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INSTITUT DE RECHERCHES D'AGRONOMIE TROPICALE

(IRAT)

RESEARCH ON CEREAL PRODUCTION TECHNOLOGY IN SENEGAL AND UPPER VOLTA

September 24, 1974
AID/Washington
Merritt Sargent

Final Report in Fulfillment of Contract Obligations

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i. Assignment

To investigate work by the Research Institute of Tropical Agronomy (IRAT) on cereal production technology in Senegal and Upper Volta with regard to its feasibility for West African farmers in the sahelo-sudanian zone.

To evaluate its applicability to proposed US/AID mid-term development projects in the Sahel and the development of a new cereal technology.

To propose further topics of study and possible avenues for IRAT/AID collaboration.

ii. Itinerary

1974

June 18	Flew to Washington for briefing by AID personnel from the Central and West Africa Region and from the Office of Development Services (AFR/CWR and AFR/DS).
June 22	Flew to Paris for discussions with IRAT personnel in the central office and with the Ministry of Cooperation. Spent time in IRAT/SATEC documents library.
June 26	Flew to Dakar. Met with AID/Dakar personnel, the Senegal representative of the French Aid and Cooperation Fund, the Director of Agricultural Services, the Director of Agricultural Research and with SODEVA personnel stationed in Dakar.
July 3	Drove to IRAT station at Bambey and met with a number of scientists in seed development, farm equipment and farm systems management. Spent time in documents library.
July 5	Drove to Kaolack and met with IRAT representatives for the experimental units.
July 6-11	Made trips to the areas surrounding Toubakouta, Keur Madjabe, Fatik and Gossas to talk with farmers and local agricultural agents.
July 12-14	Spent three days in small village near Wack Ngouna.

July 15	Return visit to Bambey station.
July 16	Drove to Dakar for return visits to AID/Dakar, the Director of Agricultural Services, the Director of Agricultural Research and SODEVA.
July 24	Flew to Abidjan for talks with AID/Redso personnel.
July 25	Flew to Ouagadougou. Met with Embassy, IRAT and UNDP/FAO personnel.
July 31	Took train to Bobo-Dioulasso to visit IRAT station at Farako-Ba, UNDP project at Matourkou and the villages of Touban Koura, Dende, Koro and Bare which are involved in the Matourkou Project. Also visited the ILO Artisan Center.
August 4	Return to Ouagadougou for further meetings with IRAT and UNDP personnel.
August 9	Drove to IRAT research station and model farm at Sarya and also met with Director of Rural Development Organisation (ORD) at Koudougou.
August 14	Flew to Paris for return meetings with IRAT and further work in documents library.
August 20	Flew to Washington for debriefing.
August 29	Flew to East Lansing to complete report.
September 24	Report completed and submitted.

iii. Preface

Originally this assignment was programmed as a four-month trip to Senegal alone. This was some years ago and certainly would have afforded the contractor the opportunity of conducting a far more detailed and analytical examination of IRAT's past and present research into cereal production technology in Senegal. My contract allowed me only four weeks in Senegal and added another three weeks in Upper Volta. Consequently, my observations must remain, in large part, tentative and highly dependent on five years experience at the local level with traditional farmers in the Sudano-Sahelian zone. I would hasten to add that the IRAT and most government extension personnel gave me invaluable cooperation allowing me to absorb far more information in such a short time than I had imagined possible.

I have basically approached my assignment from the point of view that takes the farmers' decision-making resources and constraints as the priority area of concern. Whatever package of technological innovations, equipment and indebtedness we may propose to the farmer, he will necessarily evaluate that package in terms of his own resources and constraints, the least of which not being risk aversion. With all innovations there is an inherent risk factor. The minimization of that risk will have a strong influence on the rate at which the technological package, for cereal production or otherwise, will be adopted. The abnormally difficult conditions of the last few years in the Sahel have further demonstrated the rationality of risk minimization as an explicit objective. It is my contention that this objective must be effectively integrated into whatever production technologies US/AID and other agencies may wish to introduce into the region.

1. SENEGAL

1.1. Background Information

1.1.1. Centre National de Recherches Agronomiques/Institut de Recherches d' Agronomie Tropical

In 1913, the French colonial government established a "Station d'Etudes" (Agricultural Experiment Station) on 650 hectares near the town of Bambey, Senegal to work on improved peanut production through the use of draft animals. In 1921, the taxes being levied on peanuts provided sufficient funds to allow expansion of the Station's activities to the improvement of peanut and millet varieties. In 1938, the Station was further expanded into the "Centre du Secteur Sondanais de Recherches Agronomiques (Soudanian Sector Center for Agricultural Research) responsible for the coordination of research from Niger to Senegal. With funding from FIDES (Fonds Internationals du Developpement Economique et Socials), the Station was made into the Agricultural Research Center (CRA) in 1950 and then handed to the Senegalese government in 1960, independence year. The Senegalese government entrusted management of the "Centre National de Recherches Agronomiques" (CNRA) to the "Institut de Recherches d'Agronomie Tropicale et Cultures Vivrieres" (IRAT).

IRAT is one of nine research institutes financed by the French government to do specific research on food crops. The nine: CTFT - forestry; IEMVT - livestock and veterinary medicine; IFAC - fruits; IFCC - coffee, cocoa and other stimulants; IRCA - rubber in Africa; IRCT - fibers; IRHO - peanuts and other oil nuts; CEEMAT - agricultural engineering; and IRAT are grouped under an umbrella organisation, G.E.R.D.A.T. - Groupe d'Etudes et

du Developpement d'Agronomie Tropicale, whose task is to coordinate research among the nine and with other international research institutes, such as IITA, ICRISAT, IRRI, etc. IRAT was the last of the nine to be created largely due to an admission by the French that they had perhaps spent too much time and resources on export crops.

The IRAT organisation in Senegal is divided into three geographic areas: the Senegal River Sector and the Casamance Sector which are concerned primarily with rice and the Central Sector which covers the Senegal peanut basin and is of most interest to AID project planning in arid and semi-arid cereal production.

IRAT research is divided into three areas. "Basic research" deals primarily with the pure scientific study of the climate, plant physiology, genetics and breeding, plant protection, soil-water and soil-plant relationships and agricultural machinery. "Applied research" involves adapting the pure research results to the rural farm environment largely through a network of multi-local experiment stations in collaboration with other research institutes such as IRHO, IRCT and IEMVT. "Development research" is the application of applied research to rural farms taking into account motivations and physical, economic and social constraints. This is done largely through the experimental units. IRAT/Senegal employs 45 scientists, the vast majority of whom are expatriots and about 750 Senegalese personnel.

1.1.2. Les Unites Experimentales

These pilot villages are an extension of IRAT's third category of research: development research. The objective is to study on a larger

scale (a few thousand hectares) the introduction of a new farm system based on the findings of research, the economic and social environment and centered around a village cooperative structure. The Experimental Units were created in 1968 with financing originally from the Senegalese government (1968-1971) and subsequently from the French Aid and Cooperation Fund (1972-1977). There are two in the Sine-Saloum region, one at Thysee-Kymor and one at Koumbidia. They are attempts to test the technological package in a realistic atmosphere where all "natural" variables can freely come into play. The hope is to develop a model of reasonable size which could be reproduced elsewhere throughout the region. The two experimental units employ two expatriot technicians and 36 Senegalese personnel.

1.1.3. La Societe de Developpement et de Vulgarisation Agricole/La Societe d'Aide Technique et de Cooperation

By adhering to the Yaounde Convention, Senegal lost its preferential tariffs from France for its peanut production. Consequently they mounted a program for accelerated peanut and millet production in 1964 and the management of this program was entrusted to "La Societe d'Aide Technique et de Cooperation" (SATEC). SATEC is a French quasi-governmental consulting agency or "Societe d'Etudes" which provides technical assistance and personnel to developing nations.

The program in improved peanut and millet production was intended to reach a broad spectrum of farmers in the Senegal peanut basin. In 1968 the program was turned over to a Senegalese organisation, "La Societe de Developpement et de Vulgarisation Agricole" (SODEVA), while the SATEC personnel remained as technical experts and counterparts to the Senegalese

functionaries. The main objective of the program in the peanut basin is an intensification of agricultural production, i.e., crop diversification and improvements in per unit productivity rather than an a priori expansion of land under cultivation.

In the Sine-Saloum region, SODEVA's largest effort, they employ 6 expatriot technicians and 450 Senegalese personnel.

1.2. Research: CNRA/IRAT

1.2.1. Seed Variety Selection

IRAT/Bambey's research on improved varieties has a long and productive history. In as far as responding to the requirements of arid climates, their most significant contribution has certainly been in the area of shortening growing cycles for various crops.

Perhaps the most striking achievements have come in the area of improved millet varieties. Beginning with the purification of a local short-cycle millet, Bambey's Souna I, they have moved from national average yields without fertilizer of 400-1,000 kilograms per hectare to 2,500-3,000 kilograms with the Souna II and Souna III varieties with fertilizers. Souna III was available to farmers in 1972. This variety is well adapted to dry areas requiring a minimum 70-day rainy reason and preferring light, sandy soils. Its water requirement does not exceed 400 millimeters of seasonal rainfall. Its straw-grain ration is high (4/1) and the European Development Fund (FED) has financed a large project (19,000,000 CFA) for the development of a dwarf millet primarily designed to improve this problem. For the moment, this joint project (ORSTOM-IRAT) has not been able to solve problems of male sterility, maintaining hybrid vigor and the millet disease, sclerospora. Positive results are expected in four to six years.

Sorghum variety development has been much broader yet the basic requirements of sorghums, primarily rainfall, make them less interesting for arid climates. IRAT has again researched extensively the growing cycle of sorghums in the hopes of finding varieties adapted to all regions of

Senegal. In the US/AID project area (Thies-Diourbel) in Senegal, the drought years have so discouraged farmers from planting sorghums that they have converted almost entirely to millets for their cereal crop. In fact, the research program that was developed in the III Senegalese Development Plan for IRAT/Senegal (1969-1973) restricts the research into sorghum varieties to the Senegal River Regions, the East and the Sine-Saloum regions. In the Senegal River Region there are possibilities of irrigated varieties and off-season varieties which are planted near the end of the rainy season and in lowland areas to profit from residual moisture. The East and Sine-Saloum Regions are areas in which the average rainfall is 800 millimeters and above.

Research into corn varieties is again restricted to higher rainfall areas (800 millimeters) and thus will not be of much interest to arid farming. However, the southern areas of the Sahel countries do have sufficient rainfall most of the time and the very high yields--6.5 metric tons per hectare on IRAT's research stations and 4.5 metric tons per hectare on the fields in the experimental units--make it an interesting crop, especially given the demand (as in Upper Volta) by national breweries. IRAT's basic orientation is toward developing hybrids to take advantage of hybrid vigor. They are also undertaking some work with the high-lysine American varieties to adapt them to Senegalese conditions.

There is little question that the dominant crop for Senegalese agriculture has been peanuts. The facility at Bambey was originally conceived to deal with the improvement of peanut production. The variety 28-206, which is adapted to the 800 millimeter rainfall areas and has a growing cycle of 120 days, yields 2.5-3.0 metric tons per hectare under ideal

conditions. This variety is quite widespread not only in the more humid areas of Senegal but also in the southern areas of Upper Volta. For drier climates, 600-800 millimeters, Bambey and IRHO have two varieties available, 55-437 which has a growing cycle of 90 days and 55-422 which has a 105 day growing cycle.

Not much work has been done on further diversification of crops particularly for arid areas. It is quite obvious that for the moment, IRAT research can propose a peanut and millet cropping system for areas such as the US/AID Thies-Diourbel project.

One element that seems to have questionable value as a theme of varietal research for the arid and semi-arid areas of Sahelian West Africa is the insistance on maximum fertility conditions for all varietal development. I would not argue that it is unimportant to note the optimum potential of the varieties under observation but it would also seem especially important to know how varieties perform under a whole range of fertility conditions. This seems warranted not only as a principle of scientific rigor but also as a realistic assumption of the farm situation in these countries. The increasing costs of minimal fertilizer and the logistical problems of delivering the proper quantities in the proper mixture at the proper time which are endemic to the Sahelian countries are increasingly drawing into question the economic profitability of high levels of mineral fertilization.

Another aspect of varietal development that seems to have been overlooked by IRAT and would seem useful to dry land farming conditions is the varying of plant population per unit area. When water is such a scarce resource, then one possible avenue of investigation would seem to be the

study of marginal differences in yields as a dependent variable on plant population per hectare; the goal being to make the most efficient use of what water there is. This would also be useful in discovering what plant population makes the most efficient use of the limited plant nutrients available. The off-season sorghums traditionally planted in the Senegal River Region and the Northern Cameroons and under investigation by IRAT in both areas are based on the principle by maximum efficiency in the use of water and nutrients available. The variety in Northern Cameroons is planted with 100 cm. between each plant in both directions. This would seem an interesting principle for experimentation with all crops aimed at dry-land farming situations. The principle of efficient use of resources introduces another concept of equal importance if not more so to African farmers: dependability. Taking risks is very dangerous for subsistance farmers and in general they will opt for a variety that in a wide range fertility and rainfall conditions will still produce. Certainly optimum yield characteristics as a research objective will be, to some degree, sacrificed as a trade-off for what in unpredictable situations is a more important objective, risk minimization. This is the obvious reason for the broad response to the short-cycle millets throughout the drought area.

Another area of soil chemistry that IRAT/Senegal has taken some note of, though IRAT/Upper Volta seems to have more detailed information, is on the impending problem of Ph acidity. Though IRAT has learned that one can grow crops at somewhat lower than expected Ph levels (4.0-4.5) it is obvious that in the not too distant future the level will be reached where cropping will be impossible without liming. The yield responses to

liming do not pay for the lime on a year to year basis however in the long run liming is obviously necessary. Unfortunately there seems to be little effort to discover and/or develop sources of lime in either Senegal or Upper Volta.

It is obvious that the economic resources of most farmers in the Sahel do not permit development organisms to propose maximum packages for optimum yields. These are out of reach for the vast majority of farmers. IRAT has recognized this in a number of ways when asked to propose packages for development agencies. Most notable was the recognition that a significantly smaller dose of fertilizer had higher marginal yield responses on a wide range of farms.

However, although minimum packages may be the guidelines for AID's programming in the Sahel, there is a trade-off. This trade-off will be primarily declining soil fertility. In that the fertility of Sahelian soils are low, any long run strategy will have to integrate a strategy for the reconstruction of the soil into its programs. The problems of the Ph factor have already been mentioned. IRAT has done very extensive work on evaluating the seriousness of the general phosphate deficiency in Sahelian soils. It is the limiting nutrient in the vast majority of situations. The resulting recommendation for Senegal in general is 400 kilograms of bicalcium phosphate at the beginning of the crop rotation each 4 years to make up for the deficiency and a maintenance dose built into the fertilizer doses to make up for the phosphates taken out by the annual crops and leaching.

Further work on the rebuilding of soil fertility done by IRAT is largely concerned with farming practices.

1.2.2. Farming Practices and Equipment

A precondition to the use of improved seed varieties and mineral fertilizers is the timely and effective execution of the various operations required for each crop. The potential contribution to yields from varietal characteristics and mineral fertilization (organic too for that matter) is greatly diminished if the farmer is unable to properly prepare the land, plant on time and effectively weed the crops on time. In order to do this, the farmer needs a new source of energy to improve his labor productivity. The obvious solution throughout the Sahel is the harnessing of draft animals. Animal powered agriculture not only has a significant impact on the amount of time required to perform the various operations but also a marked qualitative effect. This has been well documented by IRAT.

Animal power was first introduced in Senegal as early as 1931 and in my travels in West Africa, I have not seen such use of animal traction as I found in Senegal. As with the vast majority of traditional farming practices, there is a very reasonable explanation for such widespread adoption of these techniques. The rainy season in Senegal, even in the higher rainfall areas, is very short. The average duration for the 1973 season in the Sine-Saloum area was 100 days. The time available for planting is very constrained and is the reason for the strong pressure to discover new techniques for the superficial preparation of land and for planting. The yield effects of planting dates is very marked. In 1970, peanuts planted within 3 days after the first usable rain were 10 percent higher than those planted in more than 3 days in a study of 228 fields. Fields planted after the first rain (22 June) were 10 percent higher than those planted after the

second rain (10 July) and 60 percent higher than those planted after the third rain (24 July). In the Sine-Saloum Region there are 1.25 seeders and 1.3 cultivators for each farm. In the Tnies, Bambey and Diourbel Departments (the US/AID project area) there are 1.2 seeders and 1.1 cultivators per farm. This equipment is drawn by a single animal, usually a horse or donkey, and was developed by IRAT at Bambey. The shortness of the season requires that the ground crops be planted before the rains so that with the first significant rain, the peanut crop can be planted immediately. Planting before the rains requires some sort of mimimum tillage to allow absorption of the scattered showers which precede the beginning of the rainy season and to permit initial development of the root system. A cultivator was developed for this task and also doubles as a weeding implement. Minimum tillage operations require approximately 48 man-hours per hectare.

For the vast majority of farmers, a one-row seeder also developed at Bambey is used and is adaptable to all the relevant crops. The one-row seeder requires 14 man-hours per hectare for grains, 16 for peanuts and 20 for rice. It is possible in further stages of the technical package to combine two seeders and in advanced stages to obtain a three-row seeder The reduction in time requirements is practically linear besides the time factor, seeders also permit the farmer to establish a much more uniform stand in his field and by starting in straight rows permits animal-drawn weeding. One potential use of the seeder which would have a significant impact on the time required for weeding, a serious labor bottleneck, is the equi-distant spacing of plants on the line and between lines. This technique is referred to by a number of IRAT technicians in various

writings but neither in the packages proposed by IRAT nor on farms in Senegal does one see it practiced, save in the experimental units. It would involve adapting the population densities to this cross-hatch pattern but it seems that the potential savings in time would be well worth it. Millet densities are proposed at 90 cm. x 90 cm. Sorghums could be altered from 90 cm. x 45 cm. to 60 cm. x 60 cm. and still maintain approximately the same densities per hectare (25.000/hectare vs. 27.500/hectare). The ability to weed on the line as well as between the lines would probably save the farmer (using IRAT/Senegal's statistics) somewhere in the neighborhood of 100 man-hours per hectare.

Some of IRAT's most interesting work has been done on land preparation and plowing under of green manure or crop residues. Given the strong pressure to plant as soon as possible in Senegal, plowing preparatory to planting is not feasible. However, there is some possibility of plowing at the end of the cropping season, especially given that IRAT research results indicate that annual plowing is not necessary and in fact plowing once every two years and perhaps less is preferable. IRAT experimentation shows that the yield effects of plowing range from 20 percent on cereals, 30 percent on peanuts to 100 percent on rice compared to the control. These effects are naturally contingent on early planting and good weed control. Plowing at the end of the cropping season followed by preparatory minimum tillage the following year seems to have three effects. Firstly, it allows the farmer to conserve a certain amount of the residual moisture from the previous season. Under highly sophisticated conditions, IRAT/Bambey has been able to conserve 65 percent of the residual moisture throughout the eight-month dry season. Secondly, it inhibits the soil

from becoming seriously hardened over the dry season which permits improved development of the root systems in the early stages of plant growth. Finally, there are usually a number of scattered showers which precede the first rainfall sufficient for planting. Normally these showers are lost, either by run-off or evaporation, due to the hardness of the soil. The previous year's plowing allows this additional moisture to filter into the soil. In areas where rainfall is such a critical factor, this seems to be a remarkably responsive technique.

The other aspect of IRAT research on plowing concerns the benefits from plowing under either green manure or crop residues. In my opinion, though there is little question that at some point in time the plowing under of green manure whether they be legumious grasses (stylosanthese) or green cereals (millet or sorghum) will be necessary to soil management and also as a potential feed for livestock, for the moment the allocation of land in which the farmer has made a significant investment to a crop from which he derives little immediate and/or visible returns is not a very realistic proposal to make to the traditional farmer. The plowing under of crop residues does seem to present more realistic possibilities however.

IRAT strongly proposes that the incorporation of organic matter into these light sandy soils is of great importance not only to immediate yields but also to the long run rebuilding of the soil. The yield effect of plowing-under is comparable to simple plowing for most crops, slightly higher for millets, and somewhat lower for peanuts. Another advantage is found in the residual effects on subsequent crops, particularly if two cereals grow consecutively. In one series of tests there was a 65 percent

effect on the first year of cereals and 25 percent on the second year. There are indications that effects can be felt into the third year. With these results, IRAT concludes that millets benefit most from plowing-under, that the residual effects permit plowing once every two years if not less, and that plowing at the end of the cropping season is the preferred practice.

There is astounding evidence on the positive effects of animal manure ranging from 30 percent to 90 percent on peanut and millet fields without mineral fertilizers. The technological package requires that animals be kept on the farm. This guarantees a farm production of manure. The effects of spreading and plowing-under manure are well known even though detailed analysis may be lacking. Given the economic and logistical problems with mineral fertilizers, this would seem to warrant a much more detailed investigation into the production levels of various animals; possible methods of storage, spreading and plowing-under; and the marginal yield response to frequency of application and quantity applied.

The work on harvesting techniques has proved to be a very difficult task not only for IRAT but for most research organisations as long as they are restricted to the use of animal power. The harvesting bottleneck is really a combination of harvesting, end-of-season plowing and processing of the crop. Though the harvesting period still remains a time of peak demand for labor, some significant steps have been taken to alleviate particularly the time required for various processing activities. These developments largely concern removing the grain from the plant, threshers and shelling equipment. These machines in the vast majority of situations are too expensive and of too large capacity for a single farm. Consequently, IRAT's strategy in the development of such equipment has been

based on their use by groups of farmers.

Senegal is by far the best organized nation in French West Africa, to my knowledge, for the development and production of agricultural equipment. Beginning with a broad comparison of imported animal drawn equipment and a great deal of adaptive research, IRAT technicians have developed a varied and sophisticated line of equipment which is probably the best adapted equipment in French West Africa. The equipment ranges from single-animal implements for minimum tillage and seeding to intermediate single and double row tools to heavy-duty three-row equipment.

There are perhaps some problems with the cost of the equipment and the scale of farm that is necessary to cover such expenses. SISCOMA (Societe Industrielle Senegalaise de Constructions Mecaniques et de Materiels Agricoles) which produces all the equipment certainly produces more intermediate equipment but I think the problem arises in how IRAT puts together the whole package. For a 6-10 hectare farm, the package proposes one pair of adult oxen and a donkey or horse (preferably an adult horse) as working animals (cost: 29,300 CFA + 26,100 CFA = 55,400 CFA). The equipment package consists of two one-row seeders (24,860 CFA), one complete set of "Ariana" equipment (40,600 CFA), one horse-drawn cultivator (7,700 CFA), one horse-drawn peanut-lifter (4,200 CFA), one horse harness (1,000 CFA) and one oxen yoke (1,800 CFA). In some cases there may be need for a horse-drawn cart (27,200 CFA). The total package would then cost 135,560 CFA without the hose-cart and 162,760 CFA with it. I would point out at this time that there is a serious inaccuracy in the US/AID mid-term project design, "Senegal Cereals Production and Agricultural Extension Program" (SODEVA). On page 103 where they list the

equipment costs, the Ariana line of equipment is not the rubber-tired toolbar but rather a smaller set of equipment on two small steel wheels. The rubber-tired toolbar is the heavy-duty set of equipment called the "polyculteur a grande rendement" whose cash cost is 174,550 CFA.

The cash cost of the package is, in fact, approximately 30 percent higher than that indicated in US/AID Senegal cereals project design assuming similar levels of fertilisation. This is somewhat misleading in that it implies purchase of the entire package at one time which in fact will not be done. However, if one uses these more complete figures on the cost of the package and accepts the AID team's assumptions about yields and gross revenues, the net returns per farm, per hectare and per farm habitant are seriously diminished when the farm must maintain such a large capital investment.

One possibility of reducing this overhead would be a complete line of "Arara" equipment (25,000 CFA). This equipment is not considered very efficient by the technicians at Bambey; however, it has been used quite successfully in other areas of the Sahel. To maintain the area capacity a single animal-drawn hoe would still be necessary (7,700 CFA) and the two one-row seeders (24,860 CFA). I was unable to understand why, though there is some reference to the technique in IRAT writings, more effort was not made to split up the pair of oxen and work them individually when the traction force required permitted (seeding and weeding). This would reduce the cost of work animals to 29,300 CFA for a total of 86,860 CFA. If a cost is necessary, much less expensive carts than the SISCOMA ox-drawn cart (28,200 CFA) are possible. By simply removing the solid sides of the SISCOMA cart, the cost can be reduced to approximately 20,000 CFA. With the cart then, the total cost can be reduced by approximately 35 percent.

I would re-emphasize that the equipment itself is well designed. However, when designing a package, the resulting demands made on the capital resources of "average" farmers should be seen as a total burden and evaluated in terms of realistic yield projections and credit opportunities.

One last note before moving on to the Experimental Units deals with work animals. With the expanding use of working oxen in Senegal, relatively simple projections indicate that there will soon be a shortage of oxen. In response, IRAT has begun training cows. This innovation is not only quite ingenious but also very promising. The cows have shown their ability to work in the fields and, in addition, the farmers are very interested in the improved milk production and reproduction capacities largely due to improved care and health.

1.3. Pilot Villages: Les Unites Experimentales

The Experimental Units were conceived in 1968 by IRAT to test and evaluate the technological package developed by research in a realistic atmosphere. By working with a significant number of actual farms--212 in Koumbidia (UEK) and 145 in Thysee-Kayemor/Sonkorong (UETKS)--the object was to study the farming system in its entirety, adapt it to real economic, social and physical constraints and propose the resulting model to agricultural extension programs.

The Experimental Units are in fact collections of villages which have been reorganized on the basis of agricultural cooperatives. This is a very significant choice as an avenue for the development process to be undertaken. It implies many assumptions about traditional social and economic decision-making on the part of farmers. In situations where the potential for agricultural production is marginal at best, risk becomes an extremely important factor in decision-making. Social and economic contracts that tie a farmer to a group will have certain inherent risks that must be balanced against the projected benefits. In my experience, West African farmers will accept that risk, natural to any innovative process, if they feel they can weather the possible failure. In other words, if they feel they have a sufficient margin of survivability to withstand failure, they may attempt the innovation. The question then becomes, in the development of a rural agricultural society, can one guarantee the necessary margin or "buffer zone" to the group by guaranteeing it to individual farmers who then are in a position to risk interdependence, or by guaranteeing the margin to the group which can then protect the individuals. The majority of US/AID mid-term project proposals I have been able to read

have opted for the cooperative approach. They will be faced, I think, firstly with the poor track record of village cooperatives in French West Africa; secondly with the problem of imposing cooperative structures on social structures which, true enough, have certain cooperative characteristics but in which, nonetheless, the primary unit is still the family farm; and thirdly with the question of whether or not the farmers are organising from a comparative position of individual weakness or strength.

In point of fact, this problem was a moot question in Senegal since political policy has established the cooperative as the single structure not only for the delivery of agricultural inputs (seed, fertilizer and equipment) but also for the marketing of agricultural products and distribution of credit both short and medium-term. This in fact precluded any discussion of what form the Experimental Units should take.

As indicated in part by the earlier discussion of IRAT research, the farm system being developed includes improved seeds, mineral fertilisation, crop diversification, animal power, land management and a balancing of hectarage in cash and industrial crops. This is complemented by efforts in farm management and credit programs. Experimental Units are not attempting to introduce the most intensive programs proposed by IRAT but rather a "semi-intensive" program. The major difficulties with the adaptation of the "semi-intensive" program seem to have been land management, sufficient source of animal power and sufficient animal-drawn equipment.

The improved land management program involves a number of basic principles. The first component and the one which seems to be the biggest problem is that of sedentarizing land use. One of the basic characteristics of traditional West African agriculture has been the transitory nature of land use. The resulting problems of declining fertility and the

increasing pressure of growing populations make the necessity of stabilizing land use more and more imperative. However, the reconstruction of soil fertility requires a significant investment, particularly in labor, for which the returns, though measurable on a yearly basis, are really felt in the long run.

The restructuring of the land tenure system is a difficult task. If the farmer is to invest in land clearing, phosphating, plowing under and crop rotations, he needs some assurance that he will have access to his land on a long term basis. The current process of division of land with each succession of inheritance does not permit this. In this context, village commitments are necessary to guarantee permanent occupation of farm land. If the farmer can obtain a "title" to his land, the next requirement is that of clearing the land of roots. Roots render very difficult field work in straight lines, cause deterioration of equipment and are very difficult on the working animals. Obviously the amount of work required for land clearing is directly dependent on the density of tree cover. In the areas around the Experimental Units, the number of roots can vary from 1,000 to 6,000 per hectare. In any case it is very time consuming work and the program proposes the clearing of only one hectare per year, especially since, short of motorisation, there does not seem to be any practical mechanized assistance possible.

In Senegal, due to the natural phosphate deposits, the government has been able to induce farmers to clear and sedentarize their farm land by offering them 400 kilograms of bicalcium phosphate per cleared hectare free. This 400 kilogram application is considered sufficient to replenish the soil's deficiency.

Plowing-under is usually practiced after a short-cycle crop, normally millet, in order to take advantage of as much moisture as possible; not only to conserve it but to use it to decompose the crop residues plowed under. If the farmer does not plow under early enough, the millet stalks will not decompose and will cause very aggravating problems the following year at planting time when the stalks will interfere with the smooth operation of both the minimum tillage-equipment and the seeders.

The other component to the land management program is the crop rotation system. In Senegal the major question had been whether to include a fallow year or not and if so how many. Population growth has decided this problem in many areas. Also, the investment made in the land makes it difficult to persuade farmers to leave it fallow much less plant a cover crop he can't eat or sell. Consequently, both IRAT and the Experimental Units are exploring ways to drop the fallow year from the rotation. The rotation system proposed for the Experimental Units is (1) short-cycle millets, (2) cotton and peanuts, (3) sorghum and (4) peanuts. This is in a higher rainfall area (800 mm.) and for drier areas the sorghum and cotton is dropped leaving short-cycle varieties of millet and peanuts with some interesting possibilities of bringing in a more systematic growing of cowpeas. It should be noted that the rotation system is also intended to balance land use between cash and food crops. Furthermore, the cereals have a higher potential for increased yields and as a result the production of cereals can be hypothetically increased three-fold.

A fundamental assumption to this system is the replacement of nutrients taken out by the crops. This is certainly a sound agronomic principle. It seems to raise two areas of discussion. The first point is the question of how much of the various nutrients does a given plant extract

from the soil for its growth. The quantities taken out by the commonly used varieties are known by IRAT; however, it would seem that this should receive more interest as an avenue of varietal research. The objective would be to develop varieties which make the most efficient use of limited nutrients. The development of dwarf varieties is relevant in that it seeks to reduce the percentage of vegetable matter that is not grain; however, there will be the problems of dealing with hybrid seeds. The second point is the question of how to replace these nutrients. There are application rates of mineral fertilizers developed on the basis of plan demands, which will totally replace the nutrients taken out. It would seem that with more efficient use of animal manure and with the plowing under of other organic material, some further study should be given to the complementary effect this must have on returning nutrients to the soil and thus reducing the requirements for mineral fertilizers.

The actual results of the Experimental Units in general seem to justify the overall package from an agronomic point of view. The rate of adoption and potential for replications of the program provoke certain questions concerning its overall viability.

Over four farm seasons (1970-1973) in UEK, the fields where land improvement techniques were being applied showed consistently 35 to 40 percent higher yields for both peanuts and cereals than the average.

Peanuts for the year 1972 in UEK do not seem to benefit significantly from preparatory minimum tillage whether the fields are fertilized or not. They do react very strongly to the date of planting and consequently it is advised not to do any land preparation when it will retard the planting beyond 10 days after the first usuable rain (20 to 25 mm.) whereupon yields

have been shown to drop by 40 percent. The optimum amount of seed per hectare is 50 - 55 kilograms showing the highest return per kilogram of 93 kilograms of yield for one kilogram of seed. The response to fertilisation varies between 2.5 and 3.5 kilograms yield per kilogram fertiliser. This is significantly correlated to the date of planting and the number of weedings. Fields planted on the first rain with 91 kilograms of fertiliser showed a 3.5 response while fields planted on the fourth rain with 128 kilograms of fertiliser showed a 2.1 response. The number of weedings (including slight ridging, mechanical and manual weedings) is directly correlated to yields showing, in 1972, a 20 percent jump in yields for two weedings, another 13 percent for three, another 14 percent for four and another 3.5 percent for five weedings. This amounts to a total increase of 54 percent from one weeding to four. In UETKS, the number of weedings showed significant impact up to and including the fifth weeding for a total increase of 450 percent. This figure is misleading in that it reflects higher doses of fertilizer with each weeding, also.

For millets at UEK, a plowing at the end of the previous season showed the highest yields, especially with some fertilizer. A mixture of mineral and animal fertiliser has a significant influence on millet (17 percent). Ridging is effective up to three times and thining-out is even more significant showing a 27 percent increase in yields. In UETKS, fertilisation had a 6.78 reponse coefficient. Animal fertiliser is much more widespread in UETKS with over a 100 percent increase in yields recorded. Weedings, ridgings and thinning-out have the combined effect of a 47 percent increase in yields.

I have only cited some scattered data on millets and sorghums to show that the techniques in the package do seem to have in large part the desired

impact. However the expansion of the techniques is not as positive and the conclusion made is that, in general, the farmers are underequipped. Fifty percent of the farms at UETKS had a pair of oxen (80) in 1973 and 35 percent at UEX (78) out of a total of 367 farms. Land improvement techniques were being practiced on 251 hectares for both Experimental Units out of a total of 3,200 farmed hectares. At the end of the crop season, 1972, 42.45 hectares were plowed. The average dose of fertiliser per hectare of peanuts was 45 kilograms at UEK and 25 kilograms at UETKS. For cereals it was 74 kilograms at UEK and 26 kilograms at UETKS, all far below the prescribed dose of 150 kilograms. In 1973 there were 549 seeders and 518 single row lines. There were 81 single peanut lifters, 25 sets of Arara equipment and 50 sets of Ariana equipment, both including peanut lifters. There were 6 heavy-duty polycultivators.

One area of analysis where the IRAT technicians have spent a great deal of time collecting data is in the allocation of labor. As was admitted to me in Bambey, if a farmer were to have the necessary equipment (which from the above data he obviously does not), be a highly efficient allocator, and follow all the farming practices counseled by the extension agents for each crop, he could not possibly accomplish all the operations. There is just not enough time in each work period--land preparation, planting, weeding, harvesting and plowing--to do it. As stated above, the common conclusion has been that the farmers have been underequipped. One can probably make significant improvements through better management advice. But this does not solve the most obvious explanation of this "insufficient equipment". The most reasonable explanation is that the farmer just

cannot afford the debt entailed by such a large investment. As I discussed earlier, there are possibilities of rearranging the equipment package to make it cheaper and maintain its labor capacity.

It is very difficult to put a price on learning and much of what goes on at the Experimental Units is a learning process not only for the farmers but also for the technicians. After 5 years, with a total of about 360 farms, 158 of whom have oxen (44 percent), and a total of 3,200 arable hectares, 374 getting significant improvements (12 percent), the total budget for the Experimental Units for the fiscal year 1972-1973 was $200,000. A common way of otherwise stating this, though I believe very misleading, is slightly above 1,266$ per farm/year and 335$ per hectare/year. The expenditures in human resources are approximately 1 extension agent for 10 farmers which is a highly intensive approach to the diffusion process. IRAT has also set up their own credit and cereal marketing units for the Experimental Units to make up for inabilities and inefficiencies of the national monopoly and to provide easier terms of credit.

The Experimental Units are expensive approaches to the development process, especially in human resources, and it is highly doubtful that a development organisation such as SODEA, which must work with a much larger population base (68,000 farms in the Sine-Saloum) can, even if it could be assured of the necessary financial resources, effectively complement or supplant national institutions, as well as recruit the necessary qualified personnel.

1.4. Extension Program: SODEVA/SATEC

Though SODEVA has a mandate for agricultural extension throughout the country, their largest emphasis is in the peanut basin and especially in the Sine-Saloum Region which is the area around IRAT's Experimental Units. In principle, the SODEVA/SATEC operation is intended to be a mass agricultural extension program aimed at crop diversification and the intensification of farming practices. They have a research division designed to analyse the progress of the development program and to identify new development projects. They also have a training program, "Centre d'Enseignement des Techniques Agricoles et du Developpement" (CETAD) to supply their regional operations with extension personnel.

The Sine-Saloum Region is, by far, the most favorable area in SODEVA's operation for the improvement of farming practices and for crop diversification. With 800 mm. of rainfall, comparatively decent soils and not too serious land pressures for the moment, crops such as cotton, corn, tobacco and certain varieties of rice are possible as diversifications from the standard crop mix of peanuts and cereals. In the US/AID cereals project area (SODEVA's Thies and Diourbel divisions) where rainfall becomes a limiting factor such crop diversification is not practiced other than expanding the production of cowpeas. The Sine-Saloum program represents 50 percent of SODEVA's activity and Thies-Diourbel another 30 percent.

From 1964 to 1971, the basic techniques for diffusion were seed treatment, planting on time, planting in straight lines at the proper rates per hectare, single row animal-drawn weeding, light doses of mineral fertilizer (150 kilograms per hectare). These "light" techniques were complemented by a set of "heavy" techniques in 1971. These were based

primarily in the use of oxen-power which could provide more work than the horses and donkeys used previously. They also could for plowing, particularly as a means of minimizing the threat of dry years, and the land management techniques described earlier including crop rotations and the standardizing of field sizes and shape. Their rule of thumb for an oxen-powered operation is a 8 to 12 hectare farm of which 6 hectares are farmed yearly. The use of heavier doses of fertilizer is advised only on cleared and phosphated fields and if the farmer has sufficient equipment and well organized labor to use it efficiently.

As I stated earlier, the Senegalese government has designated the village cooperative as the authorized intermediary not only for the marketing of peanuts and cereals but also for the acquisition of inputs (seed treatments, seed, equipment and credit). Deliveries and marketing are conducted by a government monopoly (ONCAD). Whereas, the Experimental Units, given the scale of their operation, were able to effectively complement not only the credit activities of this monopoly where necessary but also the marketing of cereals, SOREVA has 68,420 farms in the Sine-Saloum Region alone on 763,740 hectares compared to 357 farms on 3,200 hectares for the Experimental Units and cannot afford such independence from national institutions. ONCAD has consistently experienced difficulties in marketing cereals and in delivering the proper amounts of the proper inputs at the proper time. In 1973 for the Sine-Saloum, Thies and Drourbel Regions, 24 percent of the special peanut fertilizer, 56 percent of the special millet fertilizer and 13 percent of the seed fungicide was not delivered and a large portion of the fungicide was delivered too late to be of any use. Of the peanut lifters ordered, 41 percent were not delivered; 46 percent

of the carts ordered were not delivered and 54 percent of the plows ordered were not delivered. SODEVA has set up a small credit and delivery system for inputs but this is necessarily selective and unable to reach 68,000 farms. Though I believe there are other reasons for the marginal impact SODEVA has had on the rural masses, the inability of ONCAD to deliver promised services will have a strong impact on any project so dependent on a new set of inputs and a ready outlet for improved production.

In the Sine-Soloum Region, SODEVA has introduced the full set of "heavy" techniques (TB/FF) including strong fertilizer doses to 978 farms or 1.5 percent. Another 5,699 farms or 8.3 percent are in a transition stage with oxen but not practicing the full package. There are 7,210 farms or 10.5 percent using the "light" techniques (TL) for a total of 13,857 farms or 20 percent whom SODEVA have worked with directly. The farms in the first two groups have a pair of oxen, almost all farms have a horse and there is one donkey for every two farms. The TB's farm 10 percent of the arable land, the TB/FF's 2.6 percent.

There are some interesting distribution questions that arise when looking at the farm size and the stock of equipment or animals. There is an average of one seeder for each farm but each TB/FF farm has three. There is slightly more than one single-row cultivator per farm for the region but 3.3 for each TB/FF. As averages, the TL farms have 11 hectares, the TB have 13 hectares and the TB/FF have 20 hectares with 9, 10 and 15 family members respectively. Counting a pair of oxen, a horse and a donkey each as a traction unit, the average for the region is 1.3 per farm, for the TB it's 2.3 and for the TB/FF it's 3.4 traction units. The TB and TB/FF (10 percent of the farms) applied 71 percent of the mineral fertilisers used in the region and all the use of the heavy doses

was applied by the TB and TB/FF on .5 percent of the total farm land.

Other indications of the extent to which the package has been adopted in the Sine-Saloum Region are a total of 1,403 hectares were plowed in the 1973 season, 4,542 hectares were classified as being cleared of roots and 5,897 were phosphated. Certain fields were phosphated without clearing given the very scarce tree cover and the low number of plowed hectares indicated the small number of plows found on the TB and TB/FF farms, only 2,028 plows for 6,647 farms. There has been however a comparatively marked acceptance of oxen power with more pairs of oxen than TB and TB/FF farms; 8,200 pairs for the 6,647 farms. More and more oxen are being obtained outside government channels, 77 percent in 1973, and trained outside SODEVA training centers, 66 percent in 1973. As stated earlier this has raised the question of the supply of oxen in the future. It seems probably that it will become more and more difficult to find decent oxen, and following developments at Bambey, SODEVA plans to initiate a program to use cows for traction.

One very interesting development in the care of work animals has been the work on local production of concentrated diet supplements. They are based primarily on a generalized measurement of mineral deficiencies in most animals and, except for some copper sulfate and cobalt sulfate, all ingredients are available locally. On the one hand, these supplements are planned as a permanent ingredient to diets and on the other hand, SODEVA has a scheme to take oxen who have reached the end of their productive years and, as a function of market speculations, put them on a finishing diet for two months in the middle of the dry season to sell them when beef prices are the highest. In general this is a standard strategy for animal traction programs but the interesting component in SODEVA's plan

is the cost and effect of their supplement. At a cost of 2 CFA per ox per day, or about a matchbox full per cow per day, I saw animals who had been gaining 500 grams per day over a two month period.

SODEVA's research division's largest activity is the monitoring of their extension agents' effectiveness, the adoption of techniques, the factors of production and the economic consequences of the package. In 1973 in the Sine-Saloum, each local agent was responsible for a total of 240 farms, including 3.4 TB/FF and 19 TB. They likely spent most of their time with about 25 farms. They are responsible for data on areas, yields and techniques practiced on the farms in their area and for more detailed information on a few fields. SODEVA also has a team of 15 informants in the Sine-Saloum who each are gathering detailed input-output data on one TB/FF, one TB and 3 TL farms. They will be compiling data to cover a five-year period which will hopefully furnish some indications on the evaluation of the package through time on real farms. It may also permit an interpretation of the program's impact void of climatalogical variables. This is of particular concern since during the years since 1964 when SATEC began the program, yields have shown great fluctuation and an overall downward trend. Furthermore, the rate of diffusion has not been strong enough to qualify as an extension program for the rural masses which is its official mandate. The data over a five-year period would allow some nullification of climate effects and permit SODEVA to make a better self-evaluation and to develop a rulebook for farm management advice.

In 1971, 260 TB farms were investigated; in 1972, 40 TB/FF farms; in 1973, 26 TB/FF, 19 TB and 15 TL farms; and for 1974, SODEVA plans to investigate 15 TB/FF, 15 TB and 45 TL farms. This shift in 1974 to follow closely more

"light" technique farms than before is indicated in SODEVA's realisation that they have largely concerned themselves with an elite group of farmers in the past.

The most exhaustive analysis to date was that done on the 260 farms in 1971. Besides running factoral correlations using 40 variables and single input variable regressions on yields, SODEVA found it necessary to separate the farms into 11 type-groups. This will have a significant impact on the 1973-77 program as it calls for working with a highly divisible package which can be molded to at least each of the 11 types of farms if not all individual farms. This calls for greatly expanded work in management counseling.

From the 1971 study, some of the practices are strongly reinforced by the farm level data and others are questioned. For mineral fertilisation, the conclusion is that the economic responses are highly dependent on the timely and effective execution of a number of other practices including plowing, land clearing and phosphating. Fertilizer responses on millet without land clearing and phosphating are about 3.5 kilograms and with them about 4.4 kilograms. On sorghum with land clearing the response is 4.1 kilograms and without, 2.9 kilograms. The yield effects of end of season plowing and dry preparatory minimum tillage range from 33 percent on peanuts and millet to 68 percent on sorghum. The loss in yield is 45 kilograms of millet for each one day delay in planting and 43 kilograms per day for sorghum. Thinning out of sorghum shows a 28 percent increased yield. A very striking response is found with sorghum and animal manure. The regression coefficient per kilogram of manure is 18.2 kilograms of grain without mineral fertilisers and 14.4 kilograms with

mineral fertilisers. Again I reiterate that this theme seems to be seriously underplayed by IRAT research.

The most significant question raised by the farm data is the lack of correspondence between the crop rotation practiced and the crop rotation proposed by IRAT research. The yield responses found for millet preceded by another cereal are 40 percent higher than millet preceded by peanuts which is proposed by IRAT.

The economic analyses conducted by SODEVA are, in large part, controlled by the data collected. The five-year data collection program is restricted entirely to field work, animal and equipment stocks, gross financial revenues and costs. Little or no work is done with economic prices (shadow prices, opportunity costs, etc.) and no data is available on non-farm activities. These lacks are well appreciated by the SODEVA personnel and especially important as SODEVA moves toward a more divisible package that can be geared to a wider range of farms. In developing a program of farm management, a much better appreciation of the resources and constraints important to a farmer's decision-making in areas of farm and non-farm activity is a necessary precondition to effective counseling.

1.5. Summary

IRAT research in Senegal has approached the problems of improved productivity primarily as problems of improved land management. This has been a very fruitful approach throughout IRAT's history in Senegal. They have developed a sound technical package for the reconstruction of soil fertility, a good set of equipment and farming practices for the production of annual crops and a range of seed varieties relatively well adapted to arid and semi-arid climates. They have not, however, done as good a job adapting their package to the realities of the majority of farm situations. In my opinion this is caused by the classic French approach to rural development. This approach is widely referred to as the "Paysan de Pointe" or model farmer approach. This strategy is by no means the restricted property of the French and in fact is the implied approach in most of the US/AID mid-term Sahel proposals.

In very general terms, this strategy seeks out the "best" farmers who will be closely counseled by the project. In gross figures, IRAT feels this group will represent about 15 percent of the rural farms. These model farmers will influence another 60 percent of the farms perhaps and the remaining 25 percent are probably not feasible units in any case and can probably not be significantly changed. This approach is often referred to as the "trickle- down" theory of development. The assumption is made that these model farmers who by virtue of their success are opinion leaders who will influence many of their neighbors not only from the respect in which they are held but also by their demonstration of the development package. With this example, more and more of the farms will opt for the package. The problem which arises is the question of equal accessibility.

Are farmers other than the model farmers able to invest in the new technology or are they forced to acquire it piecemeal without reference to the technological cohesiveness of what they can afford? This in fact challenges the representativeness of the model farmer and the replicability of the package.

The "best" farmers are very often the biggest and the richest. These farmers cannot only afford the level of debt involved but also the level of risk. In their zeal to see technological packages function and be accepted, many development research and extension projects forget that they are not dealing with the spectrum of rural farms but an elite group. There is no question that in the process of change some people will change first and some later, and if those who change first happen to be opinion leaders and/or rich, the development agency should not loose sight of its real objective--the bulk of real farms. IRAT seems to have done this. The slow diffusion rates, the piecemeal practice of various techniques and the chronic under-equipment in agricultural machinery are strong indications that IRAT has geared its research and extension models to a rather restricted portion of the population, the "Paysan de Pointe".

As I have indicated previously one of the reasons has been the heavy requirement for capital resources. This is very directly connected to the accessibility of credit. Unless the terms of credit can be adjusted to fit the requirements of the technical package and real potential revenues from that package on a national level, then it is necessary to adjust the investment requirements of the package to the national credit opportunities, rather than establish a special credit program which is available, by definition, only to those farmers involved in the project--these elite farmers. Unfortunately, in recent years the availability of money is

becoming more and more restricted throughout the Sahel as it is throughout the world. The new terms of credit in the Sine-Saloum region of Senegal are 25 percent down payment, 3 years to pay instead of 5 at 7.5 percent interest instead of 5 percent. The level of debt cannot exceed one-third of the previous year's cash agricultural income. Given the government marketing board's inability to effectively buy cereal production, this last condition refers primarily to the farm's income from peanut production.

It would seem that, aside from discussion of alternative credit programs with the national government, reorganisation of the technical package not only to fit the realities of credit opportunities but also to fit the variability of farm sizes and capacities beyond IRAT's "model farm" is necessary. Though there are a number of areas where further research is necessary, the technical components of a more highly divisible package have been developed and the area most in need of further work is farm management counseling. This would involve an explicit understanding of the resources and constraints with which the farmer must contend not only at time zero but as he progressively alters his farm production processes. It would be important to know, for instance, what sort of capital flows will be generated available for reinvestment. This will be a limiting factor for the farmer in deciding what to do next. Another serious problem of resource allocation is the organisation of farm labor. IRAT stresses this point very strongly to the default of capital allocation. However, though IRAT has collected a great deal of data on the time required to hypothetically perform each operation with different technologies, on the time various real farm families spend at field work and on the precise opera-

tions necessary for maximizing returns to various crops, they have not examined the labor requirements of the whole package on real farms. IRAT and SODEVA technicians admit that it is only rarely possible for most farms to perform all the counseled farm practices promoted in the package. Using IRAT's data, it is readily possible to show that unless a farm is exceptionally well equipped or has access to an unusually large number of laborers, it cannot accomplish a number of operations at the prescribed time within the prescribed time limits. The greatest problem is the period in which the first and second weedings, ridging, thinning-out and top-dressing must be accomplished. This bottleneck is made more difficult by the pressure from high levels of indebtedness to expand hectarage.

IRAT research analysis has been limited primarily to partial farm budgeting and single variable correlations. I have already discussed the risk involved in restricting analysis to field activities when you are trying to develop a technical package which responds well to the priorities and ambitions of real farmers. Another weakness in their analysis has been IRAT's tendancy to run only single variable correlations and over-emphasize the correlation of mineral fertilisers and yields without trying to separate explicitly the contribution to increased yields from the range of technical practices. All the indications are that mineral fertilisers need not play such an automatically prominent role in the package. Both IRAT and SODEVA have only recently realized the need for sound farm management counsel' - to farmers that is based on a range of farm resources. In order to develop this more divisible package, research will have to generate more explicit information on farm budgets including farm and non-farm activities and evaluate the economic returns to the package as a whole, as well as the relative role played by each component.

2. UPPER VOLTA

This section on IRAT cereal production research and extension in Upper Volta will discuss only those activities which are of particular interest or differ significantly from experiences in Senegal.

2.1. Background Information

2.1.1. Institut de Recherches d'Agronomie Tropical (IRAT)

IRAT's work in Upper Volta dates from 1961 with three major stations, Sarya and Mogtedo, in the central region of the country and in the southwest, Farako-Ba. Sanya does varietal research in cooperation with IRHO and IRCT and some evaluative work on farming practices. The station sits on 255 hectares of which 35 hectares are used for experiments and 45 hectares for seed multiplication. The average annual rainfall is 820 mm. The station at Mogtedo, installed in 1964, has only 15 hectares used primarily for irrigation research. Its major activity is seed multiplication and propagation of sugar cane seedings. The station at Farako-Ba disposes of 475 hectares of which 20 are used for experiments and 150 for multiplication of corn, sorghum and millet seeds. They also have a herd of cattle, Azaouak and Azaouak-N'Dama, for study and reproduction as work animals and improved dairy producers. The average annual rainfall is 1,120 mm. Beyond these principle centers, IRAT has a series of rural stations for more localized testing of their results. These are primarily found in the valleys of the Volta rivers and are linked to the IBRD/Upper Volta project for the exploitation of the valleys and the arrestation of river blindness.

There will also be some of these localized stations established in cooperation with the US/AID mid-term project for the Eastern Regional Development Organisation (ORD de l'Est). The IRAT network in Upper Volta employs nine expatriot scientists. IRAT's budget is shared by the French Aid and Cooperation Fund (64 percent) and the Government of Upper Volta (36 percent).

2.1.2. Centre Agricole Polyvalent de Formation de Matourkou/UNDP

The United Nations Development Program (UNDP) and the Government of Upper Volta initiated this program in 1963. Its major objectives were to train local and middle level agricultural agents to establish a pilot village to test the technological package and train model farmers and to begin a seed multiplication operation. In Phase II of the project (1968-1973), efforts were begun to improve local breeds of cattle, establish a breeder herd and to create an extension program in selected villages. Phase II's budget was 2.2 million dollars with 0.93 million from UNDP. There are nine expatriot technicians and about 60 Voltan functionnaries working at the Matourkou Center. The relationships between this village extension program and IRAT research are not as institutionally well established in Upper Volta as they are in Senegal but the Matourkou Center is across the road from the IRAT Farako-Ba station.

2.2. Research: IRAT

2.2.1. Seed Variety Selection

Varietal research in Upper Volta has followed perhaps even more classic guidelines of agronomic research than in Senegal but then IRAT in Upper Volta is a much smaller operation and not really set up to undertake as wide a range of study. All variety testing is conducted under conditions of identical doses of mineral fertilisation and technical practices. Separate analysis have been made according to the type of soil. A great deal of effort is being spent on the development of hybrids in an attempt to take advantage of heterosis. The other general theme of seed research has been to reduce the size of the plants in order to reduce the straw/grain ratio.

For sorghums, millets, corns and cowpeas; local varieties, varieties from other countries and crosses for hybrids, composites and dwarfs are all being researched. Upper Volta has made extended use of materials from Mali, Ivory Coast, Nigeria, Senegal, other West African nations, India and the Americas. IRAT has some long cycle F1 sorghum hybrid originating from Samaru in Nigeria which are yielding in excess of four tons per hectare. Their work on shorter cycle sorghums indicate the potential usefulness of Samaru varieties. Most of this work on sorghums has not yet born serious fruit and the most widespread variety is S29 which was perfected from local varieties by IRAT. In good conditions its yield is about two tons per hectare.

As far as millets are concerned, the major themes of research have been very similar to those for sorghums. Beyond proposing the varieties "synthetique 71 de Saria" and "Zalla" to farmers, the remainder of the varieties under investigation are not quite ready for distribution. IRAT has divided its millet research into categories following rainfall averages. For the less than 700 mm. per year areas, IRAT is making extensive use of the Souna III line from Senegal in hybridisation, however with disappointing results (500 kilograms/hectare).

More work on corns seems to have occured in Upper Volta than in Senegal. Two varieties, a white and a yellow, are being proposed to farmers. The yellow, "jaune de Fo", yields 4.5 tons per hectare and the white, Massayomba, 5.0 tons, whereas the "jaune de Fo" seems to do better in the lower rainfall areas. These varieties are purified strains from local Upper Voltan strains that were perfected at Farako-ba. Some first generation synthetic varieties taken from 8 lines of local varieties promise yields beyond the improved local varieties. Extensive comparative testing is being carried out on other West African and Central American varieties. The hope is to take advantage of the potential hybrid vigor from crosses of local and imported varieties.

In the area of cowpeas not a great deal of work has been done. Nevertheless they have begun experiments on 88 varieties, none studies in mixed-cropping, and have some inconclusive indications on a few productive varieties. Peanuts do not occupy as prominent a place in Upper Voltan cropping systems (only 7 percent of cropland) and consequently varieties such as 28-206 and 55-437 from Senegal are being envisioned for Upper Volta.

The potential for irrigated and river bottom rice is taken much more seriously in the semi-arid areas of Upper Volta than in Senegal. This refers to areas that are not major river valleys but rather small valleys and depressions where flooding is a natural rainy season occurance. Where complete control of water is possible, long cycle varieties are proposed by IRAT. Gambiaka has a cycle of 160-170 days, is a long grain rice and has a yield potential of 5-6 tons. Fossa has a similar yield potential and growth cycle but does not do well on flooded land. It prefers a saturated field rather than actual flooding. Other varieties for completely controlled conditions, though promising, are not yet perfected (Sosson and H-14).

For river bottom rice which is naturally flooded for over a long period, Gambiaka does well: but if the length of flooding is not long enough, C.74 does well with a cycle of 135 days. C.74 has been studied extensively by IRAT because it is highly resistent to diseases, responds well to moderate doses of fertiliser and is adaptable to a wide range of conditions. For river bottoms where the length of flooding is even shorter Sintane Diofor (120 days) and Dourado Precoce (105 days) are proposed by IRAT.

As the US/AID Eastern ORD project proposal states, IRAT/Upper Volta has conducted its varietal research (as has IRAT/Senegal) under ideal conditions and uses as its only criteria for selection, maximum yields. A similar lack of economic analysis exists with no study of comparative opportunity costs or input/output ratios being made. Even though these analytical techniques may have their weaknesses, some evaluation of the comparative requirements in labor and capital for each variety and the realistic potential returns to these investments would be of great use to

those responsible for the technological package being proposed to farmers.

2.2.2. Farming Practices and Equipment

The main theme of IRAT's work into farming practices has been the maintenance of soil fertility. Much of the work is similar to what is being done in Senegal. The criteria is always per unit production. This is certainly the simplest measurement, but perhaps investigation of economic trade-offs would again be enlightening.

As stated earlier, phosphorus is again the limiting soil nutrient in most fields. Whether or not this deficiency is connected with one single dose or annual doses, since phosphates cannot be supplied free in Upper Volta, IRAT's prescribed dose of 50 kilograms of P_2O_5 annually is probably more reasonable for the farmer's budget. The speed with which the deficiency is corrected will depend on how often and how much of the crop residues are plowed under. The use of nitrogen fertilisers is not proposed without corrective measures for the phosphate deficiency. IRAT has also been able to demonstrate that the use of high doses of nitrogen are not used efficiently and that nitrogen applications are very sensitive to variations in water supply. This seems to once again point out the importance of variability in potential returns to the package or any of its components. The significant variability in recent years of climatic conditions reaffirms the need for packages which are dependable under variable conditions.

IRAT/Upper Volta has placed much more emphasis on the use of manures, both animal and green. The rotation systems in Upper Volta can still permit fallow years since in most areas, including the Eastern ORD region, land

pressure is far from acute. In those fallow years, IRAT proposes various cover crops, particularly a legume (stylosanthese), as both a forrage and green manure crop. Its benefits are as a good cattle feed, a nitrogen-fixer and as a contributor to organic material in the soil. Animal manure has been shown to have significant yield effects not so much in the first year but in the second and third years. Consequently, the package proposes manure spreading before planting of cereal crops since the cereals show better responses in the first year. Besides contributing to the organic content of the soil, animal manure plays a very important role in limiting the progressive acidity common to most sudano-sahelian soils. IRAT/Upper Volta has compiled a significant amount of data on Ph levels under various conditions. Perhaps the most important observation is that high levels of mineral fertilisation lower Ph significantly (0.5 in 4 years) while heavy doses of organic matter, particularly manure, can raise the Ph factor 0.5 points in the same 4 years. The whole question of rebuilding and maintaining soil fertility is a necessary concern for whatever development package one may propose in the Sahel. The Ph factor is one component of soil fertility that has been neglected and could prove catastrophic. IRAT has discovered that crops can be grown at much lower Ph levels than thought possible (4.0), however the tendency is still towards falling Ph levels especially with higher doses of mineral fertilisers. At this time, it does not seem profitable to apply lime when using low levels of mineral fertilisers and it may be marginally profitable when using high levels of mineral fertilisers. In truth, the real payoff to liming will not be on a yearly basis but in the long run. This is potentially a serious problem and IRAT is justifiably anxious that Ph levels will descend to critical levels before sources of lime and programs for its distribution are developed.

In large part, the use of oxen and animal traction techniques are for the most part, the same as those proposed by IRAT/Senegal. End of season plowing, plowing-under, seed-bed preparation with minimum tillage equipment, weeding techniques and peanut lifting practices are all integral components of the package. The most significant difference in Upper Volta is the longer duration of the rainy season. Between 1966 add 1973, the average date for the first 20 mm. rain was about May 15, considerably earlier than what can be expected in Senegal. Consequently, there is significantly less pressure on farmers to quickly finish their land preparation and get their crops planted. This is demonstrated by the slow adoption of animal-drawn seeders. There is also less pressure on doing preparatory operations before the rains. The serious bottlenecks in Upper Volta seem to be the weeding, ridging and top-dressing period and the harvest. There is good reason to move to two-row cultivators to improve the weeding operations as well as alter plant spacing to facilitate two-way weeding. The harvest of all crops requires a great deal of labor. Cotton, where there is enough water to grow it, takes about 900 man hours per hectare; sorghums and millets 115 man/hours; peanuts 200 man/hours for a total of 1,330 man/hours for 4 hectares. This is only the simple harvesting. If the various clearing, threshing and transport activities are included, the total rises to about 2,100 man/hours. A particularly revealing statistic generated by IRAT technicians in Upper Volta from 10 years of observations including approximately 10,000 individual measurements is that the average effective daily work one can expect from Upper Voltan farmers is four to five hours per day. In general there are 60 days available for harvesting processing operations during the months of October and November. Using five man/hours per day, there are

460 man-days of work required. This would require a work force of 7.6 labor units not counting any end-of-season plowing and on only four hectares. This would be a very large family for only 4 hectares. Beyond use of the animal-drawn peanut lifter, IRAT proposes the eventual investment in a peanut thresher and a pedal operated rice thresher if he grows rice. In my own experience in northern Dahomey with the pedal operated rice threshers, we found them to be very effective on sorghums as well.

The equipment used in Upper Volta is primarily the "Arara" line of Siscoma equipment. Its price in Upper Volta is about 20 percent higher than the Senegal price but there are no alternatives for the moment. The International Labour Organisation is assisting Upper Volta in the development of an artisan workshop and the training of rural blacksmiths and carpenters. They have just developed a line of equipment based on the Arara plow and ridger and on the minimum tillage equipment from Siscoma that is 20 percent cheaper, makes a maximum use of hammer welding and is designed with the rural artisan in mind. This whole area of village-level capacity for construction and repair of agricultural equipment has been given far more consideration in Upper Volta than in Senegal.

I would like to return to IRAT's labor data to discuss its possible implications. They seem to be twofold. If one can only expect 5 hours of effective work per day from farmers, this will have a significant effect on project designs. Most planning tends to intuitively assume from a six to eight hour work day. This would mean anywhere from a 17 percent to 38 percent reduction in daily work and would seriously alter the allocation of labor in any package program. Furthermore, if the farmer is only working 5 hours per day in his fields, then there must be other activities he engages in that are important enough to him to justify his time away from

the fields and thus have a significant economic opportunity cost. What these activities are is largely unknown and simply reinforces the earlier statement that nonfarm activities play an important role in the farmer's priorities and should be given serious thought in the design of development packages.

To close this section, the primary reason for introducing the Azaouak breed of cattle from Niger was to increase the traction power available. From extensive experimentation, IRAT has determined that to perform the necessary operations correctly the farmer needs 100 kilograms of traction power. Using the standard ten kilograms of weight for one kilogram of power, this means the farmer needs 1,000 kilograms of weight or two 500 kilogram animals. The local Zebu and N'Dama breeds cannot reach this weight. The Azaouak can and is being bred with the N'Dama for the N'Dama's resistence to sleeping sickness. Although IRAT and the government seem to be in a position to deliver these animals at an economic price, the automatic habit of castrating local breeds for working animals may affect their work capacity. In Dahomey, the marginal weight of the local Zebu was recognized and rather than render them more docile through castration, we preferred to depend on their spirit to make up for what they lacked in weight. Furthermore, castration was usually performed on animals far too old for it to have the desired weight effects.

2.3. Pilot Farm: Sarya

As I stated earlier, IRAT/Upper Volta does not operate on as wide a scale as IRAT/Senegal. At the Sarya station, they did establish a farmer on 8 hectares in order to study their package on a full scale. This farm was begun at the end of the 1968 rainy season to simply test the package as a whole under constraints true to a real family. The principle techniques employed were a progressive installation on the eight hectares, simultaneous use of all the farming practices and application of maximum doses of mineral fertiliser and plowing-under techniques. A significant adjustment was made in the farm in 1972. The field plots were reduced from one hectare to .8 hectares to accommodate the family's labor force, 7 workers. The rotation system introduced at one crop per year was cotton, sorghum, peanuts, sorghum, family crops, and .4 hectares of river botton rice, with 3 plots of fallow for a total of 6.8 hectares. This is a rather small crop acreage for 7 workers, 4.4 hectares or .62 hectares of crops per worker. It is not clear what the limiting labor constraints were, but they seem to be in the planting and weeding operations. It would seem possible to alleviate these bottlenecks with seeders and two-way weeding, but as I said no clear explanation of the constraint seems to be readily available.

The economic evaluation again is simply field accounts and even these are misleading as the farmer rents the majority of his equipment from IRAT at rather complicated financial accountings of rental rates that seem to grossly underestimate what the farmer would be paying if he had to buy the equipment on credit. Even using their methods, the average annual net profit not counting nonfarm expenses other than grain consumption was only about 30$ per capita per annum. For that matter, the gross per capita

income was 70$ per annum once the whole rotation system was installed. This 70$ does not include nonfarm expenses and uses low equipment cost estimates. Another interesting observation is that 68 percent of his field costs over 5 years were mineral fertilisers and in the fifth year with all the crops installed, fertilisers represented 40 percent of his costs. These costs were calculated using what today are outdated fertiliser prices.

IRAT did not intend this farm as a development project but primarily as a laboratory. Their conclusions from the 5 year study were the need for more extensive use of the animals, an improvement of weeding techniques and mechanisation of certain harvesting operations. Despite IRAT's intentions, the farm did have a demonstration effect on neighboring farmers. By 1973 about 20 farmers had requested similar assistance from IRAT. This not being IRAT's role, they referred the farmers' names to the local Rural Development Organisation (ORD) at Kondougou. Once again the problem of replicability presents itself. The very close supervision, the loan of equipment and the loose financial terms are services that cannot be provided on a large scale. As a laboratory, the pilot farm certainly services a purpose, but as a mechanism for diffusion significant changes in its design are necessary, especially if the parameters used for economic analysis are expanded to encompass the resources and constraints actual farmers must deal with.

2.4. Extension: Matourkou/UNDP

As its title indicates, the Matourkou project has many areas of activity. Since 1963, the Matourkou project has had a training center for agricultural agents. Matourkou has trained 144 Agricultural Technique Agents (ATA) and 332 "Enadreurs" or village-level extension agents. Matourkou has established a 30 family prototype village at the center much along the lines of Israeli pilot village programs where farmers practice the package of agricultural practices under the close supervision and study of Matourkou personnel. The prototype village is seen largely as a laboratory to test Matourkou's package. Matourkou has a livestock program aimed at improving dairy production with a herd of Azaouak and at improving meat production and animal traction stock with Azaouak-Zebu crosses. They also have a seed multiplication program which has produced, between 1966 and 1972, 100 tons of sorghum seeds, 105 tons of corn seeds, 20 tons of peanut seeds, 35 tons of cotton seeds and 270 tons of grass seeds. An interesting observation is that the vast majority of corn seed produced is an improved local variety, Koriba, that IRAT makes little use of. Nowhere in IRAT research did I see any reference to the peanut variety, 1040, which has the largest seed production at Matourkou. Neither of these varieties appear in the US/AID Eastern ORD proposal. I cannot explain this.

The component of the Matourkou project of most direct concern to this paper is the village extension program. In 1969 and 1970, while looking for a method of diffusion for the package that would be of use to Upper Voltan agricultural extension services in general, Matourkou evaluated two basic approaches--a concentrated, intensive village approach and an extension individual approach. In 1971 the decision was made to opt for the

village approach with a total of 200 families in 6 to 7 villages. As of 1973, there were 198 families in 6 villages.

It is somewhat difficult to make a serious analysis of the impact of the village project. The data available to me in the final report of Phase II includes no breakdown by farm of techniques practiced, yields per hectare, variable and fixed costs or of population. All data is given in monetary terms and aggregated to the total number of farms in each village who are participating which is an average of about 25 percent of the village farms.

Judging from the reports and discussions with agents in the field, the village approach and the method of diffusion are critical elements in the Matourkou program. The objectives of the program are to sedantarize farming and maintain fertility levels to allow permanent farming. The experimental aspect of the program is to discover how a new integrated farming system can be introduced, what assistance is necessary and how must the "model" be adapted to varying ecotypes. The hope is that this will serve as a guideline to development programs throughout Upper Volta. A great deal of reference is accorded to group dynamics. Their conclusion from the individual farmer approach is that it tends to create too many rivalries, jealousies and factions in a village to be effective beyond a few farmers. Also, given the need for some sort of permanent "title" to land to justify the long range investments the farmer will be making in his land and in the absence of any official land tenure program, a village agreement to cede various farmers the land is the next best thing. In point of fact this has been where these jealousies have surfaced in the village approach. When others see the progress these farmers are making, they are trying to

reclaim land that had been handed over to the Matourkou farmers and only through continued pressure by the agricultural agents has this been avoided. This "community development" approach goes further than just the animal-traction farmers to include self-help well, bridge and storehouse construction; cooperative ownership of carts and crop processing equipment and the establishment of farmers' credit unions. The credit unions, however, have been effectively vetoed by the National Development Bank (BND) for the time being.

I must admit that the physical appearance of 14 rectangular 8 hectare plots on the edge of Tongan-Koura was very impressive. Each village has its own agricultural agent, there are 4 home economics agents, 2 expatriot experts and 2 Voltan counterparts. That is a lot of agricultural extension agents for 6 villages in Upper Volta and immediately raises the question of replicability and to what extent is the viability of the program dependent on the constant support and presence of the extension agent.

Using the oldest of the villages, Kono and Bare, and very general data of questionable value, even Matourkou's data indicates a gross per cepita income of 33$ per annum and 19$ net income per capita per annum. I am not sure that these figures are very significant other than to point out that the Matourkou project, though exbiting some rather interesting diffusion techniques, has not attempted a rigorous defense of their model through a careful economic analysis either of the project costs nor of the economic returns to farmers. In the Phase II final report, the disclaimer is made that the project is too new, 4 years old, for any economic analysis to be meaningful and consequently the economist's report has been withheld as an in-house paper.

2.5. Summary

This section on Upper Volta has been brief for two reasons. I only wanted to highlight research developments that offered a significant addition to IRAT's experience in Senegal. The other reason is the extremely short amount of time I had in Upper Volta.

IRAT research in Upper Volta is a much younger and smaller network than its Senegalese counterpart, but it has done some very useful technical work. Though much of its varietal work perhaps overemphasizes the promises of hybrids, IRAT has made extensive use of varieties from other parts of the world, a cooperation that should be taken for granted when working in such difficult climatological conditions. Their work on the relationship of man/hours per crop and man/hours per day has very significant repercussions for project planning.

The approach to farming practices is similar to IRAT/Senegal's and the frank admission is made that the efficient use of improved varieties and mineral fertilisers must be preceded by the adoption of a cohesive package of farming practices. Their concern for the maintenance of soil fertility led them to emphasize manure spreading and the danger of falling Ph levels. Unfortunately, I could not uncover any estimates of potential farm production of manure which would influence the rates at which it could be spread.

Economic analysis suffers the same deficiencies as in Senegal. At best they are restricted to partial farm budgets which make poor sense in West African rural farming where the farm is not only the producer but the processor and major consumer of the farm's produce. The almost total lack of reference to nonfarm activities further distorts partial budgeting, especially since the farmer seems to spend about 10 hours a day doing something

other than field work.

The equipment package is simplier than in Senegal but also less divisible. The lack of data makes it difficult to discuss capital requirements but the credit terms available to farmers outside the Matourkou project are 15 percent down and 3 years to pay while within the project they are three years grace, 5 percent interest and 5 years to pay. I don't argue that Matourkou's terms are better adapted to their package but can the same package be proposed to farmers who don't have access to such terms? Here again the lack of complete data makes it impossible to evaluate how much disposable income is in fact generated by the package and what credit terms would be necessary.

3. CONCLUSION

IRAT research in Senegal and Upper Volta has a long and technically productive history. The underlying objectives of their work have been to develop seed varieties for cereal crops with high yield potential and/or short growing cycles and to rebuild and maintain soil fertility. The development package that has grown out of their research results is in large part technically quite effective. One of the difficulties with the technical package has been that the evolution of its design occured largely in response to physical agronomic constraints observed in research situations. Consequently there are serious questions of labor and capital requirements, of scale and divisibility and of credit and marketing accessibility.

The components of the package, given that one is operating with significant mineral fertiliser requirements and a high level of capital and labor investment, would seem to promise an improvement in soil fertility. The connection of phosphate deficiencies and plowing-under are the fundamental elements. Identification of the serious problem of soil acidity will hopefully stimulate planners to incorporate some sort of remedial strategy. The wide range of benefits from animal manure and its potential on-farm production has received far less emphasis that it warrants.

The animal-drawn equipment designs developed by IRAT are fortunately highly divisible. The proposed package, however, tends to be a product of solely physical requirements with little or no reference to the farmers' economic and resource capabilities. The result is a package that in most situations is feasible for a small minority of farmers, the "Paysan de Pointes". If significant progress is to be made in agricultural production,

in the standards of living and in the reconstruction of soil fertility, then the package which development programs propose will have to be far more responsive to the real capacities and constraints of a broad spectrum of farmers. This will require a higher degree of divisability and a lesser emphasis on optimum conditions. The rates of adoption observed in Senegal and Upper Volta seem to indicate that the farmers are being handed a package which they are forced to acquire in a piecemeal fashion and impose an incohesive divisibility. This should not be a farmer's responsibility but rather the responsibility of research and extension agencies.

The methods of agricultural extension of the package are strongly influenced by the "Paysan de Pointe" or model farmer approach. The tendency of model farmers to be big or rich farmers and the desire to achieve a diffusion that is both measurable and visible in a short period of time have strongly influenced the choice to use village cooperatives as the central engine of developmental change. The US/AID projects have basically accepted the "Paysan de Pointe" approach as well as the IRAT technological package. I have stated my reservations earlier. It would appear that from a technical point of view, the package does lend itself to a reshuffling of its components which will be necessary if accessibility to the package is to be guaranteed to a wide range of farm situations. Unfortunately, two important components which the projects can do little about beyond the few hundred farmers they will be able to reach are credit and marketing. In a very real sense, national credit terms must be taken as a given if the project looks outside itself and beyond its life span and the package must be geared to the real terms of credit. This is likewise true of marketing systems. An objective evaluation of the real opportunities for the sale and price of cereals should be a given component of the package. Undoubtedly,

the greatest weakness in the US/AID mid-term Sahel projects is their three to five years time horizon. Most animal traction programs in my experiences take about three years to show reasonable returns to farmers and it is usually in the third or fourth year that the program really takes hold. Assuming that an improved degree of divisibility is programmed into the package, the US/AID projects will obstensibly be backing out just as the package begins to prove itself. This necessitates that even more serious thought and planning be given to the real conditions in which farmers will be operating and to the building of viable institutions that can be realistically expected to maintain its delivery of services after the termination of US/AID intervention.

Economic evaluation of the technical package has been very rudimentary. This has been a classical deficiency in technical research and is by no means unique to IRAT. It has consisted primarily of partial farm budgeting and single variable regression techniques. As I stated earlier, the rural farm is a producer, processor and consumer all at the same time. The economic criteria that the farmer uses to assist himself in making decisions needs much more analysis. His allocation of time for both farm and nonfarm activities will have economic consequences. It is crucial that a better understanding of how much disposable labor and how that labor is utilized be obtained and that the proposed package be designed with reference not only to technical requirements of the package but also to the farmer's system of priorities and resource capacities. We need a much better understanding of the real economic costs and returns to the whole range of proposed inputs. IRAT has consistently reduced yield response analysis to single variable correlations and consequently has very inspecific data on the responses to various inputs. By reducing the increased yields to

solely fertiliser responses, the contributing effects of the other inputs and farming practices are lost. Multi-variable correlations would provide valuable information to planners and I would venture a contention that the package could be reorganized in such a fashion as to significantly reduce the role of mineral fertilizers.

In conclusion, IRAT has a wealth of research and farm data that will be of great use to US/AID project programming. The first priority should be more sophisticated economic analysis of experiences to date and the acquisition of broader economic information on rural farm activities such that the technological components developed and tested by IRAT can be integrated into development package which will be relevant to the bulk of rural farmers. In the sudano-sahelian zone and especially with the abnormal conditions of recent years not a great deal is understood about traditional farmers' decision-making and particularly the role of risk aversion. Development programs which propose to reach the bulk of rural farms, much less the "poorest of the poor", require a more precise knowledge of the economic tradeoffs confronted by the farmer in evaluating the proposed package than is presently available and a significantly longer time horizon than three years.

4. BIBLIOGRAPHY

4.1. Senegal

IRAT, L'IRAT au Senegal, Bambey, Senegal, Novembre 1973.

IRAT, L'IRAT dans le Sine Saloum, Bambey, Senegal, Decembre 1971.

IRAT, Fiches Techniques Etablies en vue de la Realisation de L'Experimentation Agronomique (Campagne 1974-75), Bambey, Senegal, Mars 1974.

IRAT, Les Mils (Pennisetum Typhoides) Cultives au Senegal, Bambey, Senegal, Octobre 1972.

Etasse, C. Laurent, P., "Index des Principales Varietes de Sorgho Cultivees au Senegal, Varietes Locales et Recommandees," Les Cahiers d'Agriculture Pratique des Pays Chauds, no. 1, 1971, Paris.

Etasse, C. Laurent, P., Additif a l'Index des Principales Varietes de Sorgho Cultivees au Senegal (Varietes Locales et Recommandees), IRAT/Bambey, Senegal, Mars 1974.

Magne, Aubin, Gracien, Delafond, Les Varieties de riz Cultivees au Senegal, IRAT/ Bambey, Senegal, Juillet, 1972.

Magne, Aubin, Gracien, Delfond, Additif au Catalogue des Varieties de riz Cultivees au Senegal, IRAT/Bambey, Senegal, Mars 1974.

Durovray, J.; Gracien, F., Les Varietes de Mais Pluvial au Senegal, IRAT/ Bambey, Senegal, Octobre 1972.

Plessard, F., Une Experience d'Introduction de la Batteuse a Mil Mecanique en Milieu Rural - Analyse et Resultats, IRAT/Bambey, Senegal, 20 Avril 1974.

Tourte, R., Reflexions sur les Voies et Moyens d'Intensification de l'Agriculture en Afrique de l'Ouest, IRAT/Bambey, Senegal, Mai 1973.

IRAT, Necessite Agronomique et Interet Economique d'une Intensification des Systems Agricoles au Senegal, Bambey, Senegal, Fevrier 1972.

Ramond, C., Introduction of Intensive Schemes in Traditional Farms - Economic Consequences, Bambey, Senegal, January 1971.

IRAT, Cereal Problems in Senegal, Liaison Document No. 4/72, December 1972, Bambey, Senegal.

Monnier, J.; Talibart, P., Contribution a la Definition de l'Exploitation Agricole au Senegal - Exploitation et Intensification, IRAT/Bambey, Senegal, Decembre 1972.

Ramond, C.; Tournu, G., La Penetration des Themes Thechniques et Leurs Incidences sur les resultats Agro-Economiques, IRAT/ Bambey, Senegal, Mai 1974.

Monnier, J., "Relations entre Mecanisation, Dimensions et Systemes d'Exploitation," Machisme Agricole, No. 38, Parc de Tourvoie, 92-Antony, France.

Razakaboana, F., Adaptation des Innovations Techniques de la Recherche au Milie Rural, Document no. 373, IRAT/Senegal, Decembre 1972, Dakar.

Monnier, J.; Plessard, F., "Materiel a Grand Rendement pour Traction Bovine," Machinisme Agricole - No. 42, Parc de Tourvoi, 92-Antony, France.

Albenque, D., Organisation du Travail dans le Carre Ouolof, IRAT/Bambey, Senegal, Mai 1974.

Gillain, Sadoul, Rapport de Mission au Senegal - Recommandations et Decisions pour l'Utilisation des Resultats Obtenus dans les Unites Experimentales Conduites par l'IRAT dans le Sine Saloum pour les Structures de Developpement Rural, Secretariat d'Etat des Affaires Etrangeres Charge de la Cooperation, Direction de l'Aide au Developpement Rural, Service des Etudes Techniques, Paris, France, Janvier 1973.

IRAT, Note d'Observations sur le Rapport de Mission au Senegal de MM. Gillian et Sadoul (26 Novembre - 16 Decembre 1972), Bambey, Senegal, 1973.

Tardieu, H. Ramond, C., Premier Essai d'Application de l'Analyse Factorielle a l'Economiq des Exploitations dans les United Eperimentales du Sine Saloum - Campagne 1969-1970, IRAT/Bambey, Senegal, Decembre 1970.

Raymond, C., Analyse des Rendements Parcellaires en Milieu Paysan - Resultats Obtenus Pendant la Campagne 1970, IRAT/Bambey, Senegal, Mars 1972.

Ramond, C., Economiq des Exploitations Paysannes des Unites Experimentales (Campagne Agricole 1970), IRAT/Bambey, Senegal, Avril 1972.

Monnier, J. Talibart, P., Premiers Resultats de l'Enquete Socio-Economique Detaillee Entreprise en 1971 dans le Sine-Saloum - Cas d'une Exploitation de la Zone de Mioro-Du-Rip, IRAT/Bambey, Senegal, Mars, 1971.

Ramond, C.; Gorgeu, Y., Analyse des Rendements Parcellaires en Milieu Paysan - Resultats Obtenus Pendant la Campagne 1971, IRAT/Bambey, Senegal, Juillet 1973.

Tourte, R. et Kleene, P., Unites Experimentales du Sine-Saloum; Rapport d'Activites de Recherch-s (Juillet 1972 - Juin 1973), IRAT/Bambey, Senegal, July, 1973, 8 vols.

Ramond, C.; Tournu, G., Unites Experimentales du Sine Saloum: Analyse des Rendements Parcellaires en Milieu Paysan - Resultats Obtenus Pendant La Campagne 1972, IRAT/Bambey, Senegal, Fevrier 1972.

Richard, J. F., Le Conseil de Gestiln aux Exploitations Agricoles du Sud du Sine-Saloum, IRAT/Bambey, Senegal, Mars 1974.

Ramond, C.; Tournu, g., Les Facteurs de la Production Agricole dans les Unites Experiemntales du Sine Saloum - Bilan de 4 Annees d'Observation, IRAT/Bambey, Senegal, Mai 1974.

SODEVA, Presentation de la Sodiete de Developpement et de Vulgarisation Agricole, Dakar, Senegal, Decembre 1973.

SODEVA, Presentation du Projet du Developpement Rural de la Region du Sine-Saloum (Sud et Est), Dakar, Senegal.

SODEVA: Delegation du Sine-Saloum, Bilan Technique des Activites 1973; Preparation de la Campagne Agricole 1974, Decembre 1973 - Janvier 1974, Kaolack, Senegal.

SODEVA - Delegation du Sine Saloum, Annexe du Bilan Technique-Campagne 1973, Kaolack, Senegal.

SODEVA, Compte-Rendu du Stage de Formation des Enqueteurs-Kahone, Kaolack, Senegal, Mai 1974.

SODEVA, Resultats des Enquetes dur les Structures d'Exploitation dans la Region du Sine-Saloum (Annee 1971), 142 Rue de Bayeaux, Dakar, Senegal.

SODEVA, L'Equipment des Paysans en vue de l'Intensification et de la Diversification des Exploitations Agricoles Encadrees par la SODEVA, Kaolack, Senegal.

SODEVA, Examen des Operations de Credit Pratiquees par la SODEVA-Credit Special, Dakar, Senegal, 1973.

SATEC, Selected References, Paris, May 31, 1971.

SATEC, Bibliographie des Rapports "Senegal"; Annees 1963 a 1969, Paris, Septembre, 1972.

SATEC, Bibliographie des Ra-ports "Senegal"; Annees 1970 et 1971, Paris, Septembre 1972.

Hopkins, E., La Reaction des Paysans a un Programme de Developpement Agricole - La Traction Bovine au Senegal, Institute of Development Studies, Brighton, England.

Hopkins, E., "'Operation Groundnuts': Lessons from an Agricultural Extension Scheme," Institute of Development Studies Bulletin, Vol. 5, No. 4, May 1974, Brighton, England.

Attonaty, J-M., et Hautcolas, J-C, Du Programme Linearire au Calcul Automatise de Budget d'Exploitation Agricole, I.N.R.A., Laboratoire d'Economie Rurale, 78-Grignon, France, 1970.

4.2. Upper Volta

IRAT, L'I.R.A.T. en Haute Volta, Ouagadougou, Upper Volta, Juin 1974.

IRAT, Rapport Annuel 1967 - Machinisme Elevage et Cuotures Fourrageres, Ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1968 - Machinisme Agricole, Ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1970 - Machinisme Agricole - Cultures Maraicheres, Ouagadougou, Upper Volta.

IRAT, Principaux Resultats Agronomiques Obtenus par l'Institut de Recherches Agronomiques et des Cultures Vivrieres en Haute Volta - 1960-1971, Ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1970-Selections Vegetales, Ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1971-Selections Vegetales-Sorgho-Mil-Mais, Ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1972-Selections Vegetales-Sorgho-Mil-Mais, ouagadougou, Upper Volta.

IRAT, Rapport Annuel 1973-Selections Vegetales - Sorho-Mil-Mais-Niebe, Ouagadougou, Upper Volta.

IRAT, Experimentation Agronomique d'Accompagnement - Resultats 1973, Ouagadougou, Upper Volta, Fevrier 1974.

IRAT, Liste des Experimentations Agronomiques Conduites par l'IRAT/Haute Volta en 1974, Ouagadougou, Upper Volta.

IRAT, Programme de Recherches dans le Domaine de la Pedelogie, l'Agronomie et l'Evaluation des Systemes Techniques de Production, Ouagadougou, Haute Volta, Mai 1974.

Poulain, J. F., Arrivets, J., Effet des Principaux Elements Fertilisants Autres que l'Azote sur les rendements des Cultures Vivrieres de Base, Sorgho-Mil-Mais, au Senegal et en Haute Volta, IRAT/Ouagadougou, Upper Volta, Juillet 1971.

IRAT, Fumures proposees a la Vulgarisation et Fumares Appliquees dans les Experimentations IRAT en 1973, Ouagadougou, Upper Volta, Juin 1973.

IRAT, Proposition pour un Appui de l'IRAT au Projet US-AID est-Fada N'Gourma en Haute Volta, Ouagadougou, Upper Volta, Juin 1974.

IRAT, La page de la Recherche - L'Amelioration Varietale du Riz, Ouagadougou, Upper Volta.

IRAT, La Page de la Recherche - La Maisiculture - Resultats de la Recherche en Haute-Volta, Ouagadougou, Upper Volta.

IRAT, Note sur le Travail du Sol avec l'Aide de la Motoculture, Ouagadougou, Upper Volta.

IRAT, Station de Saria - Resultats 1969-1970-1971, Saria, Upper Volta, Octobre 1968.

IRAT, Etude des Systemes Techniques de Production - Premier Bilan des Resultats Obtenus sur l'Exploitation Experiemntale de Saria - (1968-1973), Ouagadougou, Upper Volta, Mars 1974.

Fraddosio, Ugo, Rapport Final de Synthese Projet UPV-68-507 (1 Mai 1968 - 30 Avril 1973), UNDP/FAO, Matourkou, Upper Volta, 15 juin 1973.

Fraddosio, Ugo, Rapport Final de Synthese - Annexes, UNDP/FAO, Matourkou, Haute Volta, 15 jiun 1973.

Peeters, W.H.A., Aspects Communautaires dans l'Action de Matourkou - I Rapport, UNDP/FAO, Matourkou, Upper Volta, Janvier 1973.

Peeters, W. H. A., Aspects Communautaires dans l'Action de Matourkou - II Annexes, UNDP/FAO, Matourkou, Upper Volta, Janvier 1973.

Moreno, Amos, Rapport Final de l'Expert en Vulgarisation Agricole, UNDP/FAO, Matourkou, Upper Volta, Avril 1973.

Van Binsbergen, Hans, Rapport Final de l'Expert en Production Animale, UNDP/FAO, Matourkou, Upper Volta, Fevrier 1973.