contacts) in promoting the adoption of improved technologies for rice, coarse grains, and groundnuts in each agricultural zone.

Among the major contributions of the Djibelor PSR program were (1) SOMIVAC's acceptance of the agricultural zones delineated by the Djibelor team as the framework within which development and extension themes should be conceptualized, (2) a renewed spirit of research relevance as a result of gradual interaction with on-station programs, and (3) a direct acceptance by some farmers in the Oussouye (Zone I) and Niaguis (Zone III) zones of the team's recommendation to increase total production by relaying sweet potatoes on short-cycle improved rice varieties. As a result, links with PSR clients--the extension agency, thematic researchers at Djibelor and farmers--have been reinforced, thus creating the conditions for continuing research that is relevant to Lower Casamance farmers. The Djibelor experience also demonstrates that it is possible for PSR to work effectively as part of a broader research and extension system, and not simply as a hand-maiden of thematic and disciplinary research.

Conducting interdisciplinary research was a major challenge for the Djibelor team. Although every scientist benefitted greatly from the experience, it appears that interdisciplinary maturity and effective research planning and implementation arose mainly through open interchange of ideas, mutual support and cooperation, and longevity in the field.

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ANNEX 1

36a

Table 1. Land Use Distribution and Utilization in the Lower Casamance, Senegal.

		Administrative Departments (Percent of Area)			
Topographical Position	Land Use	Bignona	Ziguinchor	Oussouye	Lower Casamance Province
Dryland					
	Forest	30	33	15	29
	Savanna	8	7	10	8
	Upland cropping and fallows	24	23	8	22
	(Subtotal)	(62)	(63)	(33)	(59)
Wetland					
	Arable low land inundated	13	20	22	15
	Mangrove swamps	18	9	28	18
	Surface water	7	8	17	8
	(Subtotal)	(38)	(37)	(67)	(41)
Total land area (ha)		529,500	115,300	89,400	734,200

Source: SOMIVAC, 1978; HARZA, 1984.

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Table 2. Production System Research Phases and Activities, Lower Casamance, Senegal, 1982-83 thru 1985-86[a]

Year/Season	Phases and Activities	Instruments	Output/Objectives	Participants and Collaborating Institutions
Year 1: 1982-83	PRE-DIAGNOSIS			
(off-season)	1. Studies of existing farming practices and body of knowledge	- Exploratory/informal surveys - Contacts with development/extension agencies - Discussions with thematic researchers - Literature review (agronomic and socioeconomic studies)	- Farm level constraints identified - Development and extension priorities considered - Criteria for and delineation of farming systems zones - Identification of suitable technical alternatives	- PSR team, thematic researchers - SOMIVAC officials - PIDAC officials; farmers - Extension agents
(off-season)	2. Site selection and sampling of participating farmers.			- PSR team, ISRA - Extension agents
(cropping season)	3. Testing improved technologies	- Indicative on-farm trials - On-station agronomic trials	- Alternative technology potentials assessed. - Agro-economic parameters of farming systems zones derived. - Information on farmers' practices	- PSR team - Field assistant; farmers
(cropping season)	4. Characterization of major farming systems	- Verification (baseline) surveys - Survey of agricultural practices	- First year results made available to ISRA, SOMIVAC.	- PSR team, ISRA
Year 2: 1983-84				
(cropping season)	5. Testing/Screening improved technologies	- Indicative and on-farm verification trials at operational scale (researcher/farmer managed).	- Indicative results of technology evaluation at farm level. - Feedback from farmers	- PSR team ISRA - Field assistants - Extension personnel
(year around)	6. Study of the dynamics of farming systems.	- Sociological surveys	- Input-output coefficients for crop enterprises derived. - Knowledge of rules governing resource allocation; migration determinants; land tenure aspects.	
	7. Livestock systems and mechanization research (Prediagnostic and diagnostic)		- Typology and livestock systems.	- PSR team, ISRA
Year 3: 1984-85				
(cropping season)	8. Testing/screening of selected technologies	- Farmer managed trials, (replications) Verification trials	- Promising technologies screened (early maturing, salt tolerant rice varieties, sweet potatoes in relay cropping etc.) - Suggestion to extension agency of viable technical packages.	- PSR team, ISRA - Farmers - Extension
(off-season)	9. Evaluation of technologies	- On-farm visits/addition informal surveys.	- Knowledge of herd management systems.	- PSR team, ISRA - Farmers
	10. (Dynamics of livestock systems)	- Following up of herd conduct and management		
Year 4: 1985-86				
(cropping season)	11. Testing/pre-extension of some technologies	- More replication for selected technologies on-farm. - Adoption surveys - Special focus studies - Statistical analysis of agronomic surveys	- Recommendation for rice technology proposed - Recommendation for upland crops being considered - Additional studies proposed	- PSR Team - Field assistant - Extension personnel
(off-season)	12. Critical review of research results to date			
	13. (Animal/crop interaction investigation)	- (Surveys on animal traction, manure utilization and experiments)	- (Animal cropping system interface and parameters derived)	

[a]The ordering of research phases follows the implementation of activities regarding cropping systems. Livestock systems and agricultural mechanization subprograms introduced since 1983-84 followed the same sequence of phases with a time lag.

Table 3. Characterization of Agricultural Zones in the Lower Casamance, Senegal.

	Agricultural Situation (Zone)				
	I Oussouye	II Blouf	III Niaguis	IV Sindian-Kalounayes	V Fogny-Combo
Classification criteria					
Division of labor[a]	A	A	B	B	A
Use of animal traction for land preparation	no	no	very little	yes	yes
Importance of aquatic rice vs. upland cereals	very large	large	small	very small	small
Tool used in manual land preparation for lowland rice	*cajendo*[b]	*cajendo*	*fanting*[c]	*fanting*	*fanting/cajendo*
Major problems/constraints	o Loss of low lying rice land (salt intrusion) o Cereal deficit o Lack of improved rice varieties o Labor shortage	o Substantial loss of low lying rice land o Cereal deficit o No improved technique for land preparation of upland crop o No improved rice varieties o Severe labor shortage due to migration	o Farm equipment needs o Weeds infestation for rice o Upper toposequence too dry for rice o Soil acidity in available rice land o Labor shortage	o Need for more farm equipment credit o Modern inputs (fertilizer and variety) not used on upland crops o Soil fertility (plateau) o Labor shortage	o Loss of rice land (salt intrusion) o Need for more farm equipment credit o Modern inputs not used o Labor shortage

[a] A indicates men and women work on upland crops and in lowland rice cultivation (division of labor by task).
B indicates men work on plateau crops and women cultivate rice (division of labor by crop).
[b] Traditional Diola tool for constructing ridges.
[c] Traditional Manding tool for plowing on flat land.

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Table 4. Population Characteristics in the Production Systems Research Sample, Lower Casamance 1982 and 1985.

Zone	Villages	Total Number of: People	Compounds	Households	Compounds in Sample	Size of the Sample[c] Households 1982	Farms 1985	Number of Plots Monitored 1982	Average Size of Work Force (in Man Equiv.) Household/Farm 1982
I	Loudia-Ouoloff	306	38	43	15	17	15	60	5
	Boukitingo	482	83	85	10	16	15	75	4
	Seleky[b] (1985)	1108	205	205	NA		20	NA	3
	Mahamouda[a]	282	31	32	10	20	NA	59	4
II	Tendimane	956	36	109	10	38	27	126	4
	Mangagoulak[a]	956	36	44	15	30	NA	199	3
III	Boulom[a]	696	57	69	10	18	NA	119	6
	Maoua	246	25	27	15	24	14	127	7
IV	Boulandor	427	23	24	10	28	6	190	6
	Medieg[a]	1122	72	148	15	22	NA	222	6
	Toukara[b] 1985	271	14	32	NA	NA	8	NA	5
V	Bandjikaki	623	57	72	15	22	13	121	6
	Suel[b] (1983)	1078	83	172	NA	NA	17	NA	5
Total		6096	458	683	125	235	135	1298	4.9

[a]Mangagoulak was later dropped as it was judged to be misrepresentative of the zone; Mahamouda, Boulom and Medieg were phased out in 1985 for cost effectiveness.
[b]Suel was added to Zone V in 1983 as a replacement for Tendimane (absence of animal traction); Seleky and Toukara were selected in 1985 to represent strictly upland and lowland rice cropping systems, respectively.
[c]The relationship between household and farm was not well defined in 1982. Data was subsequently collected for each household.

NA indicates the village was not included in the sample when the respective data was collected.

Source: Production System Research Surveys.

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Table 5. Classification of Research Sites by Production System and Availability of Land and Cultivation Technique, Lower Casamance Senegal

	Social Organization of Production			
	Diola System		Manding System	
Availability of Cultivable Land	Hand Cultivation	Animal Traction	Hand Cultivation	Animal Traction
Low-lying rice land only	Seleky			
Low-lying rice land and plateau fields	Tendimane Loudia-Ol. Boukitingo	Bandjikaki Suel	Maoua	Boulandor
Plateau land only				Toukara
Corresponding zone	I,II	V	III	IV

Source: Production System Research Surveys.

Best Available Document

Table 6. On-Farm Experiments,[a] Lower Casamance, Senegal, 1982-86.

	Upland (Plateau Crops)		
Crop	Type of Trial	Phreatic (Water Table) Zone (Direct Seeded Rice)	Low-lying Inland Valleys (Aquatic Rice)
Rice	Tests of varieties[b] adapted to rainfed conditions (I)	Rice varieties[h] for temporary flooded conditions (I)	Yield loss profile[k] on rice.
Cowpeas	Variety evaluation[c] Variety x date of planting (II) in June-July in pure stand or association with groundnut or maize: in September planted in maize stubble Fertilizer in pure stand	Fertilizer on phreactic rice[i] (I) Land preparation: manual (*cajendo*) ridges versus flat plowing. Land preparation: manual versus oxen plowing on direct-seeded rice (tests of row-seeder) (I).	Tests of 4 rice varieties[l] for flooded conditions (I) Tests of abandoned rice land[m] from salt intrusion; use of drain plowing techniques and anti-salt dam (III)
Maize	Land preparation and mechanical weeding (I) animal traction Fertilizer at 1/2 recommended dose[d] (I).	Tests of oxen-drawn pin-wheel rice weeder (I). Herbicide[j] x tests on rice.	Tests of relay cropping for sweet potatoes, cowpeas, maize and millet[n] (IV)
Millet	Variety[e] x date of planting (II) Plowing + mechanical weeding (I)		
Sorghum	Variety[f] x date of planting (II) and fertilizer.		
Groundnuts	Mechanical weeding (I, II) Fertilizer[g] x variety		

[a]Each experiment is associated with the research theme under consideration: I = intensification of production on good land, II = diversification of the cropping system, III = rehabilitation of abandoned productive land, and IV = relay cropping and harvesting residual moisture.
[b]DJ-8-341, 144 B/9: and IRAT 112.
[c]Mougne, Ndiambour; 58-57; N66-16; trials at 8 sites, treated against thrips. Variety 58-57 in farmer-managed trials at operational scale.
[d]Variety ZM10 at 200 kg/ha 8:18:27; also non-fertilized vs 120 kg/ha urea in farmer-managed trials at operational scale.
[e]Variety 8001, 8004, H7-66, Souna III, Sanio Sefa.
[f]Variety V2, V3, V6, V9, V10, 51-59, Congosane; fertilizer at 100 kg/ha urea (1982-85).
[g]Variety 69-101; non-fertilized vs increasing doses 75, 150 kg/ha 8:18:27 + 200 kg/ha line.
[h]IRAT 112, IRAT 133, DJ 12-519 and IKP.
[i]Manure versus 1/2 and full level of recommended doses (200 kg/ha urea + 200 kg/ha 10:10:20 + 400 kg/ha of natural phosphate).
[j]Using Ronstar CE 250 at a cost of 3500 CFA/litre.
[k]In collaboration with entomologist and pathologist.
[l]IR 1529, BR 51-46-5; DJ-684 D, IKP.
[m]Research theme later taken over by the watershed management team (1984).
[n]Short cycle varieties of maize (composite 77: 75 days), millet (IVS 5454: 75 days), cowpea (Ndiambour 65 days), sweet potatoes (Ndargu, 120 days).

Table 7. Results of Farmer-Managed (Rice) Trials at Operational Scale,[a] Lower Casamance, Senegal, 1983-85.

		Number of Trials:			Comparison with Traditional Variety[c]			Yields (kg/ha)	
Varieties	Total No.	Abandoned (No.)	Yielding[b] 500 kg/ha (No.)	Analyzed (No.)	Better	Equal	Mediocre	Improved Variety	Traditional (Local) Variety
Phreatic Rice									
DJ-12-519	18	3	3	12	8	4	0	2068	1443
IRAT 133	13	0	1	12	5	5	2	1761	1408
IRAT 112	18	5	0	13	3	3	7	844	1025
144 B/9	22	12	1	9	3	2	4	1066	1203
SENICOLY	13	2	1	10	7	3	0	2036	1010
TOTAL	84	22	6	56	26	17	13	1551[d]	1204[d]
Aquatic Rice									
IR-1529	8	3	0	5	0	2	3	637	939
BR-51-46	6	0	2	4	3	0	1	834	663
DJ-684 D	11	1	2	8	4	1	3	1897	1463
ROK 5	8	1	1	6	4	0	2	2288	1647
SENICOLY	9	1	0	8	3	0	5	1136	1373
TOTAL	42	6	5	31	14	3	14	1362[d]	1288[d]

[a]500 m^2 for phreatic rice and 300 m^2 for aquatic rice.
[b]Number of tests (improved and traditional variety) with yields below the acceptable minimum of 500 kg/ha.
[c]Characterization of number of tests conducted: Better if the improved variety outyielded the traditional by at least 20%. Mediocre if the yield of the improved variety is below 20%, and Equal if the yield of the improved variety is between - 20% and + 20% of the traditional variety yield.
[d]Weighted average.

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Table 8. Yields of Marketable Sweet Potatoes From On-Farm Relay Cropping Trials, Lower Casamance, Senegal, 1983-84 Through 1985-86.

	Maoua			Loudia-Ouoloff (1)		
Year	Trials (No.)	Trans-planted[a]	Yield (kg/ha)	Trials (No.)	Trans-planted[a]	Yield (kg/ha)
1983-84	4	Oct. 11	2,478	4	Feb. 3	4,201
1984-85	5	Oct. 22	2,559	5	Feb. 5	5,000
1985-86	9	Oct. 20	2,535	[b]	[b]	[b]

[a]Average date of transplanting.
[b]Six on-farm tests conducted at Loudia-Ouoloff in 1985/86 season were not properly tended, so yield data were not available.

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Table 9. Major Production Systems Research Surveys Conducted in the Lower Casamance, Senegal, 1982-1986

Type	Disciplines Involved	Duration	Unit of Observation and Sample Size	AGRICULTURAL ZONES (villages) I			II		III		IV			V		Output and Observations
				Loudia-Ouoloff	Boukitingo	Mahamouda	Mangagoulak	Tendimane	Maoua	Boulom	Medieg	Boulandor	Toukara	Bandjikaki	Suel	
Exploratory Survey	Economists, Agronomists, Plant Breeder & Entomologist	Feb-May 1982	35 Villages	x	x	x	x	x	x	x	x	x		x		Production constraints and research themes identified
Household Census	Economists	June 1982	10 Villages	x	x	x	x	x	x	x	x	x		x		Description, analysis; drawing of master sample.
Agronomic Surveys	Agronomists and Economists	June-Dec. 1982; and June-Dec. 1983	1,298 Plots 150 Farms	x	x	x	x	x	x	x	x	x		x		Description of farmers' ag. practices, crop calendar and resources; quantification of environmental variables.
Economics of Farm Production	Economists	June-Dec. 1983; and June-Dec. 1984	30 Farms	x	x	x	x	x	x	x	x	x		x	x	Input/output coefficients; structural typology of farms.
Off-farm Activities	Economists and Sociologist	June 1983 - May 1984; & June 1984 - May 1985	150 Farms	x	x	x	x	x	x	x	x	x	x	x	x	Contribution of off-farm income to family earnings; resource use in off-farm activities.
Sociological Studies	Sociologist	1983-84		x	x			x	x	x	x	x	x	x	x	Land tenure, migration, social organization of production; adoption of new technologies.
Animal Traction, Farm Equipment	Machinery Expert and Economist	1984-85	150 Farms								x	x	x	x	x	Equipment inventory, use and performance. Comparison of animal users vs. non-users. Technology evaluation.
Livestock Management Systems and Typology	Animal Scientist	1984-85	37 Villages	x	x	x	x	x	x	x	x	x	x	x	x	Systems description, cattle management; new criteria for zoning the Lower Casamance.
In-depth Agronomic Survey	Agronomists, Economists	1985-86	35 Farms	x	x	x	x	x	x	x	x	x	x	x	x	Estimates of variables directly affecting yields.
Special Focus Surveys - agricultural credit - fertilizer & improved seed adoption - upland rice constraints - technical & economic analysis of anti-salt dams	Agronomists, Economists Animal Scientists Machinery Expert	1985-86	Variable	x	x	x	x	x	x	x	x	x	x	x	x	Better knowledge of technical and socio-economic factors affecting adoption of improved techniques; feedback from farmers to thematic research.

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Table 10. Total Labor Use by Cropping Enterprise for Representative Farms in Three Selected Zones, Lower Casamance, Senegal, 1983-84 and 1984-85.

Zone[a]	Main Crops	Area Planted[b] (ha)	Labor[b] (hours)	Time Allocation by Sex (%) Female	Male
I.	Aquatic rice	0.79	898	61	39
	Upland rice	0.13	319	90	10
	Groundnut/cowpea or Groundnut/rice	0.76	385	40	60
	Sweet potato	0.10	62	51	49
	Total	1.78	1,664	61	39
IV.	Aquatic rice	0.09	97	90	10
	Phreatic rice	0.92	1,351	95	5
	Maize; Maize/cowpea	0.74	254	2	98
	Millet/sorghum	1.03	260	12	88
	Groundnut/millet or groundnut/sorghum	3.33	2,032	10	90
	Total	6.11	3,994	43	57
V.	Aquatic rice	0.31	159	90	10
	Phreatic rice	0.29	267	96	4
	Upland rice	0.30	180	82	18
	Groundnut or groundnut/millet maize	2.56	1,817	14	86
	Millet	0.27	192	15	85
	Total	3.73	2,615	36	64

[a]Cropping patterns and labor use in Zones II and III are similar to those of Zones I and IV, respectively.
[b]Average values for 1983-84 and 1984-85 seasons.

Source: ISRA/Département Systèmes, 1985a; 1985b.

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Table 11. Farm Budgets and Income (FCFA)[a] in the Surveyed Area[b] for a Drought (1983) and a Rainy Year (1984), Lower Casamance, Senegal.

	OUSSOUYE I		BLOUF II		NIAGUIS III		SINDIAN-KALOUNAYES IV		FOGNY-COMBO V	
Indicator	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984[c]
Farm area (ha)	1.77	1.78	2.1	2.58	2.98	3.66	5.34	7.17	4.12	3.98
Total labor used (man-day ha)	132	145	91	99	72	100	100	108	93	84
Value of production	72,717	98,422	98,273	138,376	150,270	215,505	298,916	506,,262	270,952	197,450
Cost of production	6,997	5,907	9,360	10,233	22,560	33,038	35,100	29,662	20,683	10,680
Net farm income	65,720	92,515	88,911	128,143	127,710	183,476	263,816	476,600	250,269	135,930
Income per ha	37,130	51,948	42,338	49,668	56,278	49,857	49,404	66,471	60,745	34,153
Income per man-day	281	358	468	502	597	499	494	615	653	406
Income per man equivalent	16,029	33,041	22,228	30,510	32,252	28,964	37,688	43,327	52,139	26,653

[a]US $1.00 equals 350 FCFA.
[b]Average budget for representative farms.
[c]In 1984 drought was severe in this zone (Bandjikaki).

Table 12. Cereals Availability at the Farm Level (kg/consumption unit), Lower Casamance, Senegal, 1982-83 Through 1984-85[a].

Zone	Village	1982-83	1983-84	1984-85
I.	Loudia-Ouoloff	95.7	63.7	172.3
	Boukitingo	92.1	59.6	115.6
II.	Mahamouda	30.4	14.2	33.3
	Tendimane	90.5	35.9	147.5
III.	Maoua	82.4	111.4	86.8
	Boulom	268.6	106.8	102.9
IV.	Medieg	264.9	103.1	382.1
	Boulandor	180.4	67.6	244.8
V.	Bandjikaki	183.7	168.6	40.8
	Suel	NA	150.3	116.0
	Average	143.2	88.1	144.2

[a]The following conversion coefficients were used to calculate the number of consumption units per farm family: pre-schoolage children: 0.25; 5-14 years: 0.50; and adults:1.0. The surplus (deficit) was measured against the FAO standard consumption rate of 250kg per capita.

NA indicates data not available.

Source: PSR Surveys.

Table 13. Farm Characteristics and Budget Comparison (FCFA)[a] of Animal Traction Users and Non-Users, Northern Casamance, Senegal, 1984

	Zone IV (Sindian-Kalounayes)		Zone V (Fogny-Combo)	
Indicator	Animal Traction	Manual Cultivation	Animal Traction	Manual Cultivation
Average farm size (ha)	5.23	3.90	4.48	3.23
Available manpower (man-equivalent)	7.3	5.2	5.2	4.9
Total labor used (man-days/farm)	398	254	329	278
Farm equipment: oxen + plow (no.)	2.1+1	NA	1.8+1	NA
Value of production	326,191	156,314	269,483	188,886
Total cost of production	23,204	16,285	14,641	12,553
Net farm income	320,987	140,029	254,842	176,333
Per hectare	49,423	35,905	56,884	54,592
Per man-day	761	551	775	634
Per man-equivalent	41,505	19,722	49,008	35,986

[a]$US 1.00 equals 350 FCFA.

NA indicates not applicable.

Source: PSR Surveys.

Table 14. Estimated Cost ($US) of On-Farm Research, Lower Casamance, Senegal, 1982-1986

Item	Average Annual Cost	Present Value Over Five Year at 20% Discount Rate[a]
Capital[b]		
Vehicles	6,858	NA
Motorcycles	4,500	NA
Office equipment	3,214	NA
Field equipment	3,785	NA
Subtotal (a)	18,357	54,898
Variable		
Operations[c]	32,974	98,612
Salaries, local staff and support	88,684	265,218
Expatriates' recurring costs[d]	120,000	358,872
Subtotal (b)	241,658	722,707
(Excluding expatriates)	(121,658)	(363,830)
Total Cost (a) + (b)	260,015	777,601
Number of households	147[e]	806[f]
Surveyed area (ha)	436	2,180[g]
Total Cost/household	1,769	965
(Excluding expatriates)	(953)	(513)
Total Cost/ha	596	357
(Excluding expatriates)	(321)	(190)

[a]Bank interests on capital averaged 20%; average exchange rate was $US 1.00 equals 350 FCFA over the 1982-1986 period.
[b]Vehicles and office equipment amortized over 4 years (linear depreciations with 20% salvage value); motorbikes amortized over 3 years.
[c]Operational costs estimated from CRA-Djibelor published accounts from 1982-85. Costs include consumables and casual labor.
[d]Salaries and fringe benefits for expatriates estimated at 21,000,000 FCFA per scientist - year over 1982-86 period.
[e]Average number of farm households surveyed per year (1982-86).
[f]Total number of households repeatedly contacted over 5 years i.e. 725 contacts in first 10 villages and 71 contacts outside.
[g]Five times the average area monitored per year.
NA indicate not applicable.

ANNEX 2

50 N

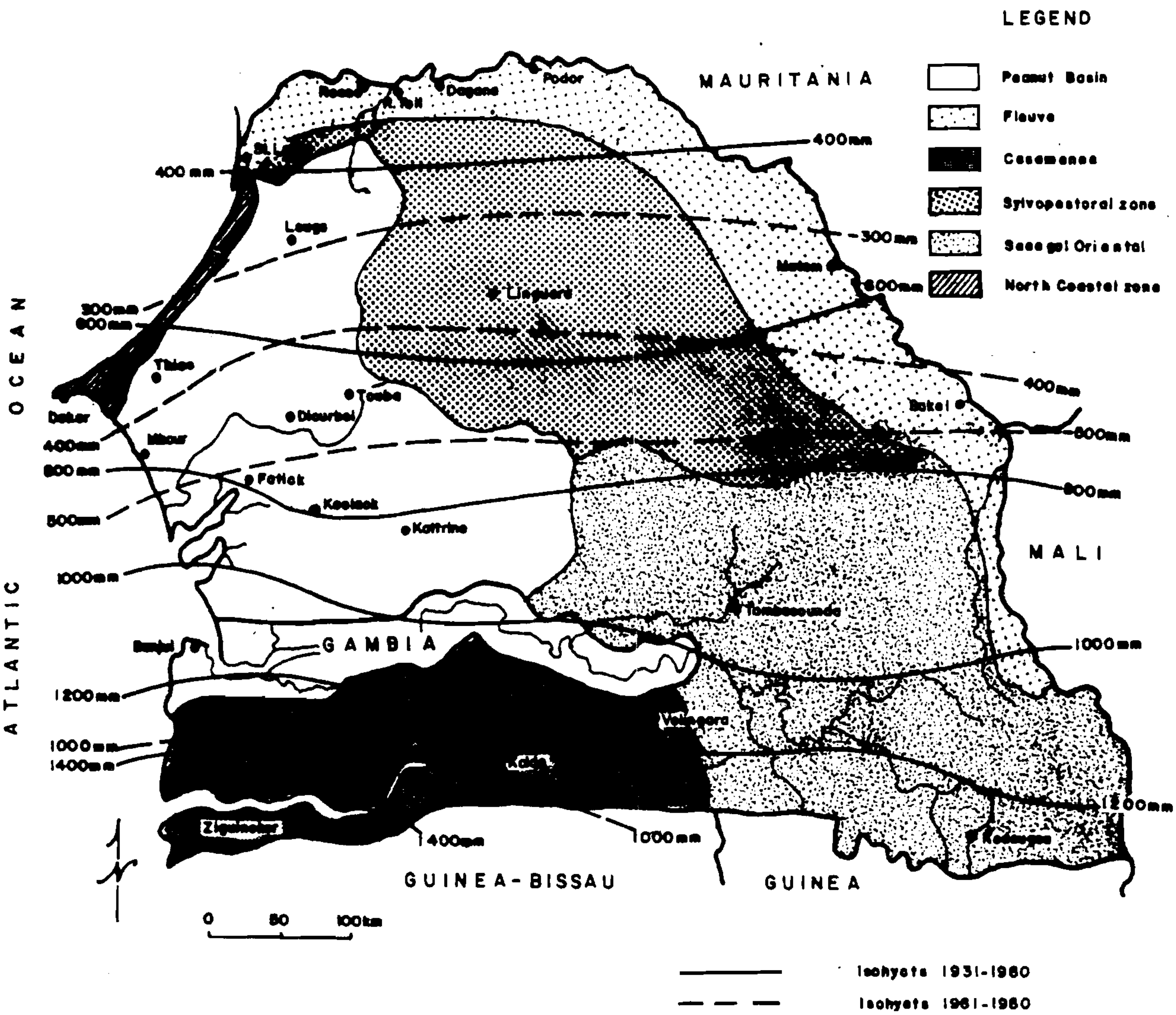

Figure: 1 AGROECOLOGICAL ZONES OF SENEGAL

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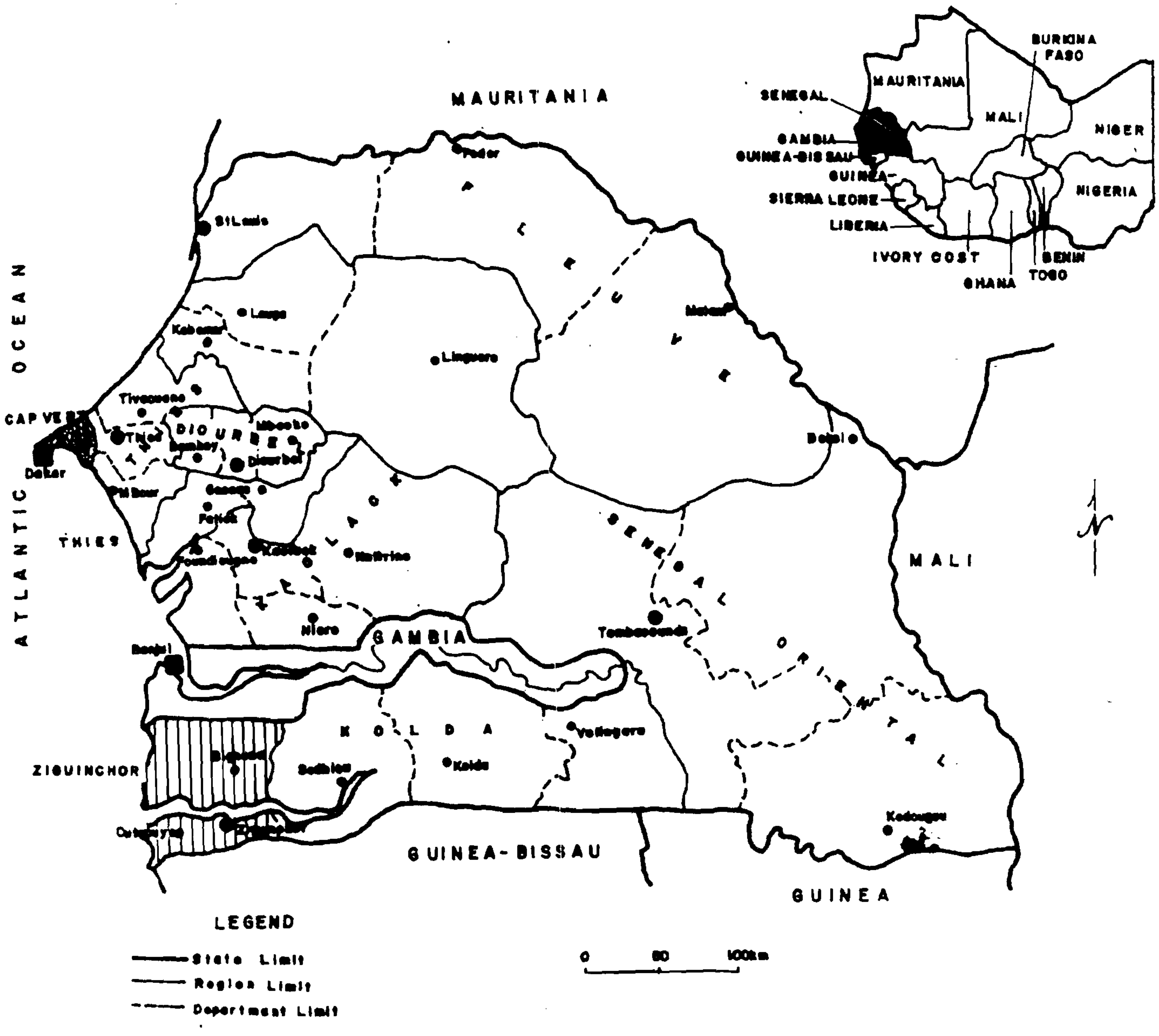

Figure: 2 SENEGAL ADMINISTRATIVE REGIONS

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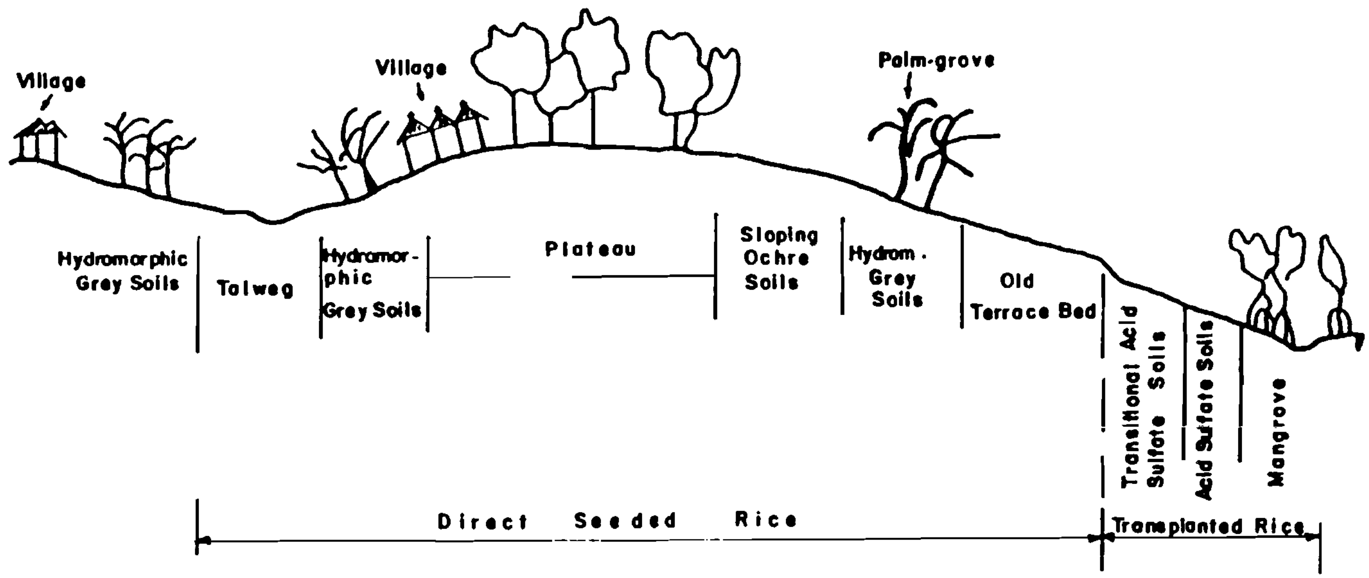

Figure: 3 TYPICAL TOPOSEQUENCE SCHEMA IN THE LOWER CASAMANCE

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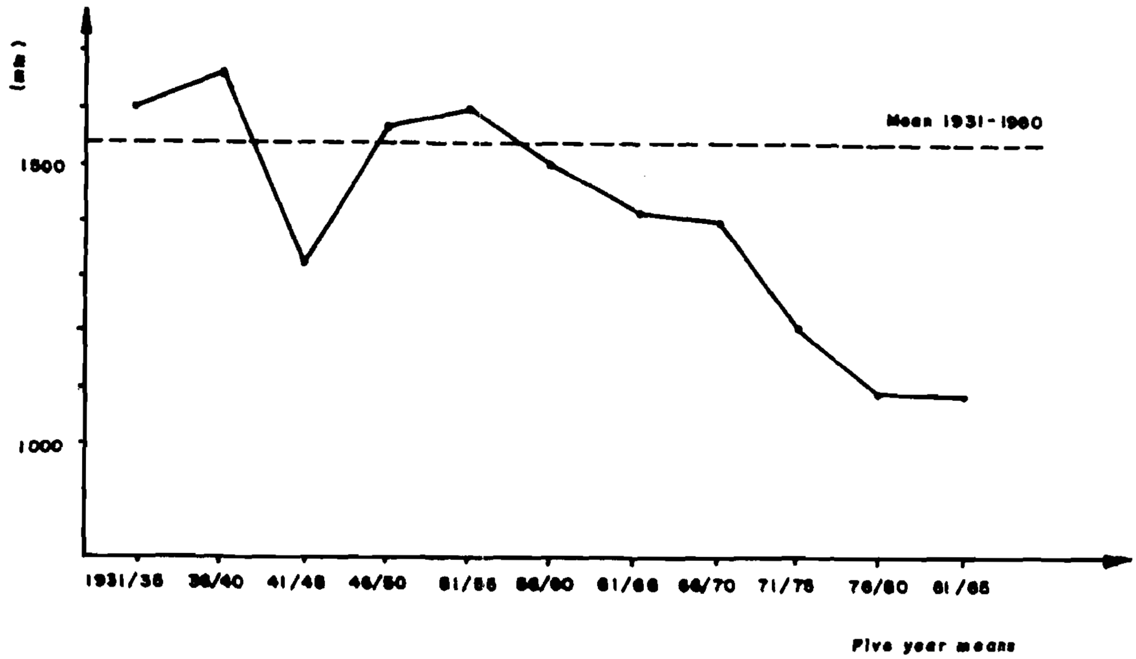

Source: ASECNA

Figure: 4 Evolution of Rainfall at Ziguinchor, Senegal 1931 – 1985

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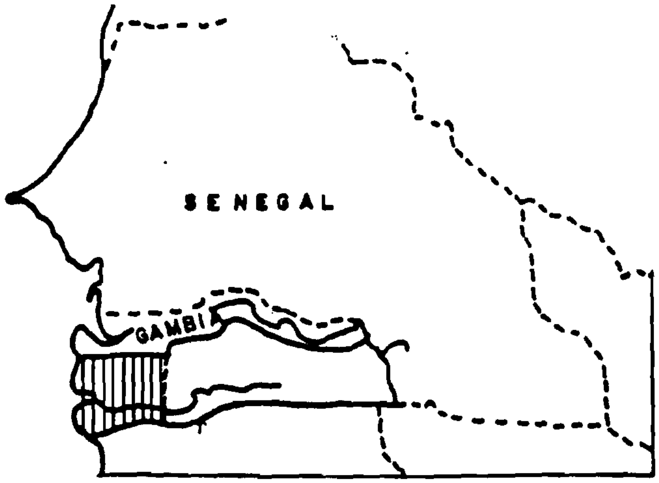


Social organization by [illegible]

I : Diola type: transplanted rice is dominant; no use of animal traction

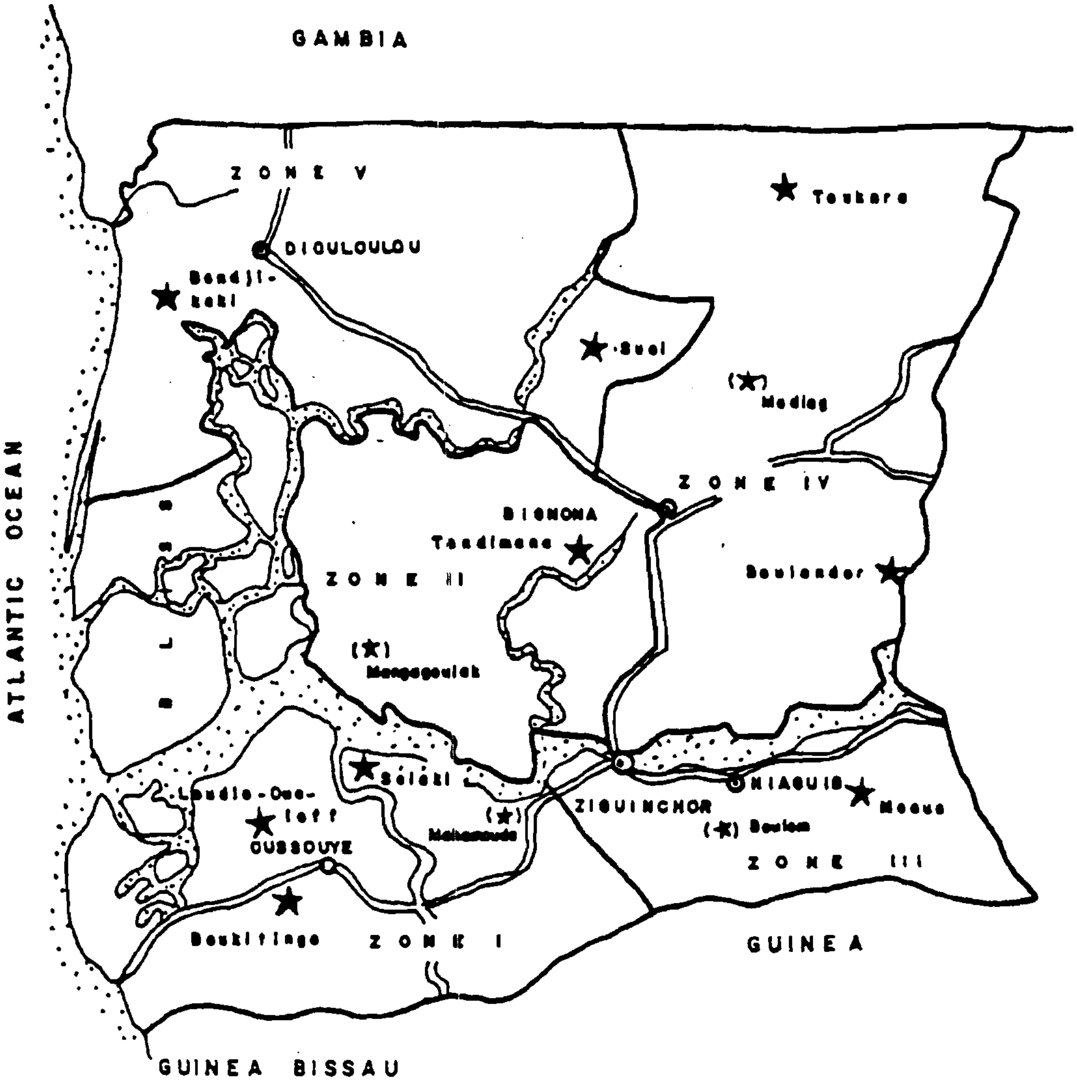
II : Diola type : transplanted and direct seeded rice equally important ; no use of animal traction

III: Manding type: direct seeded cereals are dominant; little use of animal traction

IV: Manding type: direct seeded cereals are dominant; extensive use of animal traction

V : Diola type: transplanted and direct seeded rice equally important ; wide use of animal traction

Figure: 5 AGRICULTURAL ZONES OF THE LOWER CASAMANCE



★ research sites (★) abandoned
principal road
Casamance River and affluents
zone limit
BLISS: not covered (extremely low population density)

0 10 20 30 40 50km

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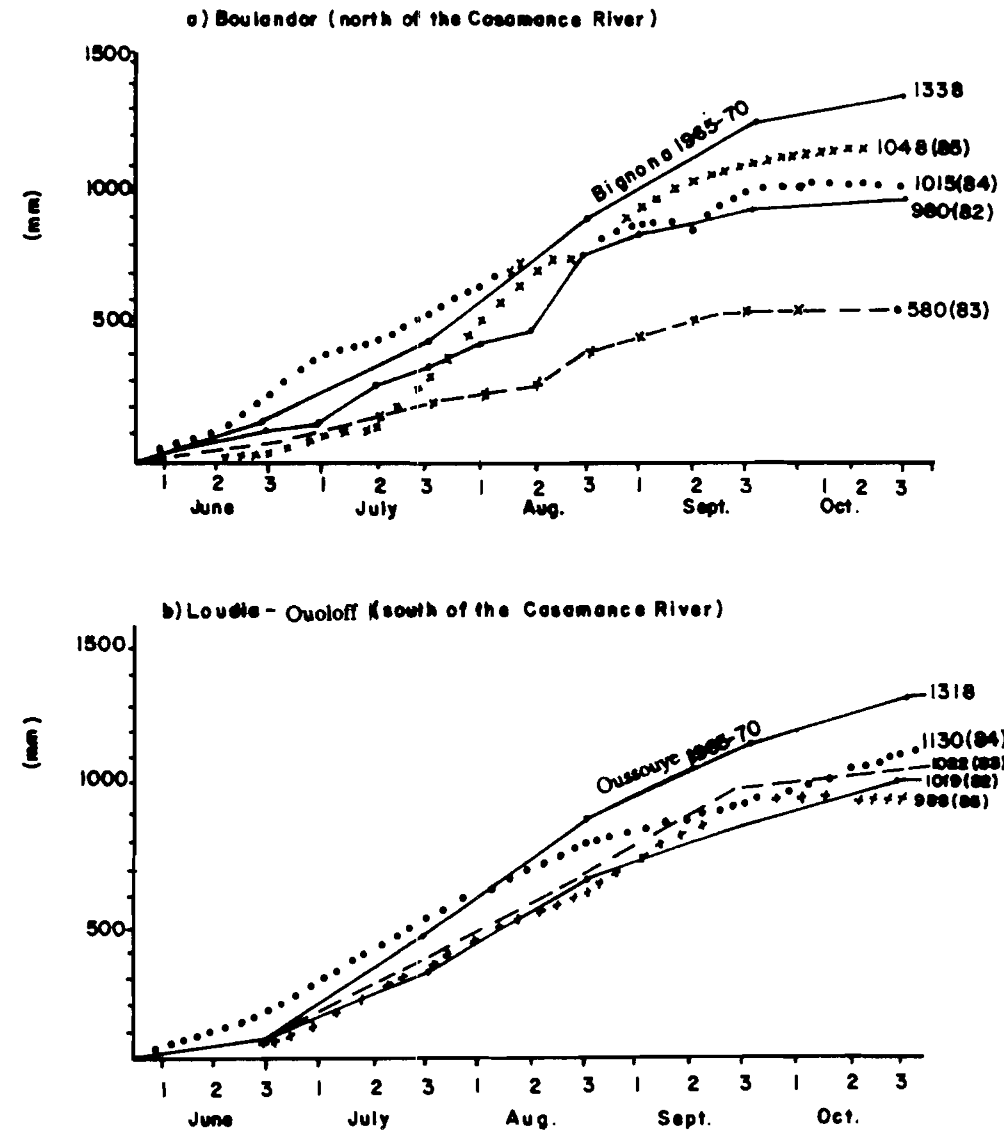

Figure: 6 CUMULATIVE (DECADE) EVOLUTION OF RAINFALL IN THE LOWER CASAMANCE 1982-1985

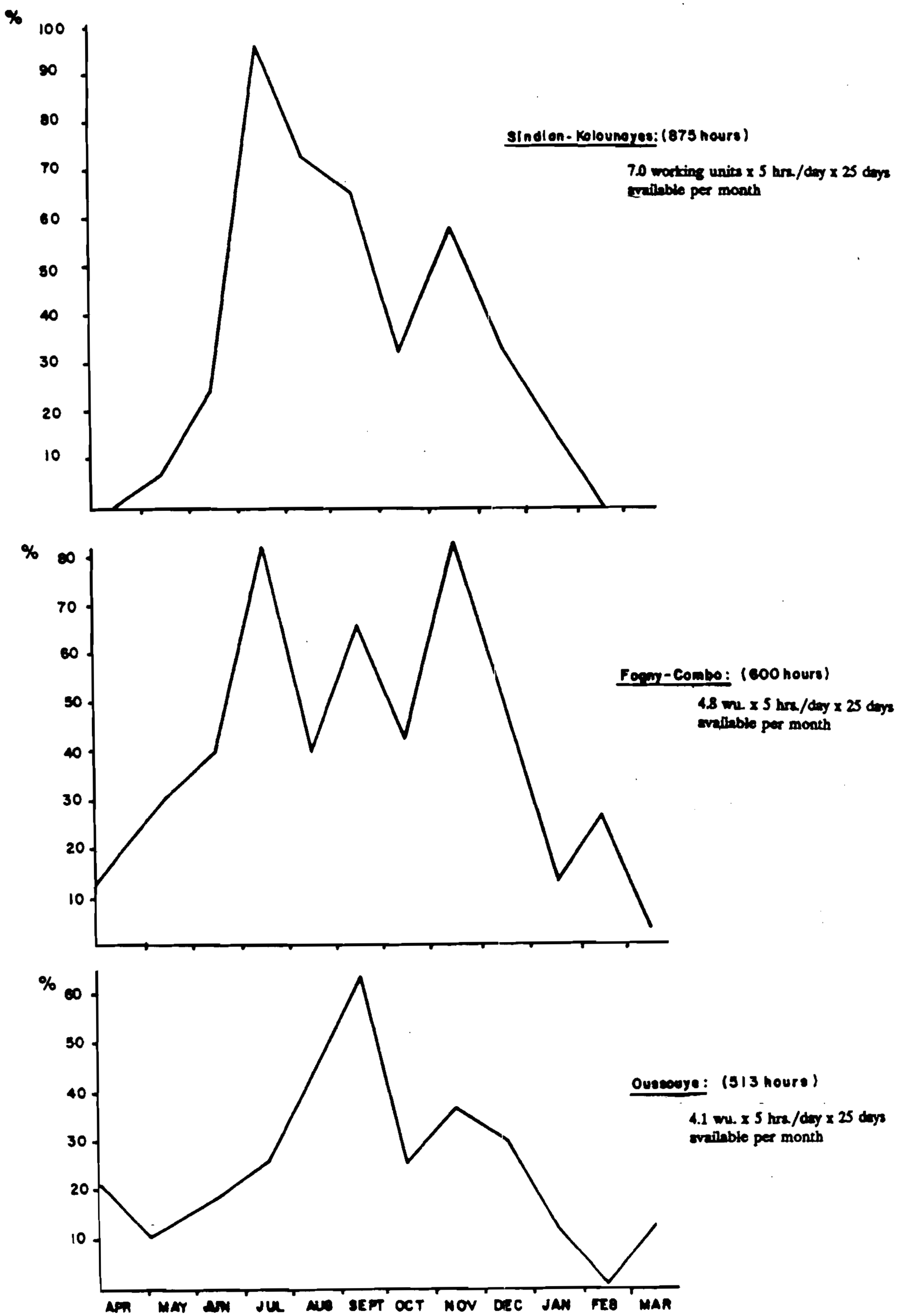

Figure: 7 MONTHLY DEMAND OF FAMILY LABOR AS A PERCENTAGE OF TOTAL HOURS AVAILABLE FOR AGRICULTURAL WORK

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