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9. ABSTRACT
Contracts AID/Afr-C-1257 and 1258 arose through a recognition of the need for a better understanding of the farming in the Sahelian country and for more date for use in project design and appraisal. In all of the small and medium irrigated perimeters, the farmers have a variety of agricultural activities including rain-fed and flood recession farming, so the two contracts have been conducted as one unified program, with separate accounting. The objectives of the two research projects taken collectively are to: identify impediments to increasing food grain production; identify technical, market and policy interventions that offer potential for relaxing constraints; evaluate the impact of alternative interventions on production of food grains and competing enterprises by typical production units; and develop a schema for the economic evaluation of small and intermediate sized irrigation projects. There are four general categories of procedures: description, model development, model application, and analysis of irrigation projects. The food proplems in the Sahel Countries first caught the attention of the world during the early 1970's when this region was hit by a very severe drought. As the situation existing in those countries and possible means of resolving their long-term problems were studied, several interrelated problems became obvious. Food grain production in the region had been stagnant several years prior to the drought and countries of this region have rapidly increasing population. The combined effect of these factors led to declining per capita food grain production. The knowledge gained in the descriptive phase of this research will be used to develop models of micro production units. These models will be used to identify those variables most constraining on agricultural development, to provide information on the sensitivity of typical farmers to changes in these variables, and to

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evaluate the likely impact of selective programs and policies on production of traditional food grains and competing crops.

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PROGRESS REPORT
ON
CONTRACTS AID/AFR C-1257 and 1258

The Costs and Returns of Sorghum and Millet Production in the Sahelian Countries.

The Costs and Benefits From Small and Medium Sized Irrigated Perimeters in the Sahelian Countries.

Prepared for USAID

April 1978

West African Program

Agricultural Economics Department

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Introduction

Contracts AID/Afr-C-1257 and 1258, arose through a recognition on the part of AID/AFR/SFWA and Purdue researchers of the need for a better understanding of the farming in the Sahelian country and for more data for use in project design and appraisal. It quickly became apparent that in all of the small and medium irrigated perimeters, the farmers had a variety of agricultural activities including rainfed and flood recession farming. With the tacit agreement of AID, the two contracts have been conducted as one unified program, with separate accounting. Although originally conceived to cover the OMVS region, in response to AID's request the study was extended to cover the six Sahelian Countries, as far as possible.

The objectives of the two research projects taken collectively are:

1. To identify impediments to increasing food grain production;

2. To identify technical, market and policy interventions that offer potential for relaxing constraints;

3. To evaluate the impact of alternative interventions on production of food grains and competing enterprises by typical production units; and

4. To develop a schema for the economic evalualuation of small and intermediate sized irrigation projects.

The first three objectives cited above pertain to both rain fed and irrigated agriculture. The fourth objective pertains only to irrigation and therefore is specific to the project on economic evaluation of small and medium sized irrigation projects.

Procedure

The procedures followed fall into four general categories. These are description, model development, model application, and analysis of irrigation projects. The purpose of the descriptive phase of the project was to characterize agricultural production and the environment in which it occurs in the Sahelian region. This characterization occurs at several levels. First, it was necessary to identify and describe the major production regions within the Sahel. Regions were described in terms of climate, soil, existing agricultural production patterns, access to markets, and population density. Secondly, it was necessary to identify and describe alternative agricultural production techniques (current and potential from research and observation in other parts of the world). Third, the economic environment within which the production unit operates is being described in terms of factor and product prices, and their variability. Collectively, these efforts provide a detailed description of the environment in which production occurs.

* This covers irrigation projects up to about 1000-2000 ha.

Having described the production environment in terms of physical, technological, economic and policy characteristics, it is then necessary to characterize farmer behavior. That is, we are trying to describe the farmer as a decision maker in terms of a set of characteristics which we hypothesize to affect the kinds of production decisions made. Some o' the variables of interest in characterizing farmer behavior are a) goals or objectives, b) attitudes toward risk and change, c) perception of government policy and attitudes toward government, d) perception of market signals and responsiveness to these signals, e) perceived constraints on production, and f) interactions between family and household goals, and production activities.

The descriptive component of the study has been based on 1) a thorough review on existing literature, 2) a survey of production units, 3) interviews with government officials, and 4) interviews with researchers. The focus of data collection and descriptive analysis will be on the micro agricultural unit. Other analysis will be conducted only to the extent necessary to define the environment within which the micro production unit exists and operates.

Model Development

The knowledge gained in the descriptive phase of the research has been used to propose models of micro production units. While the particular model structure has not been identified and is, in fact, a major component of the research itself, some desirable characteristics of models can be stated. These include: 1) behavioral rules which reflect actual micro production unit behavior, 2) the model should reflect both internal and environmental constraints on production behavior, and 3) the model should be flexible enough to incorporate a wide range of production and intervention possibilities. Thus an attempt will be made to develop a model structure which is reasonably general so that it can be applied with relatively minor modification to reflect behavior of typical production units in the various sub strata of the Sahelian region.

Application of Models

Once models have been developed and verified they will be applied so as to accomplish three purposes. First, the models will be used to identify those variables, both internal and external, which are most constraining on agricultural production. Secondly, the models will be used to provide information on the sensitivity of typical production units to changes in these most constraining variables. Finally, the models will be used to evaluate the likely impact of selective programs and policies on production of traditional food grains and competing crops on typical production units.

Analysis of Irrigation Projects

The final component of research procedures anticipated involves the analysis of existing irrigation projects to identify economic characteristics of alternative irrigation systems and to evaluate the economic viability of these alternative approaches to irrigation. Using experience gained from evaluation and analysis of existing projects, a set of criteria and procedures for evaluation of small and medium scale irrigation projects will be produced to facilitate future project evaluation.

Site Selection

We adopted three criteria for site selection:

1. that each site must form a sample of some unique and important production situations in the region. A statistically representative sample is not operationally feasible.

2. that the sites must be selected from those whose study is a government priority and one in which appropriate governmental agencies are prepared to collaborate with us.

3. that the sites should represent production situations likely to be of interest to USAID.

To avoid future misunderstanding, this inventory had to be made without committing us to any given site or even to any country. Our progress was discussed with AID field staff in each area.

We accepted the traditional division of the region into three major ecological zones by average annual rainfall:

I. Sahelian Zone, 300 to 600 mm. Millet and peanut production.

II. Sudanian Zone, 600-900 mm. Millet, sorghum, cotton and peanuts.

III. Sudano-Guinean Zone, 900-1200 mm. Sorghum, maize, pluvial rice, cotton and peanuts.
The Forest Zone, over 1200 mm is only present in very small areas (S. Casamance, S. Mali, and Western Upper Volta).

In the Sahelian Zone we identified the Senegal River Valley (dryland farming, flood recession and irrigation) the River Niger in Niger, the Dogon area in Mali, and Bol, Chad. In the Sudanian Zone we identified the Peanut basin in Senegal, Kita and Sikasso, in Mali, and the AVV in Upper Volta.

For irrigation we identified small and medium perimeters on the Senegal River; supplementary irrigation with the CNRA Liaison group; Casamance rice; a managed bas fond at Sikasso, (Mali); a pumped medium sized perimeter at Tara, Niger with complementary studies of other systems along the river; polder irrigation at Bol; irrigated vegetable production, a privately developed scheme, and a small PVO perimeter near NDjamena, Chad. As is explained later, we had to stop work in Niger and the prospects at Bol look doubtful.

All of these sites were agreed upon with the appropriate government institutions and the AID missions. Where possible we try to get active participation on the part of the local institution.

Survey Forms and Analysis

There is a strong common denominator between almost all of our surveys, a demographic census followed by a socio-economic study on a sample of farm families. We now have a fairly refined set of questionnaires in a format that is suited for direct "punching" onto cards or magnetic tape, using the original questionnaire forms. The forms are adapted to the situation of each research worker and his survey. He uses the basic forms like a scope of work and while training the survey workers, he adapts the forms to the needs.

Initially the forms are sent back to Purdue but now we are programming a small computer to permit transforming the data in the field onto magnetic tape which can be sent to Purdue. The third phase is to make the simple tabulations in the field. This will require a bigger and more costly mini-computer. The final phase would be that all of the analysis could be done in the field. It is likely that we will not progress beyond phase two within the time frame of this project.

We have found difficulty in attempting to install our programs on medium sized computers in West Africa. Equally we have found that where there is a minicomputer, the people with whom we are working do not understand how to use it. However, it seems that it will be easier to teach the use of the minicomputer than to try to get the work done in Africa on a medium sized computer.

We have access to a minicomputer at Bambey, Senegal. There seems to be need for one at the IER in Bamako and in Ouagadougou for various research organizations, such as ICRISAT, the proposed Farming Systems Unit, the MSU team at Fada, and the Statistical Section of the AVV. Such a machine would cost about $15-18,000 and have a very low maintenance cost. It does not require a special building and takes up the space of a television set plus a typewriter.

A. The data transfer and computers are a means to three ends:

provide analytical capability for the graduate students preparing theses and others preparing reports

provide the possibility for comparison between data from different study sites

provide a core of data for a data bank on the Sahélian farming

The system which we have in operation and the analytical procedures to be developed in the next 6-12 months serve not only as a model for socioeconomic research, but also for setting up continuous project evaluations for agricultural development projects in the region.

Farm Models and Budgets

One of the results of our surveys should be farm models (see Annex which serve to provide a better understanding of the farming system, farmer decision making, and the economics of improved technology. These models can be of two different kinds- budgeting models
- optimizing models

In fact both types of models may use the same solution method or algorithm. We have used an input-output format in our surveys which, given sufficient data, permits an optimizing solution although such a model is only optional.

A major problem in the data base is to establish the necessary relationships that relate the input to the output, the production function. For example, the relationships between planting date and yield, between fertilizer application and yield, etc. These relationships usually require multi year data. There is almost no multi year data that provides both measures of inputs and yields on farms. There is a limited amount of data from experiment stations. We are seeking time series data in order to estimate the production functions and to relate yield to rainfall characteristics. If we can establish the latter, we would also be able to use the weather data to predict the probable distribution of yields from year to year.

As has been mentioned, D. Barnett has a linear programming model running at Purdue using Sine Saloum (Unitées Experimentales) data. We expect to continue to improve this model. Professor McCarl is building a budgeter for the subsistence farm, which will be simpler to use and require less data; it will provide estimates of the outcome of different changes in input and could be useful in project design for example, in estimating the benefits from a change in technology.

We are, in these ways, preparing for the application of our data in farm models of the Sahelian country farms.

Document Collection

We have access to a document collection with 2500-3000 titles, covering agricultural development, farming systems, sociology, and some technical aspects involved mainly on francophone West and Central Africa. The motivating force is that students and staff on the program* have an average of 220 items out on loan at any time. We have now cataloged over 1000 document titles with our "new" system and have about 7000 index cards with which to identify them by title, author, country, region within country, source (government department or publisher), and subject matter. Another 160 titles have been cataloged but are not yet on new cards and about 1800 titles remain to be done. When the cataloging is nearly finished we propose to try to pursue a more active policy of acquisitions, assuming we can get the funds.

We are unable to lend documents on an interinstitutional basis because of the heavy local demand and the work involved in the process. Our cataloging is such that we have a code sheet for each title ready to be entered on the computer as soon as we have a suitable program available at Purdue to store the catalog. We would then be able to provide a microfiche catalog with perhaps 20,000 card entries. Of these perhaps 10 percent would be books, reprints or journals in commerce. The remainder are classed as documents.

The solution to making these accessible presumably lies in microfiching the part of the collection that is not available in commerce. We feel that we should control this process so that we can supply relatively large numbers of microfiches to about 7 or 8 universities in the U.S. which have a major research interest in this area, to African documentation centers, and to perhaps 6 to 8 institutions in Europe. A contractor, such as University Microfilms, usually charges too much to permit a library to purchase 1000 or more titles. The accessability of these documents outside Purdue could be a matter of practical importance to AID. The existance of a microform catalog of the collection that can be updated relatively simply is, in itself, a very valuable resource. However, it is obviously one thing to be able to identify the document and something else to be able to have access to the document.

We believe that this collection is one of the major foundation stones to our program. It has been a very difficult job to get it under control but, even if we and our visitors are the only users, it is certainly proving to be worthwhile.

At the outset this was a personal "office" collection, and the contents were known only to Dr. Morris. Recognizing that making this accessible to staff and students on the project, we attempted to catalog the collection. Our first attempt was unsatisfactory and did not work. A second attempt is leading to a professional job of producing a catalog with analytical refernces.

*That is on contracts Afr-C-1257 and 1258 and African graduate students.

Senegal

OMVS. As a component of the OMVS/UNDP study, which is now seeking additional funds from AID, we have four activities underway and are seeking a small expansion.

1. Study of the socio-economics of the Nianga perimeter. The survey was started by Ed Weiler in October 1977 and will be continued by John Sundman until fall of 1978. The researcher directs three survey workers who are surveying a sample of farm families in three of the "groupements producteurs" irrigating in the pilot perimeter. Weiler is now at Purdue writing his thesis on a cost-benefit analysis of the Nianga pilot perimeter.

John Sundman is carrying on supervision of the survey and has been requested to broaden the activity:

A. To study in depth the social dynamics of the groupements producteurs in order to see how their operation could be improved. He is interested in something like this as a thesis topic, which would fit in with his undergraduate training in anthropology.

B. To widen the scope of the surveys to include other perimeters, such as the Dutch small perimeters on the Ile á Morphile the perimeter assisted by the Chinese (Guede), and perhaps Aere Lao (a series of perimeters that were abandoned and are being reactivated). In the last one of the expatriate technicians has shown interest in supervising a survey.

2. Study of the socio-economics of small perimeters near Matam. Michele Fieloux, a sociologist with the 3rd cycle doctorate from the Ecole des Hautes Etudes, Paris, is supervising a survey of three small perimeters. Miss Fieloux is particularly interested in the effect of the perimeters on the work of women. Because of the proximity of the small perimeters to the villages, women participate in the field work to a considerable extent. Where the perimeter is several Kilometers from the house, a woman with only a few hours available spends too much time in walking to work and so does not do much field work.

Unfortunately the failure of the rainfed agriculture on the river in 1977 presented only one aspect of the farming system. The lack of a rainfed crop harvest distorted the calendar of work, with a void in the normal rainfed and flood recession harvest seasons, and also caused an abnormal number of workers to participate in the rice harvest. However, we can only hope for a better situation in 1978.

3. We intended to study water application efficiency or water use efficiency, assuming that the situation was relatively straightforward. That is, that deep percolation and lateral movement of drainage was not a major problem on rice growing soils. A review of the situation in Senegal

indicated that no measurement of water use had been made in a perimeter on the Senegal River. A proposition for a series of studies had been made by M. Gillet of ISRA* but the work had never been funded.

The problems connected with this type of work were discussed with irrigation and drainage specialists in the Western states and also at Cornell University (AID Project: The determinants of developing country irrigation problems). The methodology was known, although not simple to apply. However, we failed to identify a French speaking technician prepared to undertake the job. We, therefore, sought the help of the Netherlands Institute for land reclamation and improvement (ILRI) at Wageningen. The staff of this institute has had years of experience in irrigation in the Sahelian countries and Ir. Bos is in charge of the international water use efficiency study of the International Commission of Irrigation. Mr. Bos is expected to provide a francophone irrigation specialist, Mr. Van Achthoven, and supervise his work. This will probably be at Nianga, Senegal.

Within this project, this effort can only be of an introductory nature. The soils in much of the area are very permeable and lie on clay, often in the form of a sloping bed leading to lateral drainage movement. Nevertheless, we propose to start this work in a variety of different perimeters near Nianga.

Cornell University (Professors G. Levine and E.W. Coward) would be interested to collaborate with us and ILRI in a major effort to study the determinants of irrigation problems in the Sahelian countries, a complementary project to theirs. Their project will mainly cover South East Asia.

The work on water measurement is expected to start in June in Nianga.

4. We are proposing to make a broad based study of the economics of irrigation perimeters to complement studies of farming in the perimeters in Senegal on the Senegal River. The student recruited to do the job decided to study another subject. Ed Weiler, working with Professor W. Tyner, will write a thesis on the costs and benefits of the Nianga perimeter. This will serve as a model and will be discussed in early fall. This will provide an opportunity to ensure that our assessment of the criteria for evaluation of the projects is acceptable to USAID.

As soon as possible, we will identify the elements necessary for a cost/benefit study of small perimeters, which would enable us to make a study of the Matam perimeters under study by Miss Fieloux. Comparable to our study of Nianga, a medium sized perimeter.

We will then need to prepare a generalized approach of evaluation for our report to AID.

5. We have offered to assist Mr. Boutillier, the technical consultant on the OMVS/UNDP study, with analyses of data gathered by other researchers in his team or in the expanded program which has been proposed for AID.

* Etude des aspects techniques et economiques de l'utilisation de l'eau en riziculture, ISRA/WARDA (Projet Region al de Recherche sur la Riziculture Irriguee, Richard Toll - Fanaye) August 1976.

funding. Our work, which has been done in close collaboration with Mr. Boutillier, will also serve as a model for the expanded study program.

6. We propose to obtain a distribution of the value of imported rice and cereals, allowing for the interannual variations on the world market, for an input into the irrigation cost/benefit model. Miss Kathy Jabara, working with Professor Robert Thompson, is making this study for her Ph.D. dissertation. It will introduce risk as a factor in the comparative advantage of exporting peanuts and importing wheat and rice. The data for this study will be obtained from the SFRI Rice Policy Project team, the World Bank and IMF, and Senegal.

CNRA, Bambey. Our activities with the CNRA, Bambey have been along two major lines:

Modelling of peasant farming and obtaining input-output data on farming in the region of Bambey.

1. Modelling of peasant farming has been undertaken by Douglas Barnett working with Mr. Benoit-Catin, a French technician at Bambey. The Bambey model (done with the French INRA) has been modified and is now operational at Purdue. Barnett made a survey on farmer goals and this will be used in multiple objective linear programming for his dissertation, working with Professor McCarl. The model is to be extended not only to cover a case in the Sine Saloum (which it now does) but also in Thies-Diourbel.

This model is orientated towards the operations under the Chef du Carre (the head of the extended family). However, we propose to develop a model which covers the whole family farming activity, including the women. In the past the CNRA has not studied the work of women in the family farming in any depth.

2. Edna Loose, in collaboration with a CIDR project with Mr. Lalonde, is studying the effect of post harvest mechanization (threshing, decorticating and grinding millet) and ox-drawn water supply (water table at 40 meters) on the work of women in the home and on the farm. Miss Loose will return to Purdue in August to write her dissertation. We propose to send Mr. out to complete this study through to the end of harvest.

Mr. will also assist Mr. Fall of the Liaison Group (Senegal Cereals Project, AID) to launch labor studies to evaluate the effect of the different activities promoted by SODEVA, the development organization. This will provide the data needed to test the effect of the different intervention on the economics of the peasant family farming.

3. Mr. Moussa Fall is expected to visit Purdue for a month in late May and June. He will work with Douglas Barnett and our staff on linear programming models, hopefully producing a bulletin on his return to CNRA, Bambey. We also propose to show Mr. Fall how to use the mini computer (HP 9825 provided by the University of California, Riverside on AID funds) to analyze the data obtained by the Liaison Group.

We hope to work out with Mr. Fall the survey forms to be used in Mr. 's study and how they will be analyzed.

Mali

Our studies in Mali include:

1. A millet production area with a well established cash crop, Kita.

2. A millet production area with limited cash crop production and that only in part of the area, Dogon plain and plateau.

3. A bas fond amenage, a cultivated marsh with a sluice gate, with rice and vegetable production.

The study at Kita was started by Dr. Dolores Koenig in July 1977 and with a gap is being continued until harvest 1978. The study will show the adoption and economic effect of the interventions proposed by OACV in three villages in the Kita area. Dr. Koenig is also interested in the role of women in this type of agriculture. This study suffered a gap in data collection during the dry season when the new Minister of Rural Development suspended our research because AID, Bamako, had not yet negotiated an agreement with the Ministry of Foreign Affairs. The agreement apparently presented some new aspects because the project was regional in nature. The agreement has now been made.

The Dogon study in Operation Mil Mopti was prepared by Dr. Andreas Massing in summer 1977; he is now starting the study. It will cover both the irrigated farming on the plateau and the rainfed millet production on the palin. The interrelationship between the two activities, including labor movement between the two, the role of women in each case, and trading in millet are all being studied.

Miss Riitta Eskelinen, who recently made an anthropological study on the plateau, was invited to Purdue and her surveys were discussed. We have stated our readiness to collaborate with Mr. Sielibe, the agricultural economist following Miss Eskelinen, but so far nothing has been done.

The third field activity is the study of a managed bas fond in the Sikasso region, which is used for rice production in the rainy season and for vegetable production in the dry season. A small area is used year-round for banana production. This study is important because of the low cost per hectare of developing a bas fond, the wide distribution of suitable bas fonds in the Sahelian Countries, and the great potential of the additional production to enrich the diet and improve the income of the farm families.

This study is to be started in late May by Tom Whitney. We expect to study a rainy season and a dry season crop.

Another activity requested by the Institute of Agricultural Economics (IER) is technical assistance with farming systems survey analysis. We propose to send Dr. Joe Goodwin to Bamako to spend 2 to 4 weeks in reviewing the data which has been collected, working out how it could be analvzed, and agreeing what we can do to assist in the analysis.

Upper Volta

Our work in Upper Volta is related to the AVV (Volta Valley Authority). The major work to-date has been the reorganization of the Service Statistique undertaken by Dr. Josette Murphy and a Dutch collaborator Leendart Sprey of ILRI. This collaboration is the start of other collaborative activities, e.g., water measurement in Senegal River Irrigation Projects. A program of technical assistance to the AVV Statistical Service was forseen in the two AID projects proposed with the AVV. The service is now gathering sound data and we expect in June to start transposing the data onto magnetic tape in Ouagadougou. This should lead to analysis in Ouaga if a suitable small computer is available.

We have expressed our concern to the AVV (Director General Mr. Sorgho) and to the AID project manager in Ouaga, Mr. Thomas, over the failure of the AVV to provide effective counterparts in the position of head of the statistical service and Chief analyst. Unless people can be trained for these posts, there is a probability that the work of the statistical service will fall back to its previous level. It may be necessary to finance a third year of technical assistance, 1979/80, if it appears that the AVV has suitable personnel but that training is necessary.

The work and advice of the statistical service is now being used by other services in the AVV, such as the extension group, and the women's extension service.

Two new activities are forseen for 1978/79; Miss Della McMillan has just left to launch a study on the demography and socio-economics of farming in villages near Kaya; some of the villages have sent a lot of migrants to the AVV and others very few. Miss McMillan will move to the AVV villages receiving the migrants after one farming season of study near Kaya. This is expected to shed light on who migrates to the AVV and under what circumstances; what linkages exist between the AVV and the sending village; and to some extent what factors are associated with "success" of the migrants.

Mr. M. Saul will start in June 1978 in the AVV to study the relationships between the AVV settlers and the traditional villagers living nearby. He will also study the squatters, illegal settlers, and those from traditional villages who are farming land that formerly belonged to the village but now is in the AVV development area. The studies will include the farm practices used and the income of each of the groups.

We are also looking into the possibility of supporting the CVRS in completing their studies on the migrations to the Vallee du Kou irrigated rice production and the movement of the settlers away from the perimeter. This study would include the costs and benefits of the farmers at present as well as before the decline in rice yields occurred.

Niger

We had some difficulty to identify an irrigated farming study in Niger but, with the help of Mr. Al Baron, when he was RDO, settled on the Tara

irrigated perimeter, an Africaire Project. Miss Falika van de Walle was contracted to do a socio-economic study of the rainfed agriculture in the area and to study other forms of irrigated farming along the Niger River. The analysis would show how irrigated farming would "fit" into the rainfed system at Tara.

The study was to be conducted with the Dosso Office of the Ministry of Plan as the collaborating agency and IRSH as the technical advisors. This proved difficult to arrange because the two agencies would not agree to meet. Miss van de Walle also found that the director of the Tara perimeter felt that there had been enough surveys and now it was time to build the perimeter.

Miss van de Walle lost her research permit due to problems not directly related to her professional performance. Being unable to continue research activities, she left Niger and the Purdue Project.

We agreed with the AID office in Niamey that as soon as we were informed that the situation for making the study had improved, we would return to Niger to make arrangements for a replacement for Miss van de Walle. The improvement sought would include some enthusiasm in the Tara perimiter administration for a study and at least the minimum of agreement between IRSH and the "Plan." We were informed by the RDO of further problems but we have not been informed of any improvement of the situation at Tara.

Chad

We had hoped to study farming, herding and fishing in the Bol polders as a contribution to the AID polder development project. This study would include the millet production on the dunes, the traditional irrigated polders, and the modern polder. Other economic activities such as herding and fishing would be included. For this type of study it is essential to be free to survey the population in a considerable area on the north and northeast sides of the lake.

We have been informed of a delay in the building of the infrastructure, leading to the inability to accept our research worker for several months. Worse still, for security reasons people may not travel into the area by road and once there may not travel outside the modern polder and the town of Bol. This makes it impossible to undertake the type of study agreed with AID NDjamena at present.

The second study originally planned was to cover the small perimeters on the Chari, financed by the IBRD. There are economic problems with these perimeters and we hope to get information on this. However, it seemed that an in depth study could not be made because of the state of the project.

A third alternative is being pursued, a study of a "spontaneous" perimeter with a traditional leader purchasing a pump and setting up a perimeter, and a PVO perimeter near Kondoul. There was also the need to look at the vegetable market in the town and the irrigated vegetable production that has grown up around the town. Miss Ellen Deitchman is doing this study under the direction of Mr. Jean Boulet (ORSTOM) of the Geography Department of the University of Chad.

Training Program

Our department has 12 francophone U.S. students working towards the M.S. in agricultural economics and one working towards the Ph.D. We have seven of our staff directly involved in supervising parts of this program. We also are providing research opportunities for 4 francophone Ph.D. students from other U.S. universities. We have 6 francophone West African graduate students at Purdue associated with this program; three of them have had experience in government jobs in the Sahelian Countries and give considerable help to our students.

The majority of our students have had experience in West Africa in the Peace Corps and several have worked on short term contracts for USAID. Some of the students are expected to take Ph.D.'s but a number will be available to work with development agencies within the next 12 to 24 months. Their skills are particularly appropriate in project evaluation.

The projects also have a training effect in the field. In each country we are working with the appropriate government agencies and where possible we perform a training function within the institution. This is working to some extent at CNRA, Bambey, Senegal but is especially pronounced with the IER in Mali, where we have two counterparts, and in the AVV, Upper Volta. In the AVV we would like to be able to do training at the level of head of the service but the Voltaics have not nominated a suitable candidate.

Extension Activities

Project staff has made contributions at professional meetings:

1. American Society of Agricultural Engineers on farm mechanization and machinery problems in West Africa
2. African Studies Association on food production problems in West Africa
3. American Anthropological Association

We have assisted AID in policy making activities:

1. 1977 Workshop on Review of Club du Sahel working group papers
2. 1977 December submission to AFR/SFWA SDP for Congressional report
3. 1978 March AFR Colloquium on Irrigation Strategy

We participated in the conference on Sahel Documentation held at Michigan State University in 1977.

We have participated in the two Bamako Conferences on farming systems, November 1976 and February 1978, which were, in part, sponsored by AID.

We have had discussions with missions on program problems and with other researchers in the field.

Outside the project activities with USAID have continued, such as the Senegal Cereals Evaluation and the LCBC project evaluation exercise; these activities provide an application for the knowledge gained on the project and bring additional experience and knowledge to the program.

Within Purdue presentations have been made to various groups, mostly within the school of agriculture.

Our experience has also been used to make proposals to USAID for other activities that will help to continue the program beyond the life of Afr-C-1257 and 1258.

Staffing

Recruitment of qualified francophone staff with experience in West Africa has proved to be a considerable problem. Recruitment of experienced french speaking agricultural economists has been particularly difficult and time consuming.

The bulk of the field work is being done by our own graduate students and this also imposes a delay while the students are recruited and trained.

The following people are working on the projects:

At Purdue:

Professional Staff:

W. H. M. Morris, Production Economist
T. Kelley White, Production Economist
J. Goodwin, Production Economist
M. Saunders, Anthropologist
R. B. Thompson, International Trade
W. E. Tyner, Natural Resources
B. A. McCarl, Operations Research

Associates:

D. Koenig, PhD Anthropologist
J. Zarick, Programmer
S. Miller, Documentalist
K. Ibrahim, Administrator

Secretaries:

J. Viray
S. Scheuffler
P. Weddington

Graduate Students:

C. L. Jabara, PhD, will go to Senegal
E. M. Weiler, M.S., writing dissertation
D. A. Barnett, M.S., writing dissertation
T. R. Whitney, M.S., will go to Mali
S. A. Cohen, M.S., will go to Mali
A. P. Fleming, M.S., will go to Senegal
M. A. Versel, M.S., will go to Senegal
L. A. Malczynski, M.S., not yet assigned
D. K. Ritchie, M.S., not yet assigned

In the field:

Senegal:

J. R. Sundman, M.S. student
M. Fieloux, has Doctorat 3rd cycle
E. Loose, M.S. student
C. Ross, PhD, Collaborator

Mali:

H. A. Schar, M.S. student
A. W. Massing, PhD

Upper Volta:

J. V. Murphy, PhD
L. Sprey, Ir, Collaborator
D. J. McMillan, PhD, student (Northwestern)

Chad:

E. J. Deitchman
J. Boulet (ORSTOM), Collaborator

At other universities expected to go into the field:

M. G. Bos, ILRI (Wageningen), Senegal water use study supervisor (TDY)
Van Achthoven, Engineer, Senegal water use study
J. Schillinger, PhD student (U. of Connecticut) Bol Polders
Marvin I. Bartel, PhD student(U. of Connecticut), CNRA, Bambey
M. Saul, PhD student (Indiana University), AVV, Upper Volta

Plans for April - September 1978

1. Maintenance of field work
   on Senegal River, Matam and Nianga
   at CNRA Bambey, Senegal
   at Kita, Mali
   in Dogon area, Mali
   at AVV and Kaya in Upper Volta
   at NDjamena, Chad

2. Start activities
   water measurement on Senegal River irrigated perimeters
   CNRA, Bambey farm input-output study
   SODEVA socioeconomic studies in Sine Saloum, Thies-Diourbel areas
   PIDAC socioeconomic study of rice production in the Casamance
   Sikasso, Mali, socioeconomic study of managed bas-fond
   AVV socioeconomic study in traditional villages and of squatters

3. Thesis work at Purdue
   Weiler perhaps finish thesis on the economics of Nianga perimeter
   Barnett finish thesis on lp model and multiple goals of Sine Saloum farmers
   Jabara continue work on PhD thesis on Senegal peanut-rice trade and its social cost
   Koenig write up demography and farm adoption practice in the three villages in the Kita study
   Massing start report on Dogon area studies
   Loose start writing on thesis on effect of post harvest mechanization on the role of women
   Continue development of analytical procedures for farm surveys and attempt to move data transformation into the field. At Purdue we will be working with an enlarged team (adding four full time equivalents at the coding and key punch level) on the analysis of the data that we have and will continue to receive from the field.

Estimated Duration of Field Work

	1977 June	September	December	1978 March	June	September	December	March	June
Senegal									
OMVS									
Nianga	Weiler			Sundman					
Matam	Fieloux								
Water use									
Economics Nianga									
Matam									
General									
CNRA	Barnett farm model								
Loose									
SODEVA Sine Saloum					Versal				
Thies-Diourbel									
Casamance PIDAC					Fleming				
Mali									
OACV Kita	Koenig		Schar						
OMM Mopti	Massing			Massing	Cohen				
Operation Riz, Sikasso					Whitney				
Upper Volta									
AVV	Murphy								
McMillan				Migration Kaya-Moktedo					
					Saul Traditional Village				
Niger									
Tara	van de Walle								
Chad									
Small irrigation				Deitchman-Boulet					
Purdue									

Rice/wheat import/domestic production
Economic evaluation of irrigation projects
Analysis of farm data series
Modelling the effect of rainfall on millet/sorghum/peanut yields and so estimating yield risk

PROJECT BACKGROUND, OBJECTIVES AND APPROACH*

T. Kelley White

As you all know the research we are undertaking is funded by USAID as two separate projects. The first of these deals with the economics of food grain production in Sahelian Africa while the second deals with the economics of irrigated food grain production and the evaluation of small and medium sized irrigation projects. I would like this morning, in opening this Workshop, to first give a little background to help you all better understand how and why we happen to be involved in these particular research projects, and why USAID was interested in funding such research. Then I will review with you the objectives of the two projects, and finally will very briefly outline the research approach that we anticipate using.

Food problems are not new to the countries of Central West Africa. However, the problems in these countries first caught the attention of the world during the early 1970's when this region was hit by a very severe drought. As the situation existing in those countries and possible means of resolving their long-term problems were studied, several iterrelated problems became obvious. First, available data showed that for several years prior to the drought, food grain production in the region had been approximately stagnant. Secondly, countries of this region have rapidly increasing population. In most of the countries, population growth rates are between 2 and 3% per year. The combined effect of stagnant food grain production add rapidly increasing population inevitably lead to declining per capita food grain production. In addition to the declining per capita

*Remarks presented at the African Project Workshop, Purdue University, March 10-12, 1977.

production of traditional food grains, mainly sorghum and millet, these countries have undergone a marked degree of urbanization. As people have moved into urban areas they have tended to develop a preference for wheat and rice - two crops not as well adapted to production in that region as are sorghum and millet. These two trends have resulted in a tendency to increase imports of food grains. Increasing imports of food grains are serious problems for countries that have very limited sources of foreign exchange and the need for large investments as a means to stimulate economic development.

Many experts have looked upon irrigation as the primary opportunity for obtaining significant increases in food grain production. This is especially true for increasing the production of rice. It has been estimated that the total area of irrigatable land in the Sahel is in the range of 2-1/2 to 3 million hectares. However, an increasing number of knowledgable people have raised questions concerning the viability of massive expansion of irrigated area as a means for increasing food grain production. Those areas best suited for construction of reservoirs and irrigation systems have been utilized already. This means that the cost of additional irrigation can be expected to increase rapidly. Also, the experience of high co and disappointing returns from existing large scale irrigation systems has raised questions about efficiency. There appears to be an opportunity to expand irrigated area more economically through the development of relatively small projects. However, very little has been done to date in developing efficient means for economic evaluation of such small and intermediate projects.

In considering the type of research needed to identify ways of increasing food grain production in the Sahelian countries, a number of hypotheses were formulated to explain the stagnation of food grain production. Price policies

followed by many less developed countries, including those of the Sahel, have tended to impede expansion of food crops. Many countries, because of the sensitivity of the government to political pressure from urban dwellers, have adopted policies designed to keep the price of food low. While in the short run this keeps consumers happy, it produces low farm prices, and in the long run reduces incentive to expand production. The Sahelian countries, individually and collectively, depend heavily upon agricultural exports to earn foreign exchange. For this reason, governments tend to adopt policies which insure farmer prices for export (cash) crops which are high relative to prices for traditional food crops. In addition, the purchasing and export of these cash crops is often vested in the hands of a government monopoly. This facilitates the distribution of technical information, modern inputs, and production credit for the cash crop relative to traditional food crops. Prices of modern inputs such as fertilizer tend to be high relative to agricultural product prices except when inputs are subsidized. Governments have tended to subsidize modern inputs for use in export crops but not for production of traditional food grains. Price policies have therefore tended to serve as an impediment to the production of traditional food crops.

A second factor limiting the attractiveness of food grain production from the farmer point of view is the inadequacy of credit institutions. Farmers who borrow from traditional lending institutions are normally required to repay loans during the harvest season. This requirement places pressure on them to market their crops during the season when prices are lowest therefore making the production of food crops as a source of cash income even less attractive.

A third factor affecting expansion of food grains is the distinct

peakedness of seasonal labor requirements. The availability of labor to perform pre-planting and planting activities during the relatively short period of time available at the beginning of the rainy season serves as a very real constraint on the area that can be planted to food grains using traditional techniques of production.

In some areas of the Sahel, increasing population density has caused farmers to reduce the concentration of livestock thereby reducing the available supply of manure. It has also brought about a reduction in the length of fallow in order to grow more hectares of food crops. The net effect of these two actions is to reduce average yields. A final constraint would appear to be the very inadequate levels of investment in research and extension oriented toward development and dissemination of improved techniques of production to alleviate some of the above mentioned impediments.

Objectives

The objectives of the two research projects taken collectively are:

1. To identify impediments to increasing food grain production;
2. To identify technical, market and policy interventions that offer potential for relaxing constraints;
3. To evaluate the impact of alternative interventions on production of food grains and competing enterprises by typical production units; and
4. To develop a schema for the economic evaluation of small and intermediate sized irrigation projects.

The first three objectives cited above pertain to both rain fed and irrigated agriculture. The fourth objective pertains only to irrigation and therefore is specific to the project on economic evaluation of small and medium sized irrigation projects.

Procedure

The procedures to be followed fall into four general categories. These are description, model development, model application, and analysis of

irrigation projects. The purpose of the description phase of the project is to characterize agricultural production and the environment in which it occurs in the Sahelian region. This characterization will occur at several levels. First, it will be necessary to identify and describe the major production regions within the Sahel. Regions will be described in terms of climate, soil, existing agricultural production patterns, access to markets, and population density. Secondly, it will be necessary to identify and describe alternative agricultural production techniques (current and potential from research and observation in other parts of the world). Third, the economic environment within which the production unit operates will be described in terms of factor and product prices, and their variability. Also, an attempt will be made to describe government policy toward agriculture in general and specifically toward traditional food grain production. Collectively, these efforts will provide a detailed description of the environment in which production occurs.

Having described the production environment in terms of physical, technological, economic and policy characteristics, it will be necessary to characterize farmer behavior. That is, we will wish to describe the farmer as a decision maker in terms of a set of characteristics which we hypothesize to affect the kinds of production decisions made. Some of the variables of interest in characterizing farmer behavior are a) goals or objectives, b) attitudes toward risk and change, c) perception of government policy and attitudes toward government, d) perception of market signals and responsiveness to these signals, e) perceived constraints on production, and f) interactions between family and household goals, and production activities.

The descriptive component of the study will be based on 1) a thorough review on existing literature, 2) a survey of production units, 3) interviews with government officials, and 4) interviews with researchers. The focus of

data collection and descriptive analysis will be on the micro agricultural unit. Other analysis will be conducted only to the extent necessary to define the environment within which the micro production unit exists and operates.

Model Development

The knowledge gained in the descriptive phase of the research will be used to develop models of micro production units. While the particular model structure has not been identified and is, in fact, a major component of the research itself, some desirable characteristics of models can be stated. These include: 1) behavioral rules which reflect actual micro production unit behavior, 2) the model should reflect both internal and environmental constraints on production behavior, and 3) the model should be flexible enough to incorporate a wide range of production and intervention possibilities. Thus an attempt will be made to develop a model structure which is reasonably general so that it can be applied with relatively minor modification to reflect behavior of typical production units in the various sub strata of the Sahelian region.

Application of Models

Once models have been developed and verified they will be applied so as to accomplish three purposes. First, the models will be used to identify those variables, both internal and external, which are most constraining on agricultural production. Secondly, the models will be used to provide information on the sensitivity of typical production units to changes in these most constraining variables. Finally, the models will be used to evaluate the likely impact of selective programs and policies on production of traditional food grains and competing crops on typical production units.

Analysis of Irrigation Projects

The final component of research procedures anticipated will involve the analysis of existing irrigation projects to identify economic characteristics of alternative irrigation systems and to evaluate the economic viability of these alternative approaches to irrigation. Using experience gained from evaluation and analysis of existing projects, a set of criteria and procedures for evaluation of small and medium scale irrigation projects will be produced to facilitate future project evaluation.

Modeling - Concept and Technique*

T. Kelley White

The purpose of this paper is to provide a brief and therefore incomplete discussion of the concept of modeling as a means of economic analysis, and to discuss some of the more common techniques for model solution. After having identified some of the more common approaches to model structure and solution one particular technique, linear programming, will be discussed in somewhat more detail.

Before attempting to reach a consensus on the usefulness of modeling or the best approach to modeling it is necessary that we adopt a common definition of the term, model. We will use a very general definition of a model as being a simplification of reality. By simplification of reality we simply mean that a model is a description of some real world phenomena which includes only those aspects of the real situation which are necessary to illustrate a specific subset of all possible structural and behavioral characteristics of the real world situation. There are many possible examples that could be used. One such example is the use of a scale floor plan as a model for a house. Such a model of the real world - actual house - can be very useful for deciding among alternative sizes, shapes, and arrangements of rooms in a house to be built. It leaves out more than it includes but includes those necessary characteristics to provide the user the ability to visualize such things

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*Prepared for presentation at African Project Workshop, Purdue University March 10-12, 1977.

as the organization of furniture within rooms or the probable patterns of circulation of people among rooms of the house. If one wants to use a model as a basis for estimating cost of construction or as a guide for actual construction a quite different kind of model will be called for.

There are many kinds of economic models also. One of the most common is the use of a demand curve as a model of consumer behavior. This is an extremely simplified model of the real world. It assumes away all characteristics of consumers except their tendency to vary the quantity of a good or service consumed in relation to the price.

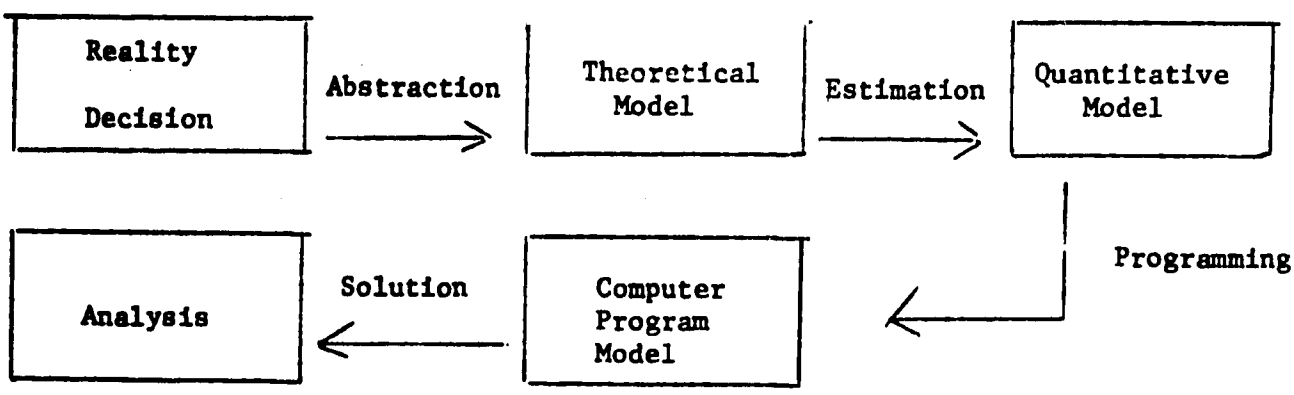
The next question is why do we need models. Models are useful to us for the very reason that they are simplifications of the real world. In many situations the real world is too complex to be easily understood, manipulated or experimented with. In our earlier example of a floor plan as a model of a house, it is obvious that one would not build fifteen different actual houses in order to decide which floor plan was best suited to his needs. It may actually be much easier to visualize the circulation patterns of people involved in various kinds of activities within the house on the basis of observing the spatial relationship of one room to another on a floor plan than by observing an actual house. It certainly is much cheaper and quicker to use the floor plan rather than actual houses to evaluate alternate sizes, shapes and organizations of rooms within a house.

We are interested in economic models because many of the economic relationships in which we are interested and with which we would like to experiment are intertwined with other aspects of human behavior making the real world extremely complex and the isolation of changes in a single economic variable difficult to isolate. If the real world can be sufficiently

understood to develop a model of the behavior of interest, this model can be used as a basis for experimentation and the drawing of implications for changes in the real world environment.

Models have become more useful and more complex with the advent of the electronic computer. By increasing the number and complexity of computations that can be handled, the advent of the computer has greatly increased the range of feasible sizes and complexities of models that can be considered. As it has become possible to increase the size and complexity of models our ability to add realism to our models has increased. The process of model development and utilization and the relationship of the model to the real world can be visualized as the flow diagram in Figure 1.

Interrelationship between reality, models and computer program



If we begin discussing the process of modeling with reality, we utilize our knowledge of the real world and by the process of abstraction, derive a theoretical model which includes our conceptualization of that part of reality in which we are interested. The theoretical model will normally, as a minimum, consist of the identification of variables of interest, both dependent and independent, and a proposed behavioral relationship among these variables. It will also normally include an indication of the direction

of causal relationships. The theoretical model should possess internal consistency, however, it may or may not be consistent with reality.

Consistency with reality and quantification of causal relationships is achieved through the process of estimation and results in a quantitative model. The quantitative model differs from the theoretical or conceptual model in two ways. First, it now not only includes identification of variables and relationships and a suggestion of direction of influence but now includes specification of magnitudes of influence. Secondly, while the theoretical model should be internally consistent, the quantitative model should be both internally consistent and consistent with the real world. That is, the estimation process provides a means of testing conceptual relationships as well as quantifying parameters of the model.

At this point, the process of model development per se is complete. Before the advent of electronic computers the next step would have been model solution and analysis. However, we now have the additional step of converting the quantitative model into a format which is compatible with computer capabilities so that a computer can be used in model manipulation and solution. Therefore it is necessary to go through the process of programming or writing a set of instructions to the computer telling it how to perform necessary operations for model manipulation. In some cases this is an extensive and time consuming operation while in others it is merely a case of organizing data into a format acceptable by an existing algoithm which has been pre-programmed. Upon completion of the programming process, a quantitative model has been converted into a computer program or computer model.

The next step is to solve the model to provide a basis for analysis of model results. The distinction between model solution and analysis of

model results is an important one. The process of model solution can be automated and accomplished by the computer. The process of analysis requires interpretation of results in view of model structure, model assumptions and simplifications, and knowledge of the differences between the real world and the model. Analysis cannot be performed by the computer. It requires intelligence.

After having analyzed our results, it is possible to draw implications of the model solution for the real world and therefore use model results to improve our ability to make better decisions with respect to reality.

It is interesting that while the flow diagram in Figure 1 implies unidirectional interaction between reality, theoretical model, quantitative model, computer model analysis and back to decisions about reality, the actual process is an iterative one involving feedback among all steps. For example, the process of estimation not only allows us to convert our theoretical model into a quantitative model but will often improve our understanding of reality pointing out inconsistencies or omissions resulting from the process of abstraction and therefore improve our theoretical model. Likewise, the process of programming to convert the quantitative model into a computer model will often identify logical inconsistencies in the theoretical model. The process of solving the model and analysis of results often lead to improvements in the theoretical model and recognition of the need for additional quantification to improve the reliability of the quantitative model.

As was pointed out earlier, a model is always a simplification of reality. The crucial question in conceptual modeling is the correct degree of simplification to be used. A practical guide in making this decision is to always utilize the highest degree of simplification consistent with the

use to be made of the model. As models become more complex the cost of quantification, programming, solution, and analysis increase rapidly. Therefore the cost of greater realism can be very high and realism which is not essential to the achievement of the objective for which the model is being designed has a very low pay off.

One additional general comment on the concept of modeling is that the utility of a model in drawing implications about reality is greatly enhanced as our ability to quantify the theoretical model increases. Quantification is expensive and difficult. Therefore our ability to quantify will quite often constrain our ability to transform the conceptual model into a quantitative model.

There are a number of ways in which the farm firm is usually conceptualized. That is, there are a number of more or less standard degrees of simplification which are utilized and differences in the nature of the simplifying assumptions made. Four of the more important choices that have to be made in selecting a conceptual modeling framework for the farm production unit are as follow:

1) static versus dynamic,

2) perfect knowledge versus risk and uncertainty,

3) optimization versus satisficing or other behavior, and

4) normative versus positive models.

Normally these four characteristics must be included in any farm firm model and therefore, choices must be made with respect to each of the four.

Likewise there are alternative techniques available for quantifying the theoretical model once it is developed. Some of the more common techniques available include 1) assumption, 2) best informed guess, 3) formal statistical estimation, 4) use of case studies, and 5) experimental results

The quantification technique selected will usually depend on the use to be made of the model at that particular stage of quantification and the cost of alternative quantification techniques. In most instances it is necessary to use some combination of the above techniques.

The techniques for solving quantitative models are also numerous. The techniques for solving quantitative models can generally be subdivided into optimizing and non-optimizing techniques. The optimizing techniques are sometimes referred to as the group of general mathematical programming techniques. This group includes a wide range of formal optimization procedures which vary depending upon the mathematical nature of relationships, objectives, and constraints allowable. Within the group of mathematical programming techniques are the following:

1) classical math programming (the marginal analysis)
2) linear programming
3) non-linear programming
4) integer programming
5) dynamic programming

With the exception of dynamic programming, solution techniques normally are available to the user in pre-programmed form. This means that the user does not have to do extensive programming to provide the computer with instructions for manipulation of data to reach the solution. That is, a canned logarithm is available for solving the model. All that is necessary is preparation of data. Dynamic programming on the other hand does require programming.

The non optimizing techniques for solving models are sometimes referred to collectively as simulation techniques. The term simulation covers a very wide range of approaches from very simple budgeting to very sophisticated

macro models which are dynamic and recognize the existence of less than perfect knowledge. Simulation can be distinguished from the math programming models in three basic ways: 1) simulation models are non-optimizing and therefore must have specified a set of behavioral rules, 2) simulation is quite flexible with respect to the mathematical form in which relationships can be expressed, and 3) there are not available logarithms for solving of simulation models. This latter characteristic implies that each simulation model must be programmed in order to make it solvable by computer.

Linear Programming

One of the most widely used of the optimizing techniques is linear programming. It has been found to be compatible with the assumptions necessary for modeling many kinds of economic problems. It has been especially useful in modeling of farm decision making, because this is to a large extent a problem in resource allocation and scheduling of operations. There are a number of efficient logarithms available for solving linear programming problems on a variety of computer systems. This makes the application of linear programming convenient, easy and economical. Because of its ease of application and its proven ability to solve many firm related problems in various parts of the world we will look briefly at linear programming as a technique, the characteristics of models that can be solved by linear programming and the assumptions of linear programming. Then we will look at a very simplified farm planning problem within the linear programming context as a means of better understanding what linear programming is and how it works. The objective of the discussion to follow is to provide a beginning understanding of linear programming as a modeling framework.

Linear programming can be defined as an optimizing technique for

maximizing a linear objective function subject to a set of linear inequality constraints. Therefore, it is well adapted to problems of allocating scarce resources among competing uses to achieve an optimal value for a goal function. This describes many economic problems associated with farm firm behavior. The linear programming problem can be stated in the simplest form as:

$$\text{Max } Z = \sum_{j=1}^{n} c_j x_j$$

s.t.

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$x_j \geq 0$$

The components of any linear programming problem can be classified as 1) an objective function, 2) alternative means (activities or processes) for attaining the objective, and 3) a set of restrictions. Therefore, if a linear programming formulation of any decision problem is to be meaningful it must be possible to 1) describe or represent all relevant aspects of the problem as one of the three components listed above, and 2) represent relationships among components by mathematical expressions which are consistent with the assumptions of linear programming with respect to form.

The assumptions of linear programming can be found stated in a number of different ways. A very brief summary statement of the necessary assumptions of linear programming are presented below.

1) Linearity: the assumption of linearity simply says that the objective function and all restrictions must be linear in mathematical form. That is, all relationships must be of the form

$$7 = b_1 x_1 + b_2 x_2.$$

2) Additivity: the assumption of additivity states that the total amount of any resource used must be equal to the resource used per unit of each activity multiplied the level of each activity summed

over activities. The same holds for the relationship between total output rate of each means of production. In economic terms this assumption rules out the possibility of complimentary among activities. It is possible to model complementarity among crop production by defining model activities which consist of combinations of crops.

3) Non-negativity: the non-negativity assumption rules out the possibility of activities entering the optimal solution at negative levels. In economics this normally presents no problem in that negative quantities are almost always impossible.

4) Divisibility: the assumption of divisibility states that resources may be used and activities produced in fractional units. This assumption sometimes presents problems in that optimal solutions will include the purchase of fractions of machines or production of fractional units of animals. When such problems are in serious divergence from reality it may be necessary to use integer programming. However, normally it is possible to make adjustments to the model solution in interpretation and analysis to account for non-divisibility.

5) Finiteness: this assumption simply states that the universe of all activities and restrictions must be finite in nature. This is necessary because if the number of activities or restrictions is infinite it is impossible to specify the model.

6) Single valued expectations: this assumption states that for any functional relationship included in the model there exists a single value for the dependent variable for each set of values of independent variables. This rules out the direct consideration of uncertainty or risky situations whereby either the dependent or independent variable is a distribution of values rather than a single value.

The concept of an objective function is reasonably straightforward and uncomplicated. The linear programming problem can have only one objective function. This objective function may define cost, physical output, revenue, profit, or any other value which is quantifiable and which the firm seeks to either maximize or minimize. The most common objective functions utilized in modeling of farm firms are profit for a short run model or present value of the net income stream in the case of multi-period models. While the problem must have a single objective function this function may be a composite of multiple goals. The results of solutions to the programming problem are usually more meaningful and much more straightforward in interpretation when

the objective function represents a single goal.

The restrictions included in a linear programming model of a farm may represent anything which limits the value of the objective function. Some of the normal kinds of restrictions included are quantities of resources available, restrictions on the size of enterprises imposed by government policy or social pressures or habit and either maximum or minimum restrictions on the size of certain activities to reflect personal preferences or institutional regulations. Restrictions are also quite commonly used to reflect goals which conflict with the one used as the objective function. One of the most difficult and important problems encountered in empirical modeling is to identify the relevant constraints on the decision process being modeled and to accurately quantify the level of these constraints.

The other component of the linear programming problem is the set of activities. An activity may be thought of as a quantitative relationship between the objective function and the restrictions. An activity is a vector of coefficients which for an arbitrarily defined unit of a process indicate the effect of this unit of process on the value of the objective function and each of the constraints in the model. That is the coefficients of an activity define the rate at which each restriction is used (or increased) and the rate at which the objective is increased (decreased) as the level of that activity in the solution is increased. In the context of agricultural production an activity may be thought of as either a) a budget for a specific process or technique of production, b) a point on a production surface or c) a ray in factor-factor space.

A linear programming problem may be presented as a system of inequalities and equations as in the general statement of the linear programming problem presented earlier. For the less mathematically inclined it is

sometimes easier to visualize the linear programming formulation of a problem when the tableau format is presented. As in illustration of the general characteristics of a linear programming problem and its solution, a simple two activity, three constraint problem is formulated below in Table 1 and solved graphically in Figure 2.

Table 2. Problem in tabular form:

Restriction	Sorg	Peanuts	Activities				Sign	Restr. Level
Objective Function	600	1800						
Land	1	1					=	5 ha
Labor	75	150					≤	500 days
Cash crop		1					≤	2.5 ha

You will notice in Table 1 that the problem consists of the first row or equation which is labeled objective function then there are three rows or equations which represent restrictions. These are labeled as land, labor and a cash crop constraint. The cash crop constraint can be thought of as a risk aversion constraint whereby the farmer has predetermined that in order to provide a safety margin in food supply it is not safe to put more than 2.5 hectares of land in cash crops with the remainder being reserved for food crops. Now looking at the tableau in terms of columns, there is a column for the sorghum activity which has a coefficient in the objective function which says that each unit of sorghum produced add 600 units to the objective functions, a coefficient in the land row implying use of one unit of land, a coefficient in the labor row requiring 75 units of labor. This activity has no effect on the cash crop

constraint. The second activity, labeled peanuts, has an objective function coefficient of 1800 indicating that this is the addition to the objective function per unit of peanuts produced. Each unit of peanuts uses one unit of land, 150 units of labor and utilizes one unit of the cash crop constraint implying that peanuts are considered the cash crop. There is then a column labeled sign which is for information and determines whether each row is an equality or an inequality and, if an inequality, whether is is less-than-or-equal-to or greater-than-or-equal-to. In this case the objective function is an equality, the other three constraints are less-than-or-equal-to, stating that the quantity of each constraint utilized in all activities collectively must be less than or equal to the quantity available. The quantity available of each constraint is indicated in the last column of the table which is labeled Restriction Level. Note that for the objective function, the word "max" is included. This indicates that the objective function is to be maximized.

We can now view this problem graphically by constructing Figure 2. This is done by constructing a constraint line for each of our three constraints. For example, if land is taken as the constraint, the five hectares may be allocated entirely to sorhgum in which case we could produce five units of sorghum or entirely to peanuts in which case five units of peanuts could be produced. Since the land requirement per unit of each of these activities is constant, the line connecting "five" on the peanut axis and "five" on the sorghum axis represents all possible combinations of units of peanuts and sorghum and that can be produced using a total of five hectares of land. This constraint line can be thought of as a production possibilities frontier assuming that land is the only constraint on production. The slope of this frontier can be thought of as the

marginal rate of transformation between peanuts and sorghum in the use of land. It states that one unit of sorghum substitutes for one unit of peanuts in the utilization of land.

The same process applied for the labor constraint produces the production opportunities frontier labeled "labor constraint" in Figure 2. It will be noted that this line has a slope of minus 1/2 implying that in the use of labor, two units of sorghum substitute for one unit of peanuts. The third constraint limits us to 2.5 hectares of peanuts regardless of the level of sorghum produced and therefore is a horizontal line with a value of 2.5 on the peanut axis. This implies that an infinite amount of sorghum is required to substitute for one unit of peanuts in satisfying this constraint.

We now have three separate constraint lines, each of which represents a production possibilities frontier with respect to a single restriction. Now considering all restrictions simultaneously, we can identify the effective production opportunities frontier as those line segments which are cross-hatched in Figure 2 and labeled segments a,b,c,d. This discontinuous production possibilities frontier identifies all possible combinations of peanuts and sorghum that can be produced considering the three sets of restrictions on production.

We can now solve the problem graphically by constructing an iso-net revenue line which is labeled on the graph. This we can construct by selecting any arbitrary value for the objective function. In this case 1800 has been selected. Divide that value by the coefficient in the objective function for the corresponding activity which yields the number of units of that activity required to produce that level of net revenue -- in this

case, one unit of peanuts produces 1800 units of net revenue and 3 units of sorghum produce the same amount of revenue. Connecting these two points produces an iso-net revenue line which represents all possible combinations of peanuts and sorghum which will yield 1800 units of net revenue. The slope of this line is the ratio of the prices, or net revenues, of the two activities and can be thought of as the rate at which the two activities substitute in the production of net revenue. Our objective is to achieve the highest value of net revenue possible given the constraint of the model. Conceptually, we can solve this problem by moving the net revenue line away from the origin until we have achieved the highest net revenue line which is consistent with the production possibilities frontier that is, which coincides or touches the production possibilities frontier. Thus, the optimal combination of peanuts and sorghum is represented by point b on the production possibilities frontier. This consists of 2.5 hectares of peanuts and 1.67 hectares of sorghum. The plan utilizes a total of 4.17 hectares of land leaving 1.83 hectares idle. The 2.5 hectares of peanuts will utilize 375 man days of labor, and the 1.67 hectares of sorghum will use 125 man days thus exhausting the total supply of labor. The value of the objective function will be 5,500 units of net revenue.

This very brief and incomplete discussion of modeling in general and linear programming as a modeling framework in particular has not been intended to provide you with enough knowledge of the technique to go out and become a user of linear programming. Instead, it has been intended as an introduction which hopefully has given you some feel for the way in which models are constructed and why models are needed. It is also intended that you should have the beginning of an intuitive understanding of what linear programming is and how it can be useful as a framework for constructing models of farm production in many real world settings.

W.H.M.M.
March 9, 1977

Review of Proposed Field Activities,

Sorghum and Millet Production and Irrigated Perimeters.

The goals of our two projects are

1. To identify impediments to increasing food grain production
2. To identify technical, marketing and policy interventions that offer potential for relaxing constraints.
3. To evaluate the impact of alternative interventions on the production of food grains and competing enterprises by typical production units.
4. To develop a schema for the economic evaluation of small and intermediate sized (under 1-2,000 ha) irrigation projects and supplementary irrigation projects, considering construction, operating and maintenance of the perimeter and agricultural production and marketing at the farm level.

Early in our work we have recognized that (1) since labor is usually the limiting factor of production and (2) since there are no small or intermediate sized perimeters in which irrigated farming is the only farming activity, the returns (expected and real) to labor in alternative occupations locally and as migrants will be a key variable and requires special emphasis. Also we recognize that the activity of irrigation farmers needs to be studied together with all their rainfed farming activities. For these reasons the farm level studies for the two projects will be combined.

The literature review is proceeding on both projects simultaneously. We have also made an inventory of current microeconomic studies under

national or regional governmental agencies. We have adopted the criteria in selecting sites for survey work.

1. that each site must form a sample of some important production situations in the region. A statistically representative sample is not operationally feasible.
2. that the sites must be selected from those whose study is a government priority and one in which appropriate governmental agencies are prepared to collaborate with us.
3. that the sites should represent production situations likely to be of interest to USAID.

To avoid future misunderstanding, this inventory has had to be made without committing us to any given site or even to any country. Our progress has been discussed with AID field staff in each area.

We have accepted the traditional division of the region into three major ecological zones by average annual rainfall:

I. Sahelian Zone, 300 to 600 mm. Millet and peanut production.

II. Sudanian Zone, 600 to 900 mm. Millet, sorghum, cotton and peanuts.

III. Sudano-Guinean Zone, 900 to 1200 mm. Sorghum, maize, pluvial rice, cotton and peanuts.

The Forest Zone, over 1200 mm. is only present in very small areas (S. Casamance, S. Mali, and Western Upper Volta) and will not be studied separately.

In the Sahelian Zone we have identified the Senegal River Valley, Senegal side, and the Niger River Valley from the Malian border to Niamey and perhaps further south into the Sudanian Zone.

In the Sudanian Zone we have identified the peanut basin of Senegal, Segou in Mali (prospective), and the Chari River irrigated perimeters in Chad.

In the Sudano-Guinean Zone we have identified the Casamance in Senegal (prospective area), Sikasso and Kita in Mali, and the AVV (Volta Valley Authority) areas in Upper Volta.

Purdue's Data Needs.

We are currently studying the methodology intensively in order to define precisely what are our data needs. We propose to draw heavily on three major "schools" with experience in the region:

Samaru-Ahmadu Bello University (Norman)

Michigan State (Winch-Dunsden Spencer)

World Bank (N. Nigeria, Steed-Zuckerman).

Our methodology involves supervision of African survey workers gathering primary data on the inputs and outputs of agricultural production at farm level, together with data to estimate the opportunity cost of labor in other activities including migration. It has become apparent that irrigation is not a single activity but one of the alternatives available to farmers in certain regions. For this reason the studies of irrigated farming will be combined with studies of the other activities, chiefly various forms of rainfed and flood or flood recession farming.

In general, there seems to be no conflict in site selection. There is one exception, Mauritania; AID/Washington and AID/Nouakchott have both expressed a need for data on irrigation in Mauritania, and the CDO Nouakchott has also expressed a need for data on dry land farming. However, GORIM has not expressed an interest, is not proposing to make such studies, and does not have the counterparts.

We, therfore, propose to develop models for irrigated and rainfed agriculture under similar conditions elsewhere in the Sahel and test these models, correcting the data where necessary, in Mauritania, with assistance from CDO Nouakchott.

Comparison of our list of sites with our project proposals indicates that we have not yet identified study sites for the indigenous crop irrigation systems, such as that of the Dogon (cited as an example in the proposal), irrigated vegetable production around the major cities, and a well managed basfond (or fadama).

Personnel

We have employed one temporary assistant professor in agricultural economics, with 2 years of experience in Upper Volta and one in Cameroons.

We have admitted 10 French-speaking graduate students for the M.S. on the project. Five of these students should be ready to go to Africa for the 1977 crop season. This group includes an instructor who has almost completed his Ph.D. thesis in Anthropology (on the Kru farming in the Ivory Coast and Liberia) at Indiana University.

We have 5 more students who should be ready to do field work in 1978.

Some of these students will want to continue their studies after the M.S. and take Ph.D.'s, others will become available for employment. They will all be French-speaking, with an M.S. in agricultural economics and experience in West African agriculture. The majority will have had Peace Corps experience also.

We are seeking francophone students from West Africa. We hope to get two to work on livestock economics programs and are still seeking some to work on crop production economics.

Cooperation. Apart from collaboration with African government organizations we are cooperating with the Stanford Food Research Institute's Rice Policy Research Project with WARDA.

We are in close contact with the Northwestern University Ecostress Project Project in East Africa on conceptualization and methodology.

We are cooperating with the IBRD, which sponsors many of the current evaluation projects in the region.

We are in contact with AMIRA, a French group at the National Institute for Agricultural Research (Paris) concerned with research on methodology of socioeconomic research in agriculture in West Africa.

We are also exchanging information with Claude Raynaut and his group on the "study of the disequilibrium of natural, agricultural and socioeconomic systems in the Maradi Region, Niger" funded by the French General Delegation of Scientific and Technical Research. We may send an agricultural economist to work with his group and, by providing him, with our reference material and receiving his, both of our projects are strengthened.

Potential Study Sites

1. Senegal River Valley. The Senegal River Valley development, although neither that with the greatest potential nor that with the greatest amount of the data necessary for development, has the greatest political momentum of all the West and Central African River Valleys. The OMVS has accepted the task of making a socioeconomic study of a sample of the irrigated perimeters on the Senegalese side. The project funded by UNDP, apparently has insufficient funding for the field work and its analysis. The project is under Mr. Boutillier*(of ORSTOM), who

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* Editor of the book La Moyenne Vallee du Fleure Senegal.

will be paid by the FAC; it will include at least one other Frenchman, Milleville, who has had experience in the area.

Mr. Boutiller would be glad to have one or two Purdue researchers with some support for their survey work. He expects to get a counterpart from Senegal, Mali and Mauritania. He is in good agreement with us on the approach, including the need to study all of the farming activities of the families in the sample and the pull of immigration as it affects the minimum acceptable return to labor in the migrant age groups. Migration is very common in some parts of the valley.

This study would also provide us access to the OMVS staff and SAED (Senegalese) personnel in the area for data on the planning, construction and operation of perimeters. We would also be in a good position to do the ground work on the question of why the cost of irrigated perimeters in Mauritania is so high.

The study will start in rainy season, 1977. We give this opportunity a high priority for its overall importance and for manning in 1977.

2. Senegal, Peanut Basin. The peanut basin is a densely populated area, with a major part of the Senegalese farm population and producing a major part of the agricultural product. USAID has a development project with SODEVA, the local development agency in the Thies-Diourbel region and an evaluation of the project by the staff of the CNRA (Agricultural Research Station, Bambey). South of this project are the IBRD-SODEVA project and the Unitées Experimentales, in the Sine Saloum. There is a continuous evaluation started in the IBRD project within SODEVA and the Unitées Experimentales have had a continuous survey, first under CNRA and now under ISRA, (the Senegalese Agricultural Research Institute,

parent organization of CNRA) for about 7 years.

In the first instance it would be possible for us to collaborate with the USAID sponsored evaluation unit at CNRA and with ISRA in the Unitées Experimentales in the Sine Saloum. Both of these have data for previous years. The Unitées Experimentales are believed to have new funding after June 30, 1977 when the old funding ceases.

These two sites could be available to start in rainy season 1977 and we give this a high priority in part for the retrospective data it will provide. We would like to man at least one of these in the 1977 rainy season and two if possible.

The third possibility, to collaborate with SODEVA in the IBRD Sine Saloum project, is of interest but of lower priority. For this reason, we have not discussed the proposal with SODEVA.

3. Casamance. The potential of the Casamance region for rice production is considerable and the Casamance Development Organization has projects with the IBRD (Sediou) and proposed with USAID. However, continuous evaluation has not yet started. Therefore, while this should be kept in mind for the future, it is not a priority opportunity at present.

4. Mali: Institut d'Economie Rurale. The evaluation of development projects in Mali is under the direction of the IER. Evaluation is proceeding in the OACV (Operation Arachide et Culture Vivrier) project area; this work could be accelerated with further personnel and funding. However, the Director of IER expressed the first priority of the GOM as a study of the Sikasso development project with dry land farming and rice production in the flooded marshes. This is

particularly interesting as a farming system with great possibilities and a low cost form of water control applicable to a substantial area of Mali and Upper Volta. The same system is being used in the North of the Ivory Coast. The GOUV (Minister Sanon) gave the need for data on this system of water control as a priority.

This opportunity for study we consider to have a high priority in terms of its importance and urgency for manning in rainy season, 1977.

The second priority of the GOM was for studies in the Kita Circle in the Operation Arachide et Cultures Vivrieres. This is an area where some hired labor has been used in peanut cultivation and the labor is now being drawn to higher wages in Senegal and Gambia. This work would be part of the OACV evaluation program. This is considered by us to have a high priority for its relevance and also for its urgency. However, it cannot be manned in 1977.

It is possible that we will be able to obtain data from the IBRD rural development project in the OACV project area from the current surveys and help in their analysis.

In 1978 the GOM proposes to start microeconomic studies of rice production in the Segou area of the delta of the Niger. This is a low cost form of rice production as identified by Dirck Stryker in the IBRD study of comparative advantage. A similar production system is also widespread in the Mopti region but is more remote and the sites are more difficult of access. It would be possible to participate in survey work in the Segou area starting in 1978. This we consider to be an important area for study but not to be feasible for manning until about mid 1978.

5. Upper Volta. The late Minister of Rural Development, Mr. Sanon, gave us two priorities: to help the ongoing studies in the AVV (Volta Valley Authority) and to provide data for planning water control and farming systems as in the North of the Ivory Coast or the Sikasso Region of Mali. The AVV is enthusiastic about the possibility of receiving some assistance in their socioeconomic surveys of farms. The director was also in agreement on the necessity to study the settler families in their entirity, with part in the settlement area and part in the village of their origin. Early studies have shown that the nuclear families are not moving as complete family units, but perhaps one wife and her children remain behind. We have not yet been able to meet the technician (expatriate) in charge of this activity.

This we consider to be an interesting opportunity to study resettlement in the one being freed from oncho cercosis as well as the adjustment of densely populated areas in the Mossi plateau from which the settlers come.

If this site is selected, we would propose to attempt to start in 1977 with a contract to intensify data collection for which we would supply technical assistance in design of the survey and in analysis. This would probably only involve surveying in the settlement area.

We would give a priority to manning this area in 1978, perhaps with a student already identified from another US University interested in the study of migration as well as with one of our own students.

6. Niger. In Niger the responsibility for agricultural economic research rests with INRAN (the Nigerian National Institute for Agricultural Research) and for sociological research, IRSH (Institute for Humanities Research) INRAN gives it first priority to the study of irrigation in its different forms along the river. The director stated that he

intended to start this research in 1977 whether he received help or not.

The area is attractive because it has small and medium sized irrigated perimeters, flooded production, as well as flood recession and dry lan farming. We place a high priority on working in this area if we can obtain administrative approval. We believe it should be manned in the 1977 crop season.

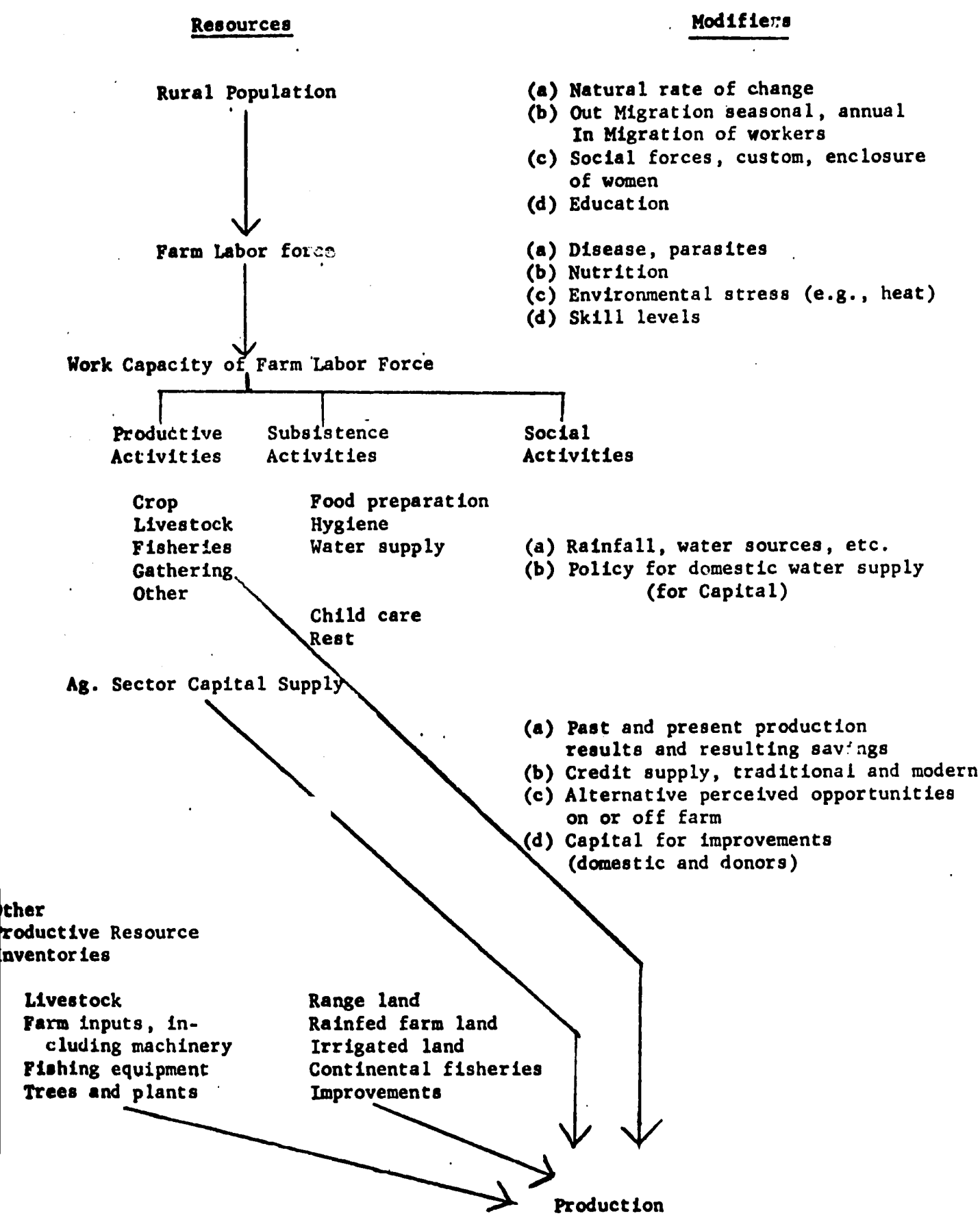
7. Chad. The IBRD has discussed with ONDR (the Rural Development Extension Organization) the possibility of farm level surveys of the farming in the small irrigated perimeters on the River Chari. This is a priority task for ONDR and, at present, the only survey activity of its sort proposed by the GOC. We have a preliminary economic study of the perimeters done by SATEC (1975/76) and have discussed getting further work done by Mr. Seignebos of the Geography Department, University of N'Djamena. However, SATEC, who are managing the project, wish to get Mr. Seignebos to make a further study for them. Mr. Seignebos has been studying the geography and his wife the ethnolinguistics of the area including the perimeters for the last 4 years.

We have decided to wait and see Mr. Seignebos's new report for SATEC and then to review the situation. The management of these perimeters is having problems with the farmers, who have other activities during the dry season. There are also problems in selecting sufficiently profitable irrigated crops to be attractive enough for the farmers in the dry season. Thus, these perimeters demonstrate interesting socioeconomic problems.

This we consider to be an interesting and important opportunity but to have a lower priority than some of our others. It would, in any case, not be ready for survey work until the 1978 crop year.

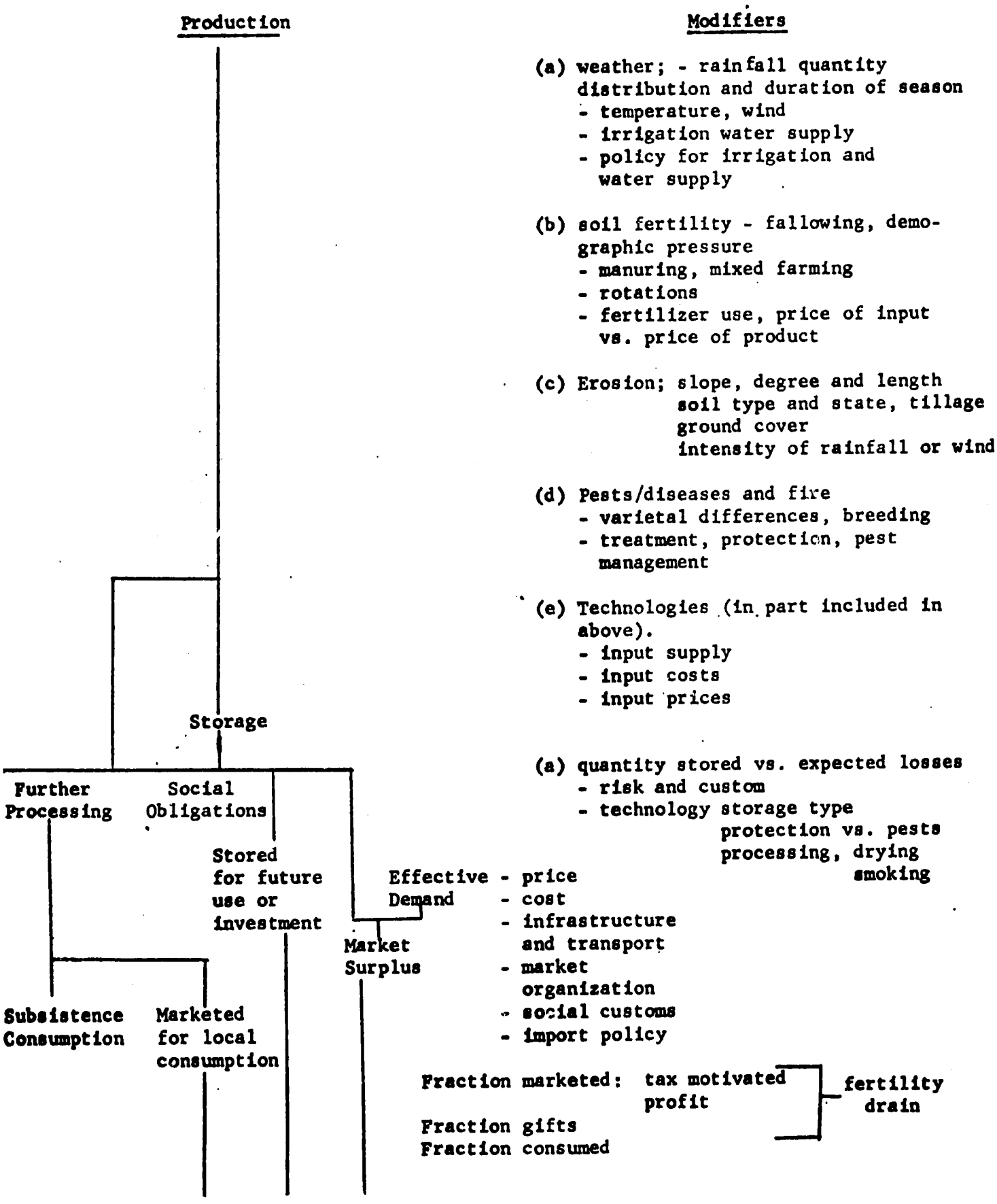
8. The systems which are not covered above, as might be expected, include the indigenous systems of cereal and vegetable crop irrigation, which have been developed outside formal development projects. The smaller bas-fond which does not have the potential of the Sikasso type of production is also not yet included. Opportunities will be sought to cover these types of situations if funds permit.

Sahelian Subsistence Farm Model



Sahelian Subsistence Farm Model

(continued)



Sahelian Subsistence Farm Model

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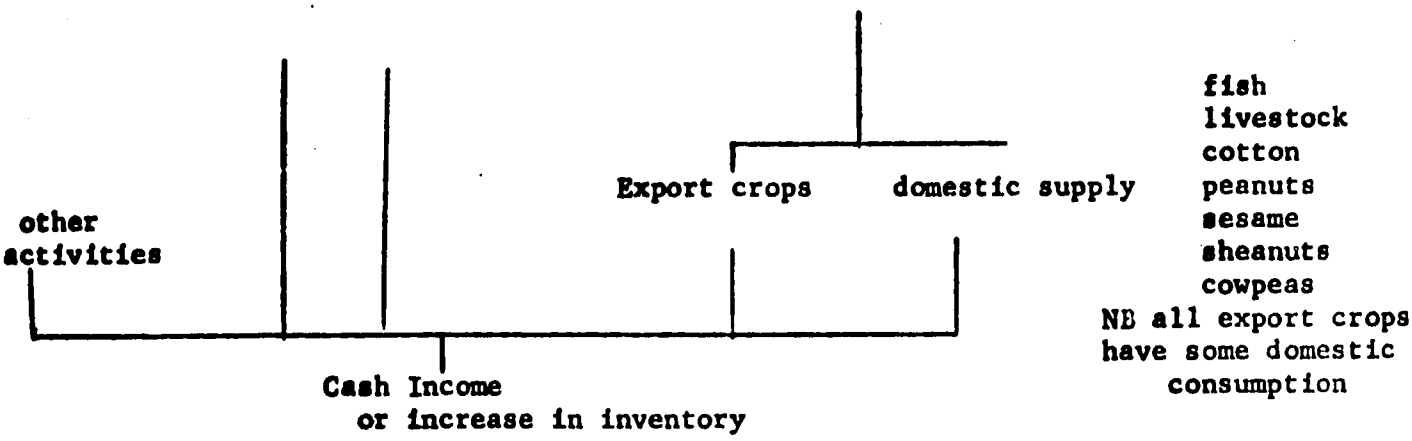


September 28, 1976

Summary of West African Visits on

Purdue Farm Management Research Progra

1. Between Sept. 5th. and 20th Mali, Upper Volta and Niger were visited to seek locations for research studies. The criteria used were:

   (a) an active effort by the local government to conduct micro-economic studies either now or within 2 years, with at least minimal capability to conduct the research.

   (b) interest by the government to use such data in project evaluation and planning.

   (c) interest by the government and the mission in a collaborative effort by Purdue with the appropriate arm of government in training and carrying out research on micro-economics of rain fed and irrigated farming.

2. Mali. The responsibility for carrying out micro-economic studies lies clearly in the Unite d'Evaluation of the Institute d'Economie Rurale. This work is already under way in IBRD financed projects and under IBRD sponsorship. This includes OACV, the peanut "operation". Evaluation is also proposed in other parts of OACV (near Segou) and in the rice operations at Mopti and Segou; this will be followed by studies in the cotton zone. Unfortunately the Unite d'Evaluation is short of funds and is currently having problems in analysis.

   Dr. N'Gollo Traore would welcome Purdue's assistance both in irrigated and rain fed farming projects. However, his first preference is for USAID or Purdue to provide more all-terrain vehicles. He was told that this was

not possible. Further possibilities will be worked out while Dr. Traore is at the University of Michigan.

An attempt might be made to collaborate with the U.S. agricultural economist who will be working under Michael Horowitz's direction in the Millet Production Project on the Dogon plateau.

3. Upper Volta. Due to inability to meet Dr. Salyia Sanon (Minister of Development) because of a helicopter crash killing several members of the Government and requiring the Minister's presence at the separate funerals, nothing definite could be arranged.

However, the Volta Valley Authority (AVV) is continuing to make socio-economic studies of the settlers in the development scheme. M. Malcoif (IRAT), who has been involved in agronomic research in the AVV said that there were only funds to provide 7 of the 20 interviewers needed and little money for systematic analysis. After getting the blessing of the minister, this would be an interesting area for a collaborative study.

Proposed plans for the development of the ORD of the Sahel currently include a Bureau d'Etudes at Dori. The GOUV has submitted the proposal to the Mission d'Aide Cooperative (at Ouaga). However, the whole planning effort for the ORD is in a state of uncertainty and is under discussion in the GOUV (between Rural Development and the Plan) and between the planning team members (the Director wishes to stay in Onega and work under the plan and the assistant, who has done a major share of the work, wants to work from Dori, the ORD headquarters). This discussion will certainly not last long into Calendar 1977 and if the Bureau d'Etudes is set up it would provide an unparalleled opportunity to collaborate in socio-economic studies of farming in the Sahel itself, with the immediate prospect of the results of the studies being used in program planning.

During the next visit a discussion with the Minister should be possible. The position of the Planning Unit set up by IBRD and FAO in the Secretariat of the Executive Committee on Rural Development, should be clarified.

A third opportunity is the further study of the Matourkou data. Discussion with Mr. W. Peeters (FAO, Matourkou) resulted in the offer is a PCV, graduate in agronomy, for help in analyses at Matourkou. Peeters said that the Matourkou data should be available by the year-end. The Dutch government is considering funding a socioeconomic research unit at Bobo-Dioulasso, with Peeters holding a responsible position. Purdue cooperation with this unit would be welcome.

A further possibility of interest to the Mission is an economic analysis of the 1,000 ha Vallée du Kou irrigation project. However, it is not known what the Minister's attitude would be to the analysis of this project, which is currently having serious difficulties due to decline in yield. It might be possible to obtain assistance (e.g., from Dr. Sam Litzenberger) for the conduct of some trials in the perimeter to overcome the current problems with low yields.

While the precise nature of the potential areas of Purdue Collaboration is not yet defined, it is clear that the GOUV and the AID CDO will welcome collaboration.

4. Niger. The Institute of Agronomic Research of Niger (INRAN) is in the process of setting up an agricultural economics department with the responsibilities of economic planning and micro-economic and statistical research. This is to start in 1977.

Dr. Garva, the director of INRAN, would welcome any collaboration in training and research that can be given by Purdue; however, he expects that Dr. Eicher will be able to provide him with some fellowships for training his new staff in agricultural economics.

The research proposed for 1977 includes rain fed and irrigated farming but the geographic area is yet to be defined.

The RDO (Al Baron) and the Ag. Officer (Jim Livingston) both said that they would welcome collaboration between INRAN and Purdue on micro-economic studies. Livingston said that there were some training fellowships in the budget submission (as well as in the Entente Food Production Project) and that Purdue might receive some of the students.

Completion of the inventory of possible areas of cooperation. Dr. Morris has been asked to go to Senegal early in October for a week on another task and it would be feasible to contact the RDO and GOS on what should be the possibilities there. Harry Petrequin should also be consulted with the OMVS (Senegal River Valley Authority) on the possibilities in the Senegal River basin area, specifically in Senegal and Mauritania.

A visit should also be paid to the OMVS documentation center at San Luis.

In this way, an inventory of the activities and interests of the Sahelian governments, excluding Chad, in micro-economic analysis of rain fed and irrigated farming should be finished by about mid-October (1976).

Monthly Report Nov. to Mid Dec., 1976

W. H. M. Morris

The first activity in November was participation in the African Studies Association meeting at Boston. My activities included leading the discussion in the session on library resources. My conclusion was that, while the US resources (as a whole) in periodical holdings covering Africana are substantial and the book holdings are also satisfactory, for the development economist the major source of information is proceedings of seminars and workshops and documents. Holdings of these two types of material is much less adequate and less well cataloged. That is, it is not difficult to locate periodicals and books and to borrow them through interlibrary loan, but documents were much more difficult to locate and collections were less complete. Michigan State's African Agricultural Collection, now moved from Agricultural Economics to the Main Library and AID's proposed document center will be helpful but will not answer the problem for the majority of workers in the field.

The needs of undergraduate students for Africana in several centers are quite well met. New programs starting on rural development in Africa are less well served. The West African documentation centers are helpful (Niger River Basin, Niamey; International Hydrological Center, CIEH, Ouagadougou; Senegal River Basin, OMVS, St. Louis, and W. African Rice Development Association WARDA, Monrovia), but most of them are not able to supply copies of documents although each is equipped to prepare microfiches.

My second activity at the meeting was to present a paper on Cereal Production in the Sahelian region and its problems; Charles Hanrahan ERS,

USDA and Dirck Stryker, Fletcher School, were on the same panel. We had a good session but attendance was poor (last morning of the meetings). My thesis was that most of the Sahelian countries (Mauritania excluded) now have the farm production capacity to be self-supporting in basic foods. Low prices for food grains is the major barrier to self-sufficiency. Senegal has a comparative advantage in exporting peanuts and cotton and importing low quality rice. The Sahelian countries have traditionally exported and imported cereals along their borders and this should be encouraged. Most droughts are not widespread like the 1969-74 episode; indeed, there are dry areas in the region almost every year. Traditionally the supply for these areas has been evened out from farm storage and trade.

Stryker's paper was mainly on trade within the states and Hanrahan's on the trend in levels of food production in relation to population within the region.

The visit to Boston provided an opportunity for discussion with Stryker, including obtaining a copy of Charles Humphrey's Ph.D. thesis, which uses an innovative single survey (as opposed to serial surveys usally used) technique for microeconomic studies in a developing country (Ethiopia) and identifying two students who might be able to work on the Purdue program after Ph.D. prelims. Six weeks later Stryker said that Tufts has jobs for both of the students.

A second major activity was participation in the Conference on Farming Systems at Bamako, Mali. This included a pre-conference tour to the Sikasso region, under the leadership of the Director of the Rice Project and with Mr. G. Pocthier (ISRA, Senegal) and Mr. M. Braud (Director IRCT - Cotton and

Textile Fibre Research Station - Paris). The low cost irrigation in the broad valley bottoms was very interesting, as was the way in which irrigation fitted into the rest of the farm and non-farm activities during the year.

The Conference, sponsored by the Ford Foundation and World Bank, covered research on the economic aspects of farm production systems and its potential role in the design, monitoring and improvement of agricultural development projects. This subject area includes the scope of the Purdue projects. Participants included representatives from most of the countries and organizations involved, including IBRD, MAC (France), Ford Foundation, IITA, ICRISAT, Samaru (Nigeria). A full set of notes is being typed and copies of the papers were brought back. Copies of forms, code books and analytical procedures have been requested, particularly from the IBRD project in North Nigeria. This material provides us with a "state of the arts" report and a methodology that we can start using with a minimum of adaptation; this would make our results comparable with those from other countries.

The Conference also helps to indicate where microeconomic studies are being carried out and to complete our inventory. It also showed that evaluation using this methodology is probably beyond the capability of an extension organization and has to be undertaken as applied research. It does not fit in the existing agronomic research system, which tends to be restricted to stations or substations or, in the Senegalese case, to pilot farms and villages, and not to have a direct involvement with farmers at large.

David Norman (lately of Samaru, Zaria, Nigeria) and P. Zuckerman (lately of IITA and now IBRD) both agreed to come to Purdue for discussions

with our staff. It would be useful if one of our staff could visit ICRISAT to review the farming systems work in progress there and the methodologies involved.

During the conference it was possible to discuss the Malian priorities for microeconomic studies with Dr. N'Gollo Traore, Director of the Agricultural Economics Institute (IER), in which the work is being done. Related to this is a need expressed by the Minister of Rural Development of Upper Volta for information on irrigation development such as is seen in the Ivory Coast (out of our region) and the Southeast of Mali, which we could study.

The visit to Mali was also used to arrange for the nomination of Tiena Coulibaly (of Laval University) as an AID fellow to come to Purdue and to discuss the possibility of Mr. Niang working at Purdue on the Mali Livestock Model. The proposed 211d symposium in Bamako was also discussed. Dr. Sy requested that we get a clarification of David Shear's plans for subsequent action on the livestock model if the Malians wish to continue work with Purdue and some other members of the consortium after the termination of the 211d grants.

With reference to the proposed 211d workshop, Dr. Sy needs to know, before he approaches his minister, what will the workshop accomplish and will it help the Malians to fulfil their plans? Dr. Sy also wanted some financial help to pay for one man's travel to Abidjan and Accra for a simple market Survey. We sould attempt to obtain similar information in Dakar and Monrovia. This material would be presented at the workshop in relation to the export potential for Mali.

Other activities on the Nov./Dec. trip included:

1 Further study of the situation in Senegal. Completion of the inventory in Senegal has been delayed by the absence of Dr. Saugier, Director of ISRA (Senegalese Agricultural Research Institute) who returned to his post on Dec. 1. It is hoped to see him in January in Dakar. A visit should also be made to the OMVS documentation center and to the various other organizations that will be clarified in the outcome of discussion with Dr. Saugier.

I have now had discussions with one development organization (SODEVA) and two of the research departments involved. The major item to be resolved is our relationship vis-a-vis ISRA and the Ministry of Agriculture. Attempts to solve this at an inappropriate level would probably lead to trouble.

2. During a visit to the Gambia on the OECD mission, I found that there will be a symposium on the tsetse fly problem in livestock production in April. An important contribution will be a report on an epidemiological study of N'Dama cattle and trypanosomiasis. This could serve as a model for a similar study in an area where there were zones of production with N'Dama, crossbred, and zebu cattle, such as South Mali or Western Upper Volta. This would provide data for economic analysis of the alternatives for cattle production in areas infested with different flies and at different levels of intensity.

This is interesting as a potential activity to Purdue and Texas A & M animal scientists.

3. Discussion of priority areas for our research in Upper Volta with Minister Sanon. Last time I was in Upper Volta the AID Mission director sought an official appointment with the minister and failed to get one. This time I was able to get a meeting and had a good discussion but the time did not permit following up by making an appointment with the organization with which we will be involved, the AVV (Volta Valley Authority). A summary of the discussion with Mr. Sanon is appended (Annex 1).
4. Discussion with Professor Anthony Hall, University of California, Riverside, on the MUSAT project. This project covers the agronomy of arid lands with a Sahelian type climate, while the Oregon State project covers the semiarid tropics with winter rainfall (Mediterranean climate). This discussion should lead to an active interchange between the Purdue and Riverside projects (see Annex 2).
5. Discussion with Dr. Garva, Director of INRAN (Niger Agricultural Research Institute) (Annex 3). Dr. Garva appears very interested in collaboration with Purdue as well as with Michigan State (from which he expects to get a staff of 4 experts). However, it may take time to get decisions out of INRAN and it will be advisable to discuss the terms of any agreement with the AID Mission in Niamey before negotiating with Dr. Garva.

A note on the government scale of pay for survey workers and the costs of rental vehicles as attached (Annex 4). The level of pay must be specified or you are liable to find yourself paying a higher rate than necessary.

I met Chris Delgado (Cornell and CRED) and Ken Shapiro (CRED) and it looks as if we will be able to have access to Delgado's data and Tod Eddy's data in late 1977 when their theses are completed. Both are making village surveys on farming and livestock production; the first is working in Upper Volta and the second in Niger. Discussion with Mr. Seignebos, N'Djamena.

I thought at first that Chad was too far away and might not be a good (safe) place to work for the project in general. The Senegal River (Senegal side) seemed at first sight to provide a better opportunity for study. This may be incorrect. SAED, the development organization on the Senegal River, has declined to collaborate with ISRA and the reasons for this need to be clarified. SAED also manages most of its operations on a basis of paying farmers for the weight of product with the farmers working almost like piece workers.

The additional fare to Chad is very little if anything and provided Chad is the first or last stop on the tour the visit takes only about 2 days extra travel time in all. There is a series of small perimeters (25 ha or so) on the Chari, with social problems of from the nature of the existing work calendar and its conflict with the demands for irrigation. There are two medium sized perimeters in operation on the Chaddian side of the Logone.

I have contacted a professor of geography at N'Djamena who is involved in a 6 year study of the region that includes these perimeters, who has done 4 years of work already. He is interested to collaborate with us by reporting on his study as it touches on the area in which the irrigated perimeters lie and

the activities of their people. This is a priority study area for the Government of Chad. We could send a student to work in Chad in association with the geographer and the Chaddian institution involved for the 1978 or 1979 season, if this seemed appropriate (See Annex 5).

July 23, 1977.

Internal Progress Report
Purdue West African Research
Senegal

After a period of adaptation Douglas Barnett and Edna Loose have settled down well at CNRA, Bambey. Their research programs have been agreed between Purdue and CNRA and the students. They comprise three major components:

1. Modelling of a standardized farm in the Thies-Diourbel area using data from the Cellule de Liason (USAID Senegal Cereals Project). This will attempt to model the existing situation and then to answer "what if?" questions. Such questions might include, under what circumstances would farmers grow the new Souna III selection for the market? What are profitable rates of fertilization with present and improved varieties? and hopefully provide a better understanding of the place of animal traction (horse, donkey and oxen). This will provide a useful point of departure for the design of a new project. The results will be obtained using a new Program introduced by Purdue and adapted by Mr. Yaciuk on the Senegalese IBM 360-10 computer and the report should be ready in November or December 1977. Doug and Edna will collaborate on this task.

2. A survey and analysis of the role of women in two of the villages of the Cellule de Liason study. This work will concentrate on the domestic and commercial work of women before and after the introduction of mechanical threshing, millet hulling and grinding and of ox drawn water systems. The agricultural work of the women has already been studied in the input-output studies of farming. The results should show the degree of food selfsufficiency of the family, food processing and commercial activities of women as affected by the postharvest mechanization, and the effect of an ox drawn water system in villages with wells 30-40 m deep. The effect on womens' employment and income is specially interesting.

This work, which will be done by Edna Loose in the Cellule de Liason and in collaboration with Richard Lalonde (IDRC), was in the 1977/78 program of the Cellule de Liason. Edna Loose will provide the technical help to get it done. The Cellule is providing a student to help during the summer.

Edna needs to meet Michèle Fiéloux and also Josephine Gissou (when she comes to Dakar University).

3. A survey will be made by Doug Barnett, in collaboration with Jacques Faye and M. Benoit Cattin of CNRA, to obtain a better understanding of the objectives of the individual members of the nuclear and extended families and to find out what effect these objectives have on the agricultural production in the Unitées Experimentales in the Sine Saloum. Doug will also try to include the attitude of the family member to risk as a factor in decision making. This work builds on the recent study by Richard, Fall, and Anthony, modelling a typical farm in Sine Saloum. The solution to this set of problems will be of value to research and extension (SO.DE.VA) in the peanut basin in providing a better understanding of decision making on farming in the family.

A fourth activity has been proposed to ISRA and the CNRA--a two-day workshop on modelling techniques in agriculture. CIDA (Yaciuk and Lalonde) may collaborate in organization and helping with translation. Other organizations including the University of Dakar, SO.DE.VA Bureau d' Etudes, and other branches of the research and planning organizations. The proposed date is in November and will be set shortly.

OMVS Socio-economic Study. Ed Weiler has been handicapped by delay in the arrival of Mr. J. C. Boutillier, of ORSTOM the director of the UNDP study team until the end of July. Miss Michele Fieloux will arrive at the same time as Mr. Boutillier; she will be asked to visit CNRA, Bambey, for discussion with Edna Loose on her research.

Ed Weiler has been starting work in the absence of Mr. Boutillier, by reviewing the data in the OMVS, AID Office, OMVS Dakar Office, ORSTOM (Bel Air), and the OMVS Documentation Center (San Louis). He has also had discussions with Hassan Tuluy of the Stanford FRI-WARDA study. Ed is presently trying to get the data on which to make an economic analysis of the irrigation perimeters on the Senegal River. This excludes the farm level which will be studied under Boutillier. The perimeter study is done by comparing the data in the design study and in the execution reports. This is an important phase of the Purdue - AID study of small and medium-sized perimeters.

The proposal is that Ed Weiler will supervise survey work in about 3 small (25 ha) irrigation perimeters in Senegal and Michèle Fieloux will have about the same number of survey workers (3-5) but in a medium sized perimeter (1,000 ha or so, probably Dagana or Nianga). The remaining areas including the Mauritanian side will be covered in less detail by Mr. J. D. Boutillier and a Senegalese and Mauritanian counterpart. We may take on some additional responsibilities in 1978 if the need arises (for example water management studies).

Ed seems to be interested in a thesis on either migration or the economics of perimeters. Michèle is interested in the effect of change in social structure and of the introduction of irrigation on the role of women. However, both will also have the joint responsibility of the input/output surveys.

While in Dakar I participated in the Stanford FRI-WARDA Workshop to ensure a full cooperation without duplication in the two projects.

Niger

Falika van de Walle has defined the study of the proposed Tara irrigated perimeters and has started on the first stages of the project that will lead to the socio-economic study. Three villages close to the proposed perimeter will be surveyed using the general approach of a pre-survey, sample selection, and repeated, detailed interviews. The effect of the different themes proposed in the project will be studied.

The extent to which it will be feasible to study the labor requirements of irrigated agriculture and the extent to which the data will have to be synthesized from elsewhere is still not resolved.

Opportunity costs of labor including fishing (a major dry season activity), working elsewhere (including presumably the rice project across the river in Benin), will be estimated carefully.

The interrelationship between farmers and livestock herders and the association of livestock and farming will also be included.

The study will include a review of the other forms of irrigated farming in Niger

Upper Volta

Josette Murphy our latest "find" is taking leadership in the reorganization of the Volta Valley Authority's Statistical Service. The service has had three major activities: annual population censuses, family budget studies, input/output studies of farming, together with analysis of the first two in Ouaga and third in Paris by SATEC. We found a Dutch collaborator, Leendart Sprey, an econometrician (University of Groningen) working for the International Institute of Land Reclamation, who will work with us at least for this year. This, together with Della MacMillan and Tom Vollrath for part of July and August should enable us to launch our proposed program, with the Statistical section of the AVV under Ouedrago, Francoise. That is, with Francoise, (1) To reanimate the survey workers in the field and to carry out weekly or twice a month supervisory visits to each of them. (2) To improve their training, clarify points of misunderstanding, and fill gaps in the population census (starting July 25) and in the regular surveys. (3) To supervise the population census of the Valley area and its analysis and help to produce an early publication. (4) To improve the analysis of the budget survey. (5) To send the tabulated results of the input/output survey to Purdue for analysis the first year (on paper or on magnetic tape) and next year to send back a routine suitable for processing on the local IBM 360-125. Later in the year we hope to get some data on the production and family size of the squatters.

We propose to help the AVV develop studies of what should be, not only of what is, and to help in liaison between the agricultural research and the extension sections in getting feasible techniques implemented.

The farmers seem to have two major problems: a cash flow problem which causes them to be unable to buy the inputs proposed and a proposed pace of growth of the farm that is unrealistic. We propose to send back to Purdue all the rest of the Matourkou data we can get and have it analyzed to identify the feasible pace of growth of the new farms for different sized families and to have the cash flows estimated.

We have also provided copies of Malian and Senegalese forms used by extension workers to record data on their farmers. This is for a basis for developing the AVV extension workers farm record forms.

The AVV statistical service has previously been somewhat of an orphan, lacking transport, with only one supervisor for 13 field workers, with insufficient desk calculators and so on. They seem to be very relieved to have someone really wanting to help them.

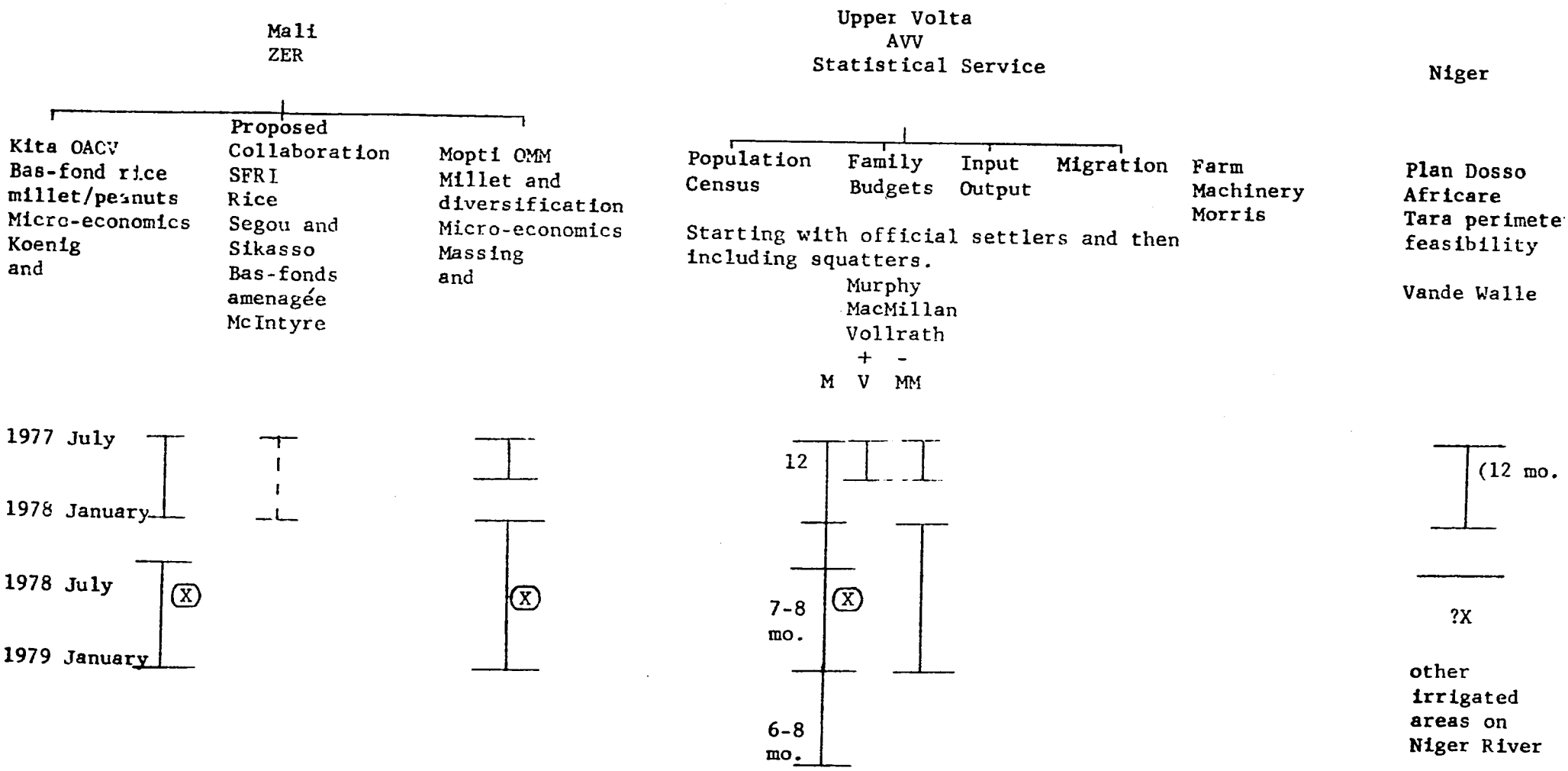
Mali

Andreas Massing is on a visit to the Dogon (Operation Mil Mopti) to do the reconnaisance necessary to decide how to select a sample for this year's surveys. He plans to stay in the Mopti area for two weeks. He is paying particular attention to opportunities of bas-fonds and irrigation as a diversifying factor for the

agriculture. The rainfall is also included as an important variable. Some villages, without possibilities for diversification out of millet or sorghum, are also being studied. The many microclimates in the plateau area make it difficult to select representative areas.

Dolores Koenig intends to do a socio-economic study of farms in the region of Kita, a region presently served by the OACV (Operation Arachides et Cultures Vivrieres). The major cash crop, peanut and the major staples millet and sorgho, are in general farmed under the supervision of men on a family field. In addition to these two major crops, rice is cultivated in bas-fonds, generally by women who also cultivate individual vegetable gardens on higher ground. This study will have two major foci: 1) to look at the variation in rice production between villages and its relationship to access to presently exploited bas-fonds as well as other criteria; 2) to examine the impact on women and their farming practices of the adoption by men of various farming improvements, especially mechanization. As women are those responsible for most of present bas-fonds rice production, these two foci are not unrelated.

Immediate plans are to work with OACV encadreurs in the region to determine the locations of presently exploited bas-fonds and to get estimates of rice production in various villages. Using this information, a preliminary typology of villages will be constructed to aid in the selection of actual village sites. Among the criteria being considered for actual village selection are the following: accessibility to bas-fonds, present rice production, access to market, rainfall variation. Secondly, plans are being made for the recruitment of encadreurs, so that discussion on the final form of the questionnaires can be begun with them as well as with agents of the local branch of Alphabetisation Fonctionelle. One place where the present questionnaire needs definite elaboration is in determination of a list of women's non-agricultural, particularly household activities so detailed work times can be done on this during the study. Thirdly, after these two things are underway, Dolores would like to hold group discussions with the women of several nearby villages in order to discuss their farming concerns so that the questionnaire can be adapted in such a way as to gain more useful information on women's range of activities (and perhaps lead to ultimate development of an opinion questionnaire designed for women farmers).


Mali
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Kita OACV
Bas-fond rice
millet/peanuts
Micro-economics
Koenig
and
Proposed
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	OMVS Senegal River Irrigation				Senegal CNRA (Dry land)		Other Senegal	
	Boutillier Senegalese & Mauritanian	Weiler Sundman Small perimeters (Senegal) Migration? Micro-economics	Fieloux Medium perimeter Senegal Womens' Roles Micro-economics	Other studies including water management, perimeter economics: Water Management	Other studies including water management, perimeter economics: perimeter economics	Cellule de Liason Loose Barnett LP model Post harvest mechanization Womens' Roles Micro-economics	Unitées experimentales Barnett LP multiple objective, multiple level of technology followed by yield variability associated with climate	Mixed farming-herding	Oth "we lan are
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Purdue

1. Irrigated perimeter economics

Westneat

2. Synthesis and modelling
   (1) Domestic production traditional & import substitution plus export crops

   (2)

1977 July | Terminate December 1977

1978 January

(X) (X)

Ph.D.

Status of AID AFR Projects

C 1257 and 1258, Purdue University

May 31, 1977

Preparations are almost complete for the departure of the researchers to the eight areas of work in the Sahelian States. These areas were selected in accordance with our report of March 2, 1977, "Review of Proposed Field Activities." That is, the areas are a priority for governments, which do or which would, otherwise have to undertake the work if our projects did not do so.

Preparations, apart from the normal course work for degree students, includes in depth review of documents, presentation of reports and discussion. A basic conceptual model of farm production has been proposed. An inventory of information needs, a workshop on survey design, and a seminar on survey execution have been carried out.

These preparations have lead to the development of a common scope of work for the study of farm and non-farm activities of the "subsistence" farmers and their families, fitting a single conceptual model. However, each area will require individual treatment; this will be assured by the development of the questionnaires during the training course for the survey workers and with representatives of the collaborative agencies of governments.

The areas have been selected to represent the different climatic zones and the different types of irrigation seen in the region. However, it cannot be said that the sample is representative of the region from a statistical point of view, and certain types of farming have not yet been included.

The whole program was discussed in Washington on March 2, 1977 and has been discussed with AID in each country. Reporting cables on each country program (except Mauritania) were sent from the field in April, 1977.

A study of the methods and criteria for the evaluation of irrigation projects has been started. When this has advanced further the methodology will be used to design survey forms for use in the field. A position paper or papers will be submitted to U.S. AID for discussion of the criteria for evaluation of irrigation projects.

The following activities are planned for the first year of field work:

A. <u>Senegal</u>

1. Fiéloux and Weiler (followed by Sundman) will participate with J. C. Boutillier (ORSTOM, Project leader), Milleville (ORSTOM) and three African counterparts in a socio-economic study of irrigated areas on the Senegal River. This study is to be done for the OMVS with UNDP and FAC financing as well as AID financing through the Purdue projects. The duration of the study in the first case is one year.

   We will contribute the economic expertise plus 2 of the 4 expatriates. The study will include all the agricultural operations, irrigation, flood recession and dry land, and the interaction between irrigation and immigration.

Details of the study will be laid out in a meeting in Dakar in the week of June 12th. The Stamford Food Research Institute/ WARDA rice policy research project will be represented at the meeting.

2. We will participate in the socio-economic studies of the "Cellule de Liason" at the Bambey Agricultural Research Station and SODEVA, in the Thies-Dioubel area. We will participate in data gathering in 5 areas under intensive surveys (3 old villages, plus a new village and a horticultural production zone). We will also participate in data analysis.

   This will provide an opportunity to review the two years of data already gathered. The current survey forms will be reviewed and amendments proposed. It has been observed in the SODEVA project area, both Thies-Dioubel and the Sine Saloum, that a single family uses several different levels of technology in its farming operation. The head of the household may have an area of heavily fertilized crops and an area, producing a lower yield, with a lower level of fertilization. His sons use a lower level of technology and get a lower yield and the wives get an even lower level of yield. This will be studied, starting from the assumption that the farmers are rational in their employment of their resources.

   This year for the first time the Liason Group will be studying the effect of use of the oxen to draw water (30-40 m deep) on the farm activities of women and the effect of post-harvest mechanization (threshing, decorticating and grinding). Work on herbicides will include labor saving since the labor supply limits the agricultural production. These activities could have an important impact on the rainy season crop production and on the production of vegetables in gardens under irrigation in the dry season.

   Sale and purchases of food grains will also be studied in this area this year. An attempt will be made to get a better understanding of the conditions under which more millet would be grown and marketed. The present practice is to use peanuts and not millet as a cash crop.

   The Liason Group is also interested in modelling the farm operation. So far, with IRAT and INRA in France, the models have only considered the family head and his farming; we propose to help to introduce the activities of the sons and of the women

into the model. The head of the Liason Group is expected to visit Purdue early in 1978 to participate in the analysis of the data and to discuss the model building.

3. A researcher will spend the crop season at Kaolak with three objectives:

   To review the historic data of the Unitées Experimentales, started in 1968/69. This data will be further analyzed.

   To collaborate with the survey workers in the Unitées Experimentales during the 1977/78 season studying some of the same new themes as in the Thies-Dioubel area.

   To collaborate with the SODEVA survey, in the Sine Saloum in an attempt to relate the practices in the pilot program directed by the agricultural research station at Bambey (in the Unitees) and those observed in the SODEVA extension area.

We are prepared to attempt to reproduce the data archives of the Unitées Experimentales for in depth analysis at Purdue. The importance of historic data giving yields and changes over time cannot be underemphasized. One or two year studies cannot be expected to give good estimates of the production functions (the relationships between inputs and outputs) or, of course, probable yields in relation to the "quality" of the rainy season.

B. <u>Mali</u>

Discussion with Dr. N'Gollo Traoré, director of the Agricultural Economics Institute, showed that for 1977/78 the Malians placed priority on starting socio-economic surveys by the "Evaluation Section" of the institute at Sikasso and Kita. Segou irrigated rice was mentioned as a possible area for 1978/79. However, in the proposals for the Club des Amis du Sahel the institute is shown as requesting funds to work in the Kayes, Bamako and Gao regions. Research under M. Horowitz is already funded in the Dogon Plateau.

As a first choice we would have concentrated on the Sikasso region in 1977/78 but Mr. Kleene (Netherlands) arranged in early 1977 to start work in the area and Dr. Traoré changed his priority for us in April to the Kita area. Because of the low cost control structures in bas fonds which permit relay cropping (2 irrigated crops a year) in the Sikasso area, and its applicability in a large area of similar physical characteristics from Senegal through Upper Volta, we are very interested to work in this area and will collaborate with Mr. Kleene to permit a better use of the resources of our project and of his.

We feel obligated to help the Institute to start work in the Kita region, a good agricultural area in the peanut and food crop extension operation (OACV) with traditional rice production in bas fonds, which has not got control structures. In this way we have contrast with the Sikasso region.

The Malian program will be further discussed with CDO Bamako before it is initiated.

C. Upper Volta

In Upper Volta we have undertaken to give technical assistance to the socio-economic studies section of the Volta Valleys Authority (AVV) which is managing the exploitation of the large areas of land being cleared of the vector of onchercircosis. This provides an example in our research of the colonization of new lands, one of the major strategies in the rain fed agricultural development of the region. Our collaboration with the AVV is being coordinated by the CDO Ouegadougou so that it complements the information system proposals of the U.S. AID proposal for Village Development in the AVV area. A major problem is that there is no technician in the AVV with the time and specific interest to supervise the survey work and the analysis. The computer work is currently being done in France, with about 2 years' lag. There will be a meeting to discuss the conception of the socio-economic survey activities in Ouaga in June/July 1977. We propose to assist in analysis of the back log of data and in changing the work of some of the survey workers from making time and travel studies to studying the inputs and outputs of the production of sorghum and other crops. The family budget surveys will be continued. In 1978, it is proposed to study the question of colonization, i.e., who moves into the area as settlers and as squatters, who migrates back out of the settlement area and who stays. The economics of the settlers and squatters will also be studied.

In order to accelerate the analysis of data so that it can be used in project management the purchase of a minicomputer (a typewriter sized, transistorised computer, with a memory, costing about $10,000) is being considered. This could be used by our researchers in Mali and Niger as well as in Upper Volta.

It is expected that our activity with the AVV will be phased into the activities proposed in the Village Development Fund activities.

We have also offered to provide short term training at Purdue for a Voltaic counterpart in survey analysis. The expenses of the travel and subsistence of the counterpart would be paid from AVV funds and we would provide the training at Purdue's expense.

D. Niger

We will undertake the socio-economic study in the preparatory action for the Tara irrigated perimeter at Gaya, Niger. This is an element in the Africaire project. We will assist in the design of the study and take charge of its execution.

This involves:

completion of the studies of the milieu and land use rights started by the Zurich Polytechnic.

- study of the farm models of traditional, improved and modern production. This includes studying how working in an irrigated perimeter fits in with other farming activities in irrigation projects already in operation.

- relationships between farmers and herders.

- attitudes to colonization of an irrigation project in the proposed project area and finding out the potential source of the irrigation farmers.

The survey itself will be developed in collaboration with IRSH (Niamey), the Institute of Humanities Research.

E. Chad

We are awaiting the sociological report of Mr. Seignebos, of the Institute of Geography at NDjamena, which is being done in the IBRD project under the supervision of SATEC, before making any decision on studies in Chad.

Staff Working on the West African Project

Professors	W.H.M. Morris T. Kelley White* B. A. McCarl* W. E. Tyner* T. L. Vollrath
Research Associate	A. Massing (will complete Ph.D. in Anthropology at Indiana University, summer 1977, working at Purdue since Sept. 1976). (Senegal)
Graduate Student Assistants Admitted 1976 Fall	D. A. Barnett (Sine Saloum) E. Loose (Thies-Dioubel, Senegal) E. M. Weiler (OMVS, Senegal River) A. S. Westneat (Cost benefit study of irrigation systems)
Admitted 1977 Spring	S. A. Cohen A. P. Fleming H. A. Schar J. R. Sundman (OMVS, Senegal River)
Admitted 1977 Fall	T. R. Whitney
Under consideration	Holland McKenna Malcolm Versal

***Do not speak French.** The rest of the staff speak French.

Associates working in the field.

Michèle Fiéloux, Sociologist, 3rd cycle doctorate, Sorbonne, Paris. Thesis on migration of the Lobi in Upper Volta. (OMVS, Senegal River).

Dolores Koenig, Anthropologist, Ph.D., Northwestern University; thesis research done in Cameroons. (Mali).

Falika Van de Walle, Ag. Economist, Engineer, Wageningen, Netherlands; lately Associate Expert of FAO in W. Africa, working on rice production. (Tara perimeter study, at Gaya, S.W. Niger).

John Curry, Economic Anthropologist, Ph.D., student/graduate assistant, University of Massachusetts. (Upper Volta). (Probably 1978).

FIELD TRIP REPORT

Senegal

A. Senegal River

1. John Sundman is now at Nianga taking Ed Weiler's place. It is hoped that he can arrange, with the help of J. L. Boutillier, to conduct a survey at Guede (a successful medium sized perimeter, formerly run by the Chinese) and in one or more of the new Dutch small perimeter near Nianga.

2. Michele Fieloux has returned to Matam to continue supervision of her three survey workers. She is enthusiastic about the way the perimeters are operating; but the year 1977, with no dry land or flood recession harvest, has some peculiarities. Labor for rice harvest was available in excessive quantities. The harvest workers and others received gifts of rice, partly because it is not possible to refuse to give rice to those that have no other food.

   As soon as Ed Weiler has a model for evaluation of costs and benefits, a list of the necessary data should be provided to Michele so that a model of the economics of the small perimeter can be made.

3. We have asked Mr. Boutillier to start the arrangements necessary for the Dutch irrigation engineer, Mr. Van Achthoven and his supervisor Mr. Bos to start the water management studies. This will probably be based at Nianga, studying Nianga, Guede, and a small perimeter. However, with the time and personnel available, we can only expect a preliminary study. A future study over a longer period of time might be sumitted to USAID, as a collaborative effort with Cornell, on a broader basis including other factors related to successful management of irrigation perimeters.

4. We have suggested to Mr. Boutillier that we would be prepared to help in the analysis of the socioeconomic surveys to be run later this year and next year under AID funding in the OMVS region.

B. CNRA, Bambey

Edna Loose is continuing her study of the effect of post harvest mechanization and ox drawn water supply on the work of women. In the village where she is working no attempt has yet been made by CNRA to propose alternative uses of women's time. As a result the time saved is not being used productively during the dry season. This study will need to be continued until December 1978, and Edna will return to us in August.

In order to provide a full time job for Edna's successor, we are discussing with CNRA the possibility of helping the liaison group to make time and work studies, as well as budget studies, covering sample carres in the three villages under study. The CNRA has usually only studied the activities on the fields of the head of the "exploitation" and has excluded the work of women and to some

extent sons and hired men. Details will be worked out shortly if we decide to undertake this study.

Mr. Moussa Fall will visit Purdue in May.

C. SODEVA

We have requested SODEVA for permission to collaborate with them in a study in the Sine Saloum, with their Evaluation Unit. This would involve socioeconomic studies on a sample of farms in two or three villages, attempting to develop a whole farm model, covering all the family members.

SODEVA is also interested in collaboration in the Thies-Diourbel area on a similar basis. We agreed to consider this as a possible activity for this year.

D. Casamance

Gene Chiavaroli, who is the program officer for the AID project in the Casamance, welcomed the idea of a study in the Casamance working with PIDAC (an extension organization). He agreed to discuss this possibility with PIDAC and advise us of the outcome.

E. ENEA

The director of the Ecole Nationale d'Economie, Papa Kane, has informed us of the ENEA program of student study teams; six students who study many aspects of village demography, sociology and economics. Papa Kane is always looking for funding for the six month or more research phase of the applied economics curriculum. He is prepared to provide and supervise students in groups or singly. No undertaking was given, but there may be ways in which we could collaborate with ENEA.

F. Mali

At the end of 1977 there was a change in the Minister of Rural Development. In reviewing activities in his ministry, the new Minister found that Purdue and Texas A & M Universities were operating research programs without official agreements. On January 17, 1978 he wrote to USAID, Bamako, suspending activities on the two projects. The letter passed from the mission director to the program office and was sent to Mr. Smith, a livestock officer. The agricultural officer, Quincy Benbow, and his colleague Lance Jeppson, were not informed. So mission clearance was given for H. Schar to enter Mali.

Two hours before Andreas Massing was due to leave an international cable was received by Dr. Morris, sent by the Rural Economics Institute, Bamako, citing the minister's letter and requesting that we not send Andreas; Andreas was stopped at the last minute. Two cables were sent to the AID Mission, but at Purdue we did not receive a word either from AID or from Schar on the situation.

At noon on February 22 Dr. Morris arrived in Bamako and in the early afternoon visited AID and subsequently H. Schar. No explanation was given on the lack of communication. We had been told in August 1977

that we were not to sign the agreement negotiated with the Rural Economics Institute, but that Mr. Golden, AID Assistant Program Officer, would negotiate an agreement with the Ministry of Foreign Affairs. Apparently the AID legal experts from REDSO/WA got involved at some stage and finally on February 28, 1978 delivered a proposed agreement to Bamako. Dr. Morris saw this in Abidjan on the evening of the 27th and gave some comments and cabled others to Bamako.

Two more cables were sent to Bamako requesting information on the status of the agreement without receiving a reply. Dr. Morris was unable to return to Mali as hoped on Monday, March 6 due to the plane being fully booked, including the wait list (even on February 27th). However, on Friday, March 10th Dr. Morris was able to give letters for Quincy Benbow and H. Schar to an acquaintance at the Bamako Airport, where the plane from Ouaga to Dakar made a refueling stop--passengers were not allowed to deplane.

On Wednesday the 15th, Dr. Morris received a cable saying that an agreement, approved by IER, had been presented officially to the Ministry of Foreign Affairs on Monday, March 13; this is seven months after AID undertook to do the job.

The situation is still complicated by the fact that the delay was so long that the presentation of the agreement took place a week after the Minister had been arrested. It is not known what further delay will be caused by the replacement of the minister.

The project manager received a letter from H. Schar in early March which explained his problems. He was very discouraged with the situation he ran into in Bamako and seriously considered returning to Purdue. He could get little information on what was going on and why he had been sent to Bamako under the circumstances. The AID mission confined him to Bamako but Dr. Morris obtained Malian Government permission for him to return to Kita to pay the survey workers and tell people what was going on. The project manager, Mr. Jeppson, was informed of this.

It is hoped that activities will soon be started again.

G. Upper Volta

Josette Murphy is back in Ouaga and the collaborative study with the AVV is progressing satisfactorily. The 1977 census of the AVV families and two months of data from a village were brought back to Purdue for analysis. We agreed to pay for the instruction for a two-day training seminar for the survey workers. The AID Mission was asked to consider what action, if any, should be taken if the AVV has not got trained people to take over from Josette Murphy and Leendert Sprey in 1979. A prolongation of our funding might be necessary.

Positions for Mac Millan and Saul were clarified. It will be necessary for Saul to work out a proposal for his phase of the research.

Mr. Poussy, Director of the Voltaic Center for Scientific Research, was informed of our activities and our proposed expansion for 1978,

which seems likely to be carried out under our original agreement with the Ministry of Rural Development and the AVV. Mr. Poussy also mentioned that he has a colleague working on the socioeconomics of the valley of Kou, an irrigation project. I suggested that we might be interested to contributing to finishing this research and the publication of the results.

H. Chad

The position in the Bol area is insecure due to a bandit force, which has already kidnapped two expatriates who are still being held. ORSTOM has suspended its salinity research project in the area. People are confined to the new Bol irrigated holder and the town. Jack Morris reports that the absorbtive capacity of the SODELAC is being exceeded and that he could not accept a researcher before July and perhaps not then. Mr. Schillinger has been informed of these developments and has requested that we inform him if we have another area where he could work apart from Bol.

The study of irrigated vegetable production around N Djamena, and two irrigated perimeters, a private one and a U. S. private voluntary organization's perimeter, has been started by Ellen Deitchman and Jean Boulet. This looks like a very promising activity and covers areas not otherwise included in our project. It does present a problem of lengthening each trip to the region. However, if one enters or leaves Africa via N Djamena and Paris the added time is reduced. Otherwise, to spend two or three days in Chad can take a week.

Purdue Activities

At Purdue apart from an intensive program on data analysis, and transforming the data onto magnetic tape in the field involving Joe Goodwin, Margot Saunders, and Joe Zarick, there are four studies in process:

1. Ed Weiler is working with Dr. Tyner on his thesis on the costs and benefits of the Nianga perimeter, tracing the history from the first feasibility studies to the realization of the project. This is building on the work done by Art Westneat.

2. Doug Barnett is working with Bruce McCarl and others on an 1 p model of Sine Saloum (Senegal) farming with a multiple goal objective function. The model is now running. Doug is also to adapt the input matrix to the Thies-Diourbel area.

3. Dolores Koenig is analyzing her data on the Kita region (Mali). This data includes a census of the three villages, with information on the adoption of the extension themes of OACV (peanut operation) and some data on labor inputs into harvesting and on family budgets. The surveys will be continued by H. Schar as soon as the GOM has given it's approval.

Kathy Jibara is working with Dr. Thompson on a study of the risk involved in exercising a policy of comparative advantages in the export trade for Senegal. The results of this study will provide probability data on the value of a policy of exporting peanuts and importing rice and wheat. This is needed for the cost-benefit study of irrigation on the Senegalese side of the Senegal River.

SOCIAL COST BENEFIT: THEORETICAL REVIEW[1/]

Arthur S. Westneat and Wally E. Tyner

Using the social cost benefit (SCB) literature, it is proposed to develop the theory upon which to base the practical guide to the evaluation of small- to intermediate-scale irrigation projects. SCB analysis is viewed as a partial equilibrium framework. No attempt will be made to present the general equilibrium issues of a macroeconomic analysis. Also, the principles central to the calculation of farmer profitability are not reviewed here because they form the basis for the farm models. The links between private farmer profitability and social cost-benefit analysis are, nonetheless, central to the evaluation of irrigation projects. Not only do farm budgets provide the basic data for estimates of benefits and costs, farmer profitability must be considered a prerequisite for successful performance of an irrigation project. This will be reported separately.

The objective of this paper is to introduce social cost-benefit concepts, issues, and references. Following a brief historical background, preliminary and general theoretical considerations will lead to a discussion of SCB analysis as an evaluation approach by a national

1/ A contribution to the Purdue West African Research Program, Contract AID/Afr-C 1258, December 1977.

government. The basic analytical issues are approached in the second section: the numeraire, the measurement of direct, indirect, and foreign exchange benefits and costs, as we the shadow prices of investment and labor. A third section focu... pon the major accounting issues of SCB analysis: social discounting, income redistribution, environmental, and risk/uncertainty. The report concludes with a rief discussion of recent evaluations of small- and intermediate-scale irrigation projects conducted in the Sahel.

General Issues

Background

As a separately identifiable part of the history of economic thought, social cost-benefit analysis originated in France in 1844 when J. Dupuit first presented his paper "On the Measurement of Utility of Public Works."[2/] Today, however, the French school which descended from Dupuit eschews the use of shadow prices and conducts its cost-benefit analysis in sharp contrast to the SCB evaluation methods favored in the United States. Evaluation methods of this type are best represented by the work of Prou, Cheval and Gardelle.[3/]

Social cost-benefit methodology first developed in the United States among engineers in response to the mandate of the U.S. Congress concerning

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2/ Dupuit, J. "On the Measurement of Utility of Public Works," International Economic Papers, Vol. 2 (translated from the French).

3/ Prou, Ch., M. Cherval, J. et Gardelle, Establissement des Programmes en Economie Sous-Developpee, Paris; (Tomes 1, 2, et 3), 1963, 1964, 1970, Editions Dunod.

water programs. The River and Harbor Act of 1902 and, later, the Flood Control Act of 1936 required the Corps of Engineers to evaluate river, harbor and flood control programs in terms of their costs and benefits. Federal participation would be authorized "if the benefits to whomsoever they may accrue are in excess of the estimated costs."[4/] The methodologies and evaluation procedures developed by Federal agencies were eventually codified in "The Green Book"[5/] published in 1950. This volume, long considered the standard for U.S. Government SCB evaluations, has since been superceded by the Principles and the Standards for water and land resource planning, published in 1970 by the U.S. Water Resource Council.[6/]

Economists in the United States came later upon SCB analysis than did the engineers. The public-sector activism at the heart of the methodology countered the long-established tenet of classical economics favoring laissez-faire government. The growth of the public sector in national economic life, starting in the 1930's with the wider use of

4/ Quotation from "Cost-Benefit Analysis: A Survey," by A. R. Prest and R. Turvey in The Economic Journal, December 1962, Vol. 75, No. 300, p. 684.

5/ Inter-Agency River Basin Committee (Sub-Committee on Costs and Budgets), Proposed Practices for Economic Analysis of River Basin Projects, Washington, D.C., 1950.

6/ United States Water Resource Council, Principles for Planning Water and Land Resources (Washington, D.C.: July 1970) and Standards for Planning Water and Land Resources (Washington, D.C.: July 1970).

large, public-sector investments requiring substantial amounts of resources and having major repercussions in the economy over long periods of time, drew increasingly the attention of economists.[7/]

Prior to the appearance of E.J. Mishan's Cost-Benefit Analysis: An Informal Introduction[8/] in 1971, cost-benefit analysis had been part of public investment literature, particularly in the area of water resource development. The early classic by Otto Eckstein, Water Resource Development[9/] was follow-d by the noteworthy works by R. N. McKean, Efficiency in Government through Systems Analysis,[10/] Krutilla and Eckstein, Multiple Purpose River Development,[11/] and the case studies by Dorfman, Measuring the Benefit of Government Investments and by Maas, Design of Water Resource Systems.[13/] Mishan's work, prepared as the first introductory text book on social cost-benefit, carefully presented SCB analysis' theoretical grounding in welfare economics.

Mishan's book appeared at a time when SCB analysis had become widely accepted and practiced procedure in economics. In addition

8/ Mishan, E. J. Cost-Benefit Analysis: An Informal Introduction (London: George Allen & Unwin, Ltd., 1971).

9/ Eckstein, Otto, Water Resource Development (Cambridge, Mass.: Harvard University Press, 1958).

10/ McKean, R. N., Efficiency in Government through Systems Analysis (New York: John Wiley & Sons, 1958).

11/ Krutilla and Eckstein, Multiple Purpose River Development (Baltimore: Johns Hopkins Press, 1958).

12/ Dorfman, R. (ed.), Measuring the Benefit of Government Investments (Washington, D.C.: Brookings Institution, 1965).

13/ Maas, A., M. M. Hufschmidt, R. Dorfman, N. A. Thomas, S. A. Marglin, and G. M. Fair, Design of Water Resource Systems: New Techniques for Relating Economic Objectives, Engineering Analysis, and Government Planning (London: Macmillan, 1962).

to a number of journal articles and conference proceedings, Steven Marglin's Public Investment Choice,[13/] which received wide attention, first appeared in 1967, and was reprinted in 1969 and 1972. Charles Howe and K. William Easter's Interbasin Transfers of Water: Economic Issues and Impacts[14/] and D. W. Pierce's The Economics of Natural Resources Depletion[15/] were published in 1971 and 1975. In 1972, J. Price Gittinger's Economic Analysis of Agricultural Projects[16/] and Richard Layard's collection Cost-Benefit Analysis[17/] appeared.

By this time, SCB analysis had been widely used in the area of international development finance. Considered classics in the field are H. B. Chenery's "The Application of Investment Criteria"[18/] and W. Galenson and H. Leibenstein's "Investment Criteria, Productivity and Economic Development."[19/]

13/ Marglin, Steven, Public Investment Criteria (London: George Allen and Unwin, Ltd., 1967).

14/ Howe, Charles and K. William Easter. Interbasin Transfer of Water: Economic Issues and Impacts (Baltimore: Johns Hopkins Press, 1971).

15/ Pierce, D. W. (ed.), The Economics of Natural Resource Depletion (New York: J. W. Wiley, 1975).

16/ Gittinger, J. Price, Economic Analysis of Agricultural Projects (Baltimore: Johns Hopkins Press, 1972).

17/ Layard, Richard, ed., Cost-Benefit Analysis, Penguin Modern Economics Readings (Hammondsworth, England: Penguin Books, 1972).

18/ Chenery, Holis B., "The Application of Investment Criteria," Quarterl Journal of Economics, Vol. 67, No. 1, February 1953, pp. 76-96.

19/ Galenson, Walter and Harvey Leibenstein, "Investment Criteria, Productivity, and Economic Development," Quarterly Journal of Economics, Vol. 69, No. 3, August 1955, pp. 343-370.

As early as 1961, cost-benefit methods were applied in the ECAFE report Formulating Industrial Development Programmes.[20/]

By far, the most significant work to appear during this period was The Manual of Industrial Project Analysis, Vol. II. by I. M. P. Little and J. A. Mirrlees and published in 1968 by the Organisation for Economic Cooperation and Development (OECD).[21/] The OECD Manual consolidated the body of knowledge on the cost-benefit evaluation of public investment in industrial projects in developing countries and was soon considered the "Bible of social cost-benefit analysis."

The United Nations Industrial Development Organization (UNIDO) published, in 1972, a work equal to if not surpassing the OECD Manual. The appearance of UNIDO's Guidelines for Project Evaluation[22/] touched off a debate between proponents of the two approaches. Little and Mirrlees, benefiting from this debate highlighted by a conference sponsored by the World Bank, and from practical applications of their methodology, published a revised version of the OECD Manual in 1974 under the title Project Appraisal and Planning for Developing Countries.[23/] Reflecting much of the dialogue between the two methods and the cost-benefit methodology of the World Bank is Squire and van der Tak's Economic Analysis of Projects[24/] which appeared in 1975.

20/ United Nations, ECAFE, Formulating Industrial Development Programmes, Development Programming Techniques Series No. 2 (Bangkok: 1961).

21/ Little, I. M. D. and J. A. Mirrlees, The Manual of Industrial Project Analysis, Vol. II (Paris: OECD, 1968).

22/ Sen, Amartya, Stephen Marglin, and Partha Dasgupta. Guidelines for Project Evaluation. (UNIDO, (New York: United Nations, 1972).

23/ Little, I. M. D. and J. D. Mirrlees, Project Appraisal and Planning for Developing Countries (New York: Basic Books, Inc., 1974).

24/ Squire, Lyn and Herman G. van der Tak, Economic Analysis of Projects, (Baltimore: Johns Hopkins University Press, 1975).

Public investment in developing countries became increasingly popular after World War II. Large-scale industrial and infrastructure projects, financed through national public-sector investments by foreign governments and marshalling substantial resources were planned in anticipation of long-term benefits and self-sustained development. Evaluation of such projects required a procedure that went beyond commercial profitability--an evaluation procedure that included costs and benefits not normally quantified and that still guided public-policy decision-makers in the national use of available public-sector investment funds. This procedure was social cost-benefit analysis.

Methodology

SCB methodology is a means for governments to evaluate projects it helps finance. It enables government to identify and to compare a project's national economic profitability relative to other project possibilities. The national economic profitability statistic is a weighted, adjusted sum of net benefits which discounts furture net benefits to the present. These measures of project worth are commonly used in SCB analysis.

1. The Benefit-Cost Ratio

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_n}{(1+i)^n}}{\sum_{t=1}^{n} \frac{C_n}{(1+i)^n}}$$

2. The Net Present Value

$$NPV = \sum_{t=1}^{n} \frac{B_n - C_n}{(1+i)^n}$$

3. The Internal Rate of Return (i)

$$\sum_{t=1}^{n} \frac{B_n - C_n}{(1+i)^n} = 0$$

where B_n equals the project benefits in each year, C_n equals the project costs in each year, n equals the number of years, and i is the interest or discount rate.

SCB analysis may be viewed as emphasizing a unitary choice coefficient. Decision-makers faced with numerous projects dealing with differing technologies and resource demands, it is argued, require a summary choice coefficient capable of homogeneously aggregating diverse types of costs and benefits. There is no reason, however, why an optimal decision-making procedure should rely on such a unitary statistic.

Hellmuth Bergmann in his Guide[25/] proposes a minimum of nine comparison coefficients, for evaluating irrigation projects while the UNIDO Guidelines, and other SCB methods, recommend a process of successive weighting of net benefits. It may be more satisfactory to the eventual decision-maker, however, to have prepared a hierarchical decision-making stratégy in which successive decisions using successive comparison coefficients systematically rank the projects.

Rather than rely on a unitary cost-benefit coefficient, it is our contention that decision-makers need more comprehensive information.

25/ Bergmann, Hellmuth, Guide to the Economic Evaluation of Irrigation Projects, (Paris: OECD, 1973).

As a result, a more detailed set of evaluative statistics will result from this procedure. The particular decision-making strategy is left to the responsible government service concerned.

Our methodology, also, recognizes that project evaluation is a continuing process, with at least three different stages: construction, adaption, and full normal operation.[26/] In helping to decide whether or not to implement a project, the evaluation procedure needs to be capable of evaluating the relative present value of the project as it proceeds and as initial parameter values change through time.

Government

SCB analysis evaluates projects for the government of the nation in which the project is conducted and for agencies considering the financing of such projects. It is a methodology which serves the national-level planner and the planning agency capable of making public policy decisions and of applying public-sector funds for the public welfare. SCB analysis serves the politically responsible and is an apolitical approach only to the extent that an attempt is made to present all of the relevant impacts of project implementation.

Government involvement in project promotion assumes that the private sector is either unable to execute the project fully. Projects may be lumpy and require such a large amount of resources that private organization is unable to manage or the private sector may be unable to reap

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26/ Ibid., p. 91.

non-market social benefits produced by a project. It is beyond the scope of this thesis to analyze the issues involved in public-sector vs. private-sector projects. "It (SCB analysis) must accept the state of the economy and the policies of the Government as given...even if the policies are at best questionable."[27/] SCB analysis rests squarely on the assumption that stable Government is the final repository of societal values.

In evaluating projects, a government may have one or more objectives. Identifying these objectives and quantifying their relative values is central to SCB analysis. There are seven typical objectives of government: increasing aggregate consumption, income redistribution, growth, employment, self-sufficiency, merit wants, and environmental quality.[28/]

Increasing aggregate consumption is the keystone upon which SCB methodology is built. It is the expression of the project's role in helping raise the standard of living of the citizenry. Income redistribution, employment, growth, self-reliance, merit wants and environmental objectives usually are considered subordinate objectives to this fundamental goal.

Income redistribution appears consistently in the SCB literature as a social objective. Benefits and costs are adjusted according to who

27/ Dasgupta, Partha, "An Analysis of Two Approaches to Project Evaluatio in Developing Countries." Bulletin of the Oxford University Institute of Economics and Statistics, Vol. 34, No. 1, February 1972, pp. 33-52.

28/ The objectives cited are included in those cited by Sen, Marglin, and Dasgupta, in the UNIDO Guidelines, pp. 28-33.

receives or pays them. Benefits to a poorer region, for example, might be more valuable to the society than those received by an already wealthy region. The benefits and costs calculated in pursuit of the aggregate consumption objective are revalued according to the income redistribution objective and accounted again.

Government may consider a certain level of growth as an important objective. The growth rate objective, however, may be viewed as being included in the benefit stream generated by the project and in the value of the social rate of discount. A government may alternatively consider the growth rate as an objective independent of its effect on future aggregate consumption—as a merit want. For the purposes of this paper, the growth rate objective will be assumed inherent to the evaluation of aggregate consumption.

Increasing employment also may be a government objective. This complex, often emotional issue, will not be considered independently of the income redistribution objective. The "concern with employment is largely a concern about poverty"..."what is wrong is more that people are desperately poor, than that they have little work."[29/] In a similar manner the UNIDO Guidelines take the position "that employment is basically not desired for its own sake, but for what it generates, namely output, for the productive system, income to certain people, opportunities for learning, increased modernization, and so on."[30/]

29/ Little and Mirrlees, Project Appraisal, pp. 60, 61.

30/ Sen, Marglin, and Dasgupta, p. 98.

Self-sufficiency as a national objective refers primarily to the contribution of a project to the nation's balance of payments situation; to its supply of foreign exchange. Consequently, the evaluation of a project's contribution to this objective will be subsumed by an appropriate shadow price of foreign exchange within the framework of the nation's aggregate consumption objective or by the use of the DRC method.

Merit wants are values, sought by the nation, which are not indicated "by individuals in their capacity as consumers."[31/] Employment and self-reliance objectives are good examples. Power and prestige are mentioned by Little-Mirrlees.[32/] Increasing the number of rural women employed or the modernization of traditional communities, or the introduction of modern education facilities may be considered "merit" objectives of government. The evaluation of merit wants depends upon the type of project and the nature of the society. Output of merit goods which cannot be realistically valued (quantified) will be included as input to the decision process in this study.

The proper use of the environment is now considered a national objective, especially in the United States. Evaluation of projects in terms of their impact on environment is finding its way into U.S.-sponsored projects in foreign countries. The Bakel program in Senegal, for example, has been suspended until the impact of the program on local health can be evaluated under Regulation 16 of the environmental guideline.[33/]

31/ Ibid., p. 33.

32/ Little and Mirrlees, Project Appraisal..., p. 65.

33/ Nelson, Gary and Fred M. Tileston, "Irrigation: A Paradox for Sahelian Development," USAID, REDSO/WA, March 3, 1977, p. 11.

Social cost-benefit analysis is a major departure from classical economics. The foundation assumptions of competitive markets do not apply necessarily, and actual markets are often distorted. Consequently, prices determined by these markets do not necessarily reflect the value of the particular good or service to society. As an example, (in a labor surplus society), it is often thought that the value of labor is zero or at least lower than the market wage. It is a primary objective of SCB analysis, then, to establish a set of shadow prices which reflect a more accurate picture of the social values of project inputs and outputs to the nation.

National weights are "those national parameters that directly reflect political value judgments." Shadow prices are national parameters which are derived in part from the national weights and in part from the national plan--"a set of consistent projections of consumption and its distribution, savings, merit wants, and other aspects of the problem of economic development. These national weights, as the UNIDO Guidelines suggest, may be treated as unknown to project evaluators.[34/]

It is at the national planning office where values reflecting development policy are given to the national weights and parameters. The UNIDO method, which this thesis largely adopts, defines a "bottom-up" method which relies on the presentation to the policy maker of his range of choices. This "bottom-up" procedure:

34/ Sen, Marglin, and Dasgupta, p. 139.

> "1)...assures that all relevant alternatives are bought to the attention of the political leadership, 2) focuses choice on the relevant variables by relating political decisions to the national parameters, 3)...serves to introduce the political leadership to the importance of national parameters; 4) finally...forms the basis for deliberate systematic determination of national parameters when the day finally dawns that these can be specified in advance of project formulation and evaluation."35/

Sensitivity analysis with its determination of switching values is basic to the establishment of these values. Switching values are points at which parameter weights are neutral to policy choice; that is, they are points which divide policy choice into different ranges. Switching value can be shown graphically for simple weighting problems, while, in more complicated problems it can be done algebraically. Generally, however, assumptions are made to simplify the estimation of weights of primary importance.36/

Debate between proponents of the Little and Mirrlees method and those of the UNIDO Guidelines has centered on the role of the national planning organization. The Little and Mirrlees method "tends to assume that the planner can dictate "from the top down" the values that are to be used in project and evaluation."37/ General agreement between the authors of the two methods indicate that neither planning process actually dominates and that, in fact, an iterative process exists with information flowing in both directions.

35/ Ibid., p. 140.

36/ The most common assumption is that the social rate of discount is constant over time.

37/ Hausen, John R., "A Guide to the Guidelines: The UNIDO Method of Economic Project Evaluation," (Washington, D.C.: IBRD/IDA, November 1973, Annex A, pp. 10-11).

Measurement of Costs and Benefits

The Numeraire

The valuation of project costs and benefits is done in terms of a numeraire. The numeraire is the common unit of evaluation which enables heterogeneous costs and benefits to be converted into one statistic. Historically, the calculation of the numeraire has been an important issue to economists. The nature of a standard of value received the attention of both Ricardo and Mathun[38/] and Pietro Siaffra for example in Production of Commodities by Means of Commodities[39/] estimates a numeraire which is not itself a commodity. The use of either uncommitted social income or government investment (needs are proposed by Little and Mirrlees as numeraire. They reject the latter in favor of uncommitted social income.[40/]

The numeraire used in the UNIDO analysis is that of present aggregate consumption and is the basic unit of welfare. The elementary estimation of national aggregate consumption is the sum of the products of the amounts of each final good and service consumed by the nation in a given time period and its domestic price.

38/ Richardo, David. The Principles of Political Economy and Taxation (London: Dent and Sons, 1976), pp. 283-86.

39/ Siaffa,Piero, Production of Commodities by Means of Commodities. Prelude to a Critique of Economic Theory (Cambridge, Great Britain: Cambridge University Press, 1960).

40/ Little and Mirrlees, Project Appraisal, pp. 146-7.

$$C = \sum_{i=1}^{m} p_i x_i$$

where C is aggregate assumption, x_i is the amount of the good or service i, and p is the price of the good or service. This procedure converts the heterogeneous national bundle of final goods and services into common units of local currency.

The numeraire used in the Little and Mirrlees method measures "all commodities in terms of convertible foreign exchange."[41/] They observed that:

> "Uncommitted social income accrues to public authorities. Since social cost-benefit analysis is essentially addressed to governments, to help them solve problems of public expenditure in general and investment in particular, it seems natural to use as numeraire something in terms of which they think and operate."[42/]

Their proposed numeraire is "present uncommitted social income measured in terms of convertible foreign exchange of constant purchasing power."[43/]

Much of the debate between the UNIDO and OECD methods has focused on the differences between these two numeraires. The distinction is purely mechanical with the UNIDO numeraire equal to 1/s times the OECD numeraire; where 1/s is the social value of a unit of consumption.[44/] From the UNIDO perspective, the difference is the value, p_o,

41/ Ibid., p. 145.

42/ Ibid., p. 146.

43/ Ibid., p. 151.

44/ Ibid., p. 359.

the current shadow price of savings, where $p_o = 1/s$. In the definitive article on the mathematical difference between the two numeraires.[45/] Partha Dasgupta demonstrated that by using the UNIDO numeraire, the present value of net benefits of the project was:

$$(PV)_u = \int_0^T \{P_t(Q_t - C_t) - W_t\} e^{-rt} dt - p_o I$$

while the present value of net benefits using the OECD numeraire was

$$(PV)_o = \int_0^T [(Q_t - C_t) - \frac{W_t e^{\alpha t}}{p_o}] e^{-it} dt - I$$

where Q_t is output, C_t is the operating cost except for unskilled labor, W_t is the shadow wage bill, I is a one-two investment, r is social rate of discount and i is the accounting rate of discount, where $\alpha \bar{=} 2\text{-}5$ and p_t is the shadow price of savings, $p_t = p_o^{-(i-r)t} > 1$ for $o \leq tcT$. T is the project life in years.[46/] As Dasgupta concludes:

> "It is clear that the only difference in the two present values lies in the factor '$p_o(>1)$. This is precisely where the numeraire comes in: in the UNIDO approach consumption is the unit of account, while in the OECD approach it is investment. But what is important for the purposes of project evaluation is that $(PV)_u \geq 0$ if and only if $(PV)_o > 0$. It follows that the two approaches make identical recommendation."[47/]

Whether one measures benefits and costs in terms of consumption or investment expressed in terms of foreign exchange, it makes no difference to project evaluation. Throughout this thesis we will evaluate projects in terms of aggregate consumptions.

45/ Dasgupta, Partha, "A Compative Analysis of the UNIDO Guidelines and the OECD Manual," Bulletin of the Oxford University Institute of Economics and Statistics, February 1972.

46/ Ibid., p. 11.

47/ Ibid., p. 12.

Direct Domestic Cost and Benefit Measurement

In evaluating direct domestic costs and benefits, the net changes in aggregate consumption are measured. An evaluator need not know the total social value of a commodity, only the value added to or subtracted from the national total. In SCB analysis it is the net output, "the goods and services made available to the economy that would not have been available in the absence of the project,"[48/] which are measured.

Benefits are measured in terms of the consumers willingness to pay for the project's output. The output is divided into that which is consumed domestically and that which is traded internationally; into that which is a final consumer good or service and that which is an intermediage good or service; and into that which adds to total national supply and that which substitutes for existing supply. Costs, considered negative benefits, are divided into like categories.

Benefits and costs are calculated for each time period (usually a year) in the evaluation. The number of years for which a project is evaluated is most often an arbitrary 25 to 50 years. This assumes, however, that the net benefits continue to exceed the project's salvage costs. It assumes that the net present value of the project remains greater than the value of alternative projects. Both situations could reduce the life of the project.

Final consumer goods produced and consumed domestically in a given year are the first category of project output to be evaluated. These goods and services are valued to the society by the consumers' willingness to pay. Consumer willingness to pay is a variation of the market

48/ Sen, Marglin, and Dasgupta, p. 41.

price. In a purely competitive market system, where goods are freely available to any potential customer willing to pay the market price, where no consumer is large enough to exercise monopsony power, and where the addition or subtraction, by a single producer, to total supply does not change the market price, the market price equals the product value to society. Where significant violations of any one of these conditions exists, the value to society will differ from the market price and demand analysis of the output will be required.

Under competitive conditions, national demand for the output is considered perfectly elastic—the market price does not change when the supply curve shifts. When national demand for the output is more inelastic, increases in supply will alter the commodity price. Market value is then different from social value measured by consumer willingness to pay.

For an individual, consumer surplus is the difference between what he would have been willing to pay for a commodity and what he paid in the market. Similarly, at a national level, consumer surplus is the triangular area under the demand curve above the market price level (for a linear demand curve) as shown in Figure 1. It is an aggregate of consumer surplus values to all purchases of the commodity.

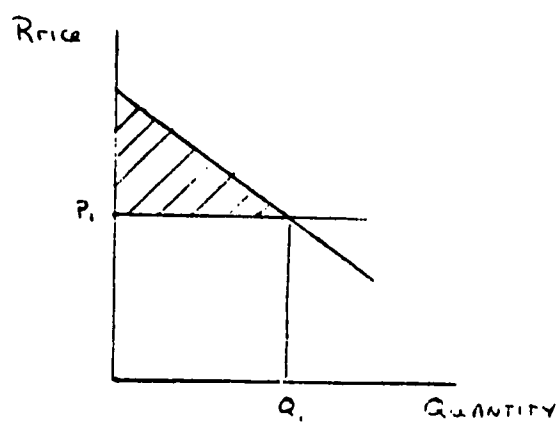

Figure 1.

When national supply of the commodity increases from Q_1 to Q_2, the price per unit falls. In terms of Figure 2, the price per unit falls from P_1 to P_2. The gross value of the output increases ~~output~~ by the shaded area P_1BCP_2. The total value of the consumer willingness to pay for the commodity is represented by the area above line P_2C.

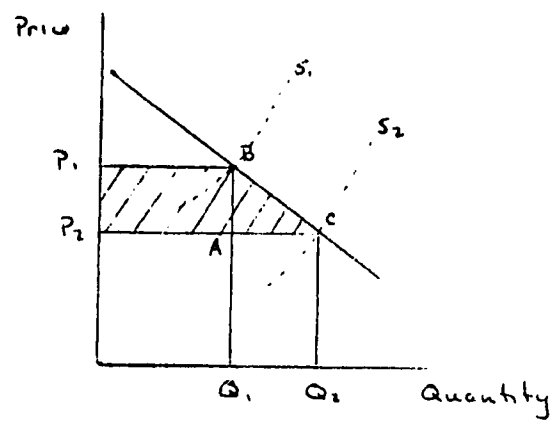

Figure 2.

The area P_1BAP_2 represents cost savings on the original level of output Q_1. Estimating the value of the net increase in output to society strictly through relative market prices does not include the addition to consumers surplus represented by the triangle ABC. In order to evaluate the triangle ABC, demand analysis of the output commodity is required.

In some cases the output of the project will substitute for already existing output. In order to measure these benefits, an estimation of the resources saved by the producers who lowered their production of the particular commodity needs to be prepared. The resultant increases in supply in the resource markets can be evaluated in a like manner to that of the final commodity originally illustrated.

In the case where project output is an intermediate good to the production of a separate final good, the value of the benefit is derived from the consumer willingness to pay for that portion of the net final output attributable to the project's input. Thus, while a considerably more complex task, it does not deviate from the evaluation principle of consumer willingness to pay, either in the case where the supply of the final good is increased or where it substitutes for existing production.

Costs to a project are negative benefits. They are valued in terms of the aggregate consumption value of decreased supply and of resource used to add to supply level.

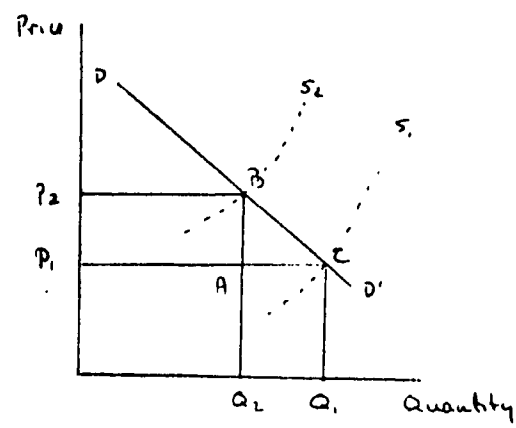

Figure 3.

The use of the good or service to the project reduces the availability of that resource to society. Consequently, in all the argument similar to that for benefits, the price of the good increases and total consumer surplus is reduced. The value of that reduced supply to society is the difference $P_2Q_2 - P_1Q_1 + ABC$.

In the case where the reduced supply of an input to society stimulates increased production by other producers, the value of the output is estimated by the values of the resources used for that increased production. This, too, is evaluated by using the consumer willingness to pay.

Two interesting special cases exist: land and labor. Land is most often considered as fixed in quantity--the supply is completely inelastic. Shifts in the consumer willingness to pay change--the net willingness to pay reduction in consumer surplus being represented simply by the difference between the initial price times the quantity of land and the second price times the quantity of land. This represents neigher a benefit nor cost, but rather an income transfer. In cases where an active land market does not exist, land is best valued by its best alternative use.

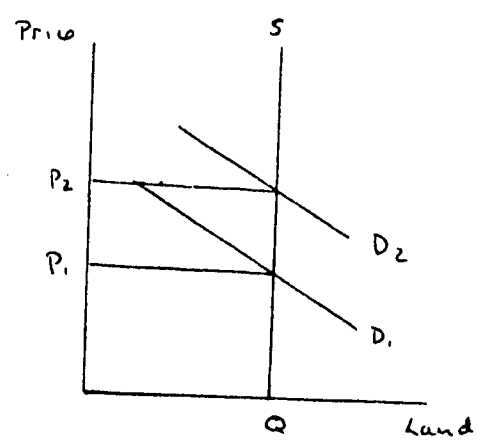

Figure 4.

In the case of labor, the supply curve is most often considered completely elastic. Shifts in demand will not alter the resource price of labor since it is drawn from a resource supply that is not fully developed.

In SCB analysis, clear assumptions are required to describe the anticipated behavior of supply and demand for project output and inputs over time. Changes in demand can occur due to changes in population, changes in income, changes in the prices of substitutes and complements of the good, and changes in the tastes of buyers. Changes in supply can occur due to price policy changes, technical innovation, better education, and the like. Each shift could change the value of the net benefit stream and so must be anticipated for during the life of the project.[49/]

Indirect Domestic Cost and Benefit Measurement

The SCB approach recognizes the costs and benefits which result from indirect impacts of a project. These are the external effects--the externalities or unquantifiables. There are numerous examples of external effects. Roads may serve to improve communication and lower transportation costs to all who use it. Education and pollution have indirect effects. Rejection of traditional modes of behavior is another. Changes in health and hygiene, recreation facilities, introduction of new industry, changes in the microclimate and wildlife may all be considered external effects.[50/]

49/ Earth Satellite Corporation and Booz-Allen Applied Research Corporation. Earth Resources Survey Benefit-Cost Study: Economic, Environmental, and Social Costs and Benefits of Future Earth Resources Survey Systems. Vol.V. Approach and Methods of Analysis (Washington, D.C.: U.S. Department of Interior, November 22, 1974), pp. IV:24-39.

50/ Bottomley, Anthony and Charles Clark. "Evaluation of the Effects of Irrigation Dams in Developing Countries," (Commission Internationale des Grands Barrages, Madrid, 1973, Q40, R.39), pp. 614-615.

By classifying indirect effects into two groups--secondaries and externalities--the job of evaluating them can be simplified. Secondaries are those indirect effects of a project whose net effect may be assumed to be the same for all projects and can, hence, be ignored in the comparison of projects. Ripple effects (multiplier impacts) of the project through the economy are considered to be secondaries.

To evaluate the remaining numerous externalities would be a prodigous task--so enormous that to measure all would strain limited budgets while the chance for results of added significance would be small. Using a variant of the "principle of insufficient reason" the sum of external effects of a project is often assumed to be zero.[51/]

Still the inability to quantify externalities is one of the most serious limitations of social cost benefit analysis. Detailing the total possible external effects and explaining their potential significance is of primary importance to the planner. With this information the policy maker will be better able to make his own evaluation.

In some cases, ranking each unquantifiable on a scale of importance for eventual inclusion in the evaluation of net benefits, a la Bottomly and Clarke, is possible. They evaluated the importance of improved transportation, for example, as a .5 on a scale of 0 to 1. This they multiplied by the probability of it occurring, 100%, to determine its relative effect, 50. Improved public services in a similar manner was evaluated as a 94, increase in shistosomiasis as a -9, increase in lake week as a -24.[52/]

[51/] Sen, Marglin, and Dasgupta, p. 67.

[52/] Bottomley and Clarke, p. 614.

Shadow Price of Investment

One special category of indirect benefits and costs that requires detailed attention is that of savings and investment. The level of savings is important to a developing country. Much of the literature indicates that savings roles may be suboptimal from a social viewpoint, and that savings has a higher social value than consumption.[53/] Since net benefits produced by a project in a given time period may be either consumed or saved, savings represents future consumption benefits and require that the present value of net benefits be appropriately adjusted.

> "As long as the value of the indirect future consumption benefits resulting from (an investment) is judged by society to be equal to the value of the direct current consumption benefit resulting from (a unit) of consumption, it clearly makes no difference to SCB analysis whether benefits are consumed or saved. But if aggregate national savings are below the social optimum, future benefits resulting from a (unit) of investment must be regarded as exceeding the corresponding present value resulting from a (unit) of consumption."[54/]

When the national savings are below the social optimum, the project's impact on the investment-consumption ratio in the economy for each year during the project's life is required. In addition an estimate of the ultimate consumption benefits from a unit of current investment is required. It is the shadow price of investment which measures

53/ Sen, Marglin and Dasgupta, pp. 67-68.

54/ Dasgupta, "An Analysis...", p. 8.

"the present value of the additional consumption that a unit of investment would generate."[55/]

The calculation of the shadow price of investment depends upon the social rate of discount, the productivity of capital over time, and the propensity to reinvest. Also, it is important to know who is doing the investing since the shadow price of investment can vary according to how capital ownership influences investment income distribution.

In its basic functional form, the shadow price of investment p^{inv}, is the ratio of the value of the marginal return on investment, q , (an annual return of $q for $1 invested and is assumed constant over time) to the social rate of discount, i,

$$p^{inv} = \frac{q}{j}$$

For a project whose initial investment was made at the outset of the project, the present value of net benefits, B*, would be:

$$B^* = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - p^{inv} K_o$$

where B_t equaled annual net benefits, i equaled the social rate of discount, T, the life of the project, and K_o the initial capital investment.[56/]

55/ Sen, Marglin and Dasgupta, p. 150.

56/ Ibid., p. 175. This result represents the present value of a project of life T, where the life of capital is infinite and produces annual streams of benefits of $q. This return is consumed immediately. The expression for this is:

$$B^* = 0 + V_1(B_1 - qK_o) + \ldots + V_T(B_T - qK_o) - \ldots - V_t qK_o - \ldots = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=1}^{\infty} \frac{qK_o}{(1+i)^t}$$

when $\sum_{t=1}^{\infty} \frac{1}{(1+i)^t} = \frac{1}{i}$, the relationship reduces to

$$B^* = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - \frac{q}{i} K_o = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - p^{inv} K$$

A more realistic model of the shadow price of investment is one which incorporates the idea that not all of the return from investment is consumed and that a fraction, s, of these returns is reinvested. In this case, the shadow price of investment has the form:

$$p^{inv} = \frac{(i-s)q}{1-sq} \quad \underline{57/}$$

57/ Ibid., p. 177. Capital accumulation in this model is the sum of the capital available the previous year and the reinvestment from the returns of the previous year (savings=investment). In year 1, the capital, A_1, equals the initial investment. In year 2, the capital accumulated includes the original investment plus the amount of the return on year one's investment which is saved:

$$A_2 = A_1 + (s)(qA_1) = (1 + sq)A_1$$

Similarly for the third year:

$$A_3 = A_2 + (s)(qA_2) = (1+sq)A_2 = (1+sq)^2A.$$

The resulting general formula for capital accumulation from one unit of investment ($A_1 = 1$):

$$A_t = (1+sq)^{t-1}$$

The return from an investment of one unit is qA_t. The amount consumed of this direct and indirect return is $(1-s)qA_t$. The shadow price of investment is therefore the present value of this consumption, or

$$p^{inv} = \sum_{t=1}^{\infty} \frac{(1-s)qA_t}{(1+i)^t}$$

By substituting the shadow price of investment becomes

$$p^{inv} = \sum_{t=1}^{\infty} \frac{(1-s)q(1-sq)^{t-1}}{(1+i)^t}$$

$$= \sum_{t=1}^{\infty} \frac{(1-s)q}{1-sq} \quad \frac{1-sq}{1+i}^{t}$$

Since $\sum_{t=1}^{\infty} \frac{1-sq}{1+i}^{t}$ is a geometric sum, it can be written $\frac{1+sq}{i-sq}$ and substituted in the preceding equation.

Hence,

$$p^{inv} = \frac{(1-s)q}{1-sq} \frac{(1-sq)}{(i-sq)} = \frac{(1-s)q}{i-sq}$$

where s equals the savings rate and is considered constant through time. It is the "present value of the stream of consumption directly attributable to marginal investment, (1-s)q, discounted at an artificial rate of discount, i-sq, representing the social rate of discount corrected for reinvestment by substituting the rates of accumulation sq from i.

In the case where investment resources are drawn from both consumption and alternative investments, and if the proportion derived from investment equals the marginal propensity to invest, then the appropriate adjustment of an initial lump capital investment would equal

$$\frac{(1-s)i}{1-sq} \quad \underline{58/}$$

58/ Ibid., p. 181. In this case, where investment funds are drawn from both alternative investment and consumption sources, the present value of the benefits from the initial investment is

$$B^* = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - (a^{inv} p^{inv} + a^{con}) K_o$$

where a^{inv} and a^{con} are the fractions of a project's capital costs which come from investment and consumption respectively.

When $a^{inv} = s$, that is when the marginal propensity to invest equals that proportion of capital costs taken from investment and when "total economic activity foregone is equal to one unit per one unit of capital outlay or:

$$a^{con} = 1 - a^{inv}$$

then

$$a^{inv} p^{inv} + a^{con} + a^{inv} + 1 - a^{inv} = s^{pinv} + 1 - s$$

Substituting for p^{inv}

$$p^{inv} = \frac{(1-s)q}{i-sq}$$

$$= \frac{sq-sq}{i-sq} + 1-s$$

$$= \frac{i-is}{i-sq}$$

$$= \frac{i(1-s)}{i-sq}$$

-the corrected opportinity cost when the appropriate condition prevails resulting in a present net benefit relation of the following form:

$$B^* = \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - \frac{(1-s)i}{1-Sq} K_o$$

Further adjustments in the present net benefit stream are indicated when the determinant parameters of the shadow price of investment change, when more than one distinct source of investment funds are available such as from government and private sectors, and when the benefits themselves are reinvested. Each of these cases are likely to occur. Their calculation, while cumbersome, is not impossible. When possible, appropriate assumptions will simplify the calculation of the shadow price of investment. The parameter which determines the shadow price of investment will be assumed constant and equal for all sources of investment funds.

Reinvestment of benefits are evaluated in the same manner as outlays which displace investment. The present value of net benefits in this case is represented in the following manner.

$$B^* = (a^{pri}p^{pri} + a^{gov}p^{gov} + a^{con}) \sum_{t=1}^{T} \frac{B_t}{(1+i)^t} - K_o$$ 59/

where a_t^{pri}, a_t^{gov}, and a_t^{con} are the yearly distribution of benefits among private and public investment and consumption.

Shadow Price of Labor

A shadow price of labor is required because the market wage in developing countries rarely reflects the opportunity costs of the unemployed and because shifts of aggregate consumption between groups in society may affect total present net benefits. The shadow wage of labor equals the market wage of labor only under strict competitive market conditions

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59/ Ibid., p. 185.

and when all shadow prices of investment are equal to one.

The shadow wage depends on two factors: 1) "the output foregone by workers from their previous employment to project employment, and 2) the shift in the composition of output from investment to consumption by the expansion of public sector employment."[60/] When the employment of an additional worker on a project increases the total employment in the society, the opportunity cost is zero. When the person employed was previously partially employed the estimation of the direct opportunity cost is more difficult. Here the relevant measure is the social value of the marginal product foregone by society. Only "if it is assumed that the foregone output would have been entirely consumed can the market value of the marginal product be used and the impact of differential social values of investment and consumption be ignored." To estimate the direct opportunity cost of labor in an economy with both traditional and modern sectors only a full study of the consequences of intersectoral labor shifts would provide an adequate framework.[61/]

The possibility of indirect labor costs must be considered in estimating a shadow price of labor. Such an indirect cost may occur if the financing of additional labor shifts consumption and investment in other sectors of the economy. The UNIDO Guidelines illustrates a case in which the wage bill for labor in a labor surplus-economy is

60/ Ibid., pp. 151-52.

61/ Ibid., pp. 203-4.

is financed through the taxation of the private investment sector.[62/]

A third element in the formulation of the shadow wage of labor is the redistribution of income. Appropriate redistributional weights

62/ The UNIDO Guidelines, p. 206, illustrates a case of an indirect cost and the shadow wage rate formulation which includes it. The principle assumptions are that the economy has a surplus labor supply, that two groups, capitalists and workers, exist and that the workers save us part of their income. A shadow price of investment under these conditions is formulated in the following manner.

ℓ is the marginal labor:capital ratio, y is the incremental output: capital ratio. One unit of investment, hence creates ℓ jobs and y output. w is the market wage rate. The nominal profit rate due to one unit of investment then $i:y-w\ell$.

The capitalists save, s^{cap} of their income and consume the rest as the annual aggregate consumption value of capitalist income from one unit of investment is:

$$p^{inv}\, s^{cap}(y-w\ell) + (1-s^{cap})(y-w\ell).$$

where $p^{inv}\, s^{cap}(y-w\ell)$ is the present value of $s^{cap}(y-w\ell)$ of investments, and $(1-s^{cap})(y-w\ell)$ is the current aggregate consumption.

Workers, who save nothing, derive $(w-z)\ell$ aggregate consumption from an additional unit of investment. The two together sum to the total aggregate consumption derived from an additional unit of investment.

$$p^{inv}\, s^{cap}(y-w\ell) + (1-s^{cap})(y-w\ell) + (w-z)\ell$$

Assuming a sufficiently large labor surplus so that the parameters above are constant over time, then the shadow price of investment--which is the aggregate consumption over the social rate of discount is

$$p^{inv} = p^{inv}s^{cap}(y-w\ell) + \frac{(1-s^{cap})}{i}(y-w\ell)+(w-z)\ell$$

$$(p^{inv})_i = p^{inv}s^{cap}(y-w\ell)+(1-s^{cap})(y-w\ell)+(w-z)\ell$$

$$p^{inv}_i - p^{inv}s^{cap}(y-w\ell) = (1-s^{cap})(y-w\ell)+(w-z)\ell$$

$$p^{inv}(i-s^{cap}(y-w\ell)) = (1-s^{cap})(y-w\ell)+(w-z)\ell$$

$$p^{inv} = \frac{(1-s^{cap})(y-w\ell}{i-s^{cap}(y-w\ell)} + (w-z)\ell$$

Paying for the added labor by taking from capitalists' income reduces the aggregate consumption value by a factor $(1-s^{cap})+p^{inv}s^{cap}$ w for each job: $(1-s^{cap})w$ measures the loss in current aggregate consumption while $p^{inv}s^{cap}w$ the loss in aggregate consumption from a reduction in investment. The amount w taken from the capitalists is the worker's gain so the indirect cost is the difference between the two, or:

$$(1-s^{cap})+p^{inv}s^{cap}\ w-w$$

$$w\ (1-s^{cap}) + p^{inv}s^{cap} - 1$$

$$w\ \ s^{cap}(p^{inv}-1)$$

The resulting shadow wage of labor then includes the direct opportunity cost and this indirect transfer cost:

$$W^* = Z + s^{cap}(p^{inv}-1)w.$$

are assigned to the aggregate consumption gains and losses of the groups involved. The UNIDO illustration divides the economy into a group of capitalists and a group of workers and illustrates a shadow wage of formulation in the following manner:

$$W^* = (1-V^{cap})((1-s^{cap}) + s^{cap}p^{cap})W + (1+V^{wrk})(Z + s^{cap}p^{wkr}-1)W)$$

where W^* is the shadow wage, V^{cap} and V^{wkr} are the redistributional premiums assigned to the two categories of consumption, s^{cap} is the savings/investment rate of the capitalist group--the workers are assumed to consume all of their income, p^{cap} and p^{wkr} are the shadow price of consumption for each group, and Z and W are the direct opportunity cost and the market wage of labor, respectively.[63/]

The shadow wage of labor varies for each category of laborer. Most commonly skilled and unskilled labor categories are identified for analytical purposes. The shadow wage also varies from region to region and between age groups. Careful consideration of the shadow price of labor is required in an evaluation of projects in West Africa. Labor migration, increased economic activty, and rapidly expanding technological base is raising the demand for both skilled and unskilled labor. Labor's opportunity cost, for example, can no longer be assumed to be zero, but requires specific evaluation in the analysis of shadow wage rates. In estimating the shadow price of labor in his study of small-scale irrigation projects, Deepal Lal argues for example that the direct opportunity

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63/ Sen, Marglin and Dasgupta, p. 205.

cost of labor in a surplus labor environment is not necessarily zero, but, due to the relationship between labor and leisure preferences, should be evaluated as "the change in agricultural output resulting from the employment of one more man on the project."[64/]

Foreign Exchange

When inputs to a project are imported into a country or when the product of a project is exported from the country, foreign exchange and its contribution to the net benefit of the project is evaluated. The degree to which aggregate imports and exports contribute to national welfare is most readily measured by the nation's balance of payments--the statistical proxy for measuring the country's self-reliance. For the purposes of SCB analysis, the value of net exports must be converted into units of aggregate consumption--the numeraire. In evaluating the role of foreign exchange, both inputs to and outputs from the project must be classified according to the percentages which originated in or are destined for external markets.

Estimating the shadow price of foreign exchange in a series of countries with currencies rigidly tied to the French franc and which have small GNP's in relation to the GNP of the whole French franc area is extremely difficult if not impossible. There are estimates used by donors, such as the World Bank, which provide an educated guess of the shadow price. The problem of estimation can be circumvented by using the Domestic Resource Cost (DRC) approach.

The problem of appropriate evaluation of foreign exchange results from the unequal values of foreign currencies by which foreign trade

64/ Lal Deepal, Wells and Welfare (Paris: OECD, 1972), p. 68.

is conducted and from the restrictions applied by governments to the international currency market. The unequal values of foreign currencies can be converted to equivalent units of aggregate consumption through use of the market exchange rate. For example, the value at the port of entry of an imported good in foreign currency times the foreign exchange rate would, under free market conditions, convert the value of the import into units of domestic aggregate consumption. The market rate for that currency, however, is distorted by the sum of the controls upon foreign currency exercised by world governments. A shadow price of foreign exchange--a price which aggregates the numerous currencies, for which the country trades to one homogeneous value and which is modified in an attempt to eliminate the distortions caused by government controls--is required.

The UNIDO Guidelines establish the shadow price of foreign exchange from historical trade data. It is a "weighted average of the ratios of market-clearing to official c.i.f. prices, the weights reflecting the content of the marginal import bill."[65/]

$$P^F = \sum_{i=1}^{n} f_i \frac{P_I^D}{P_i^{cif}}$$

The import bill for all imports, i=1, ..., n is prepared in fractions of the total, $f_1 + f_2 + \ldots + f_n = 1$, P_i^D is the value of the respective goods and services in terms of aggregate consumption and P_i^{cif} is the cif price in local currency calculated at the official exchange rate.

The shadow price of foreign exchange does not depend directly upon unknown subjective national weight: "The indirect influence of

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65/ Sen, Marglin, and Dasgupta, p. 216.

these judgments (do) not make the shadow price of foreign exchange, unlike the shadow price of investment and the shadow wage, an unknown of the problem of formulating and evaluating projects."[66/] The shadow price of foreign exchange does depend to a large extent on the national plan and the policies the government takes toward the regulation of foreign trade and rationing foreign currency.

A more comprehensive formulation of the shadow price of foreign exchange reflects a situation in which the enhanced foreign earnings relieves the pressure to export, lowering the number of exports. This is not often the case in low income countries. The formulation of the shadow price of foreign exchange is modified in the following manner:

$$p^F = \sum_{i=1}^{n} f_i \frac{P_i^D}{P_i^{cif}} + \sum_{i=n+1}^{n+h} x_i \frac{P_i^D}{P_i^{fob}}$$

where $\sum_{i=1}^{n} F_i = \sum_{i=n+1}^{n+h} x_i = 1$

and x_i equals the local currency amount by which exports fall in response to increased foreign exchange earnings. P_i^D and P_i^{cif} will differ only by the amount of import controls while P_i^D and P_i^{fob} will differ only by the amount of export controls.

Assume, for example, that tractors and cereal grains are imported into a country and exports are not affected by an increase in foreign exchange. Of each additional unit of foreign exchange earned, .8 goes to grain purchases and .2 goes to tractor purchases--$f_1 = .8$, $f_2 = .2$. If grain sells for 80 units in the domestic market and for about 60 units at the port of entry, before import controls are applied. Likewise,

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66/ Ibid., p. 153.

tractors cost 2,000,000 units in the market, and 1,200,000 units at the port of entry. The shadow price of foreign exchange, then, can be determined

$$p^F = f_1 \frac{P_1^D}{P_1^{cif}} + f_2 \frac{P_2^D}{PP_2^{ci}}$$

$$p^F = .8 \frac{80}{60} + .2 \frac{2,000,000}{1,200,000}$$

$$1.064 + .334$$

$$1.398$$

If the nation allocated all of its additional foreign exchange to tractor purchases the value of foreign exchange to the nation would increase from 1.398 to 1.667. Herein lies a major conceptual difference between the UNIDO method and the methodology of Little and Mirrlees.

Little and Mirrlees evaluate imports and exports in terms of their border prices--that is the cif price for imports and fob price for exports, prices which exclude taxes, subsidies, and special exchange rates. The use of border prices "ensures that the use of...1000 (units of accounting currency) in buying any one imported commodity is deemed to cost the economy as its use in buying any other imported commodity... Thus purchase taxes and import duties are excluded from accounting prices: for the project should not be encouraged to use inputs that happen to have low tariffs or taxes on them, since that might lead the country to spend more foreign exchanges to no advantage."[67/]

67/ Little and Mirrlees, Project Appraisal..., p. 157.

This orientation adopted by Little and Mirrlees urges "the analyst to assume that the "restrictive trade policies (of a government) will be abandoned and border prices will represent the relative opportunity costs"[68/] while the UNIDO method makes the more realistic assumption that current trade policy will remain in effect in the future and that, consequently, "the willingness to buy of domestic consumers will be the relevant measure of value."[69/]

Accounting Issues

Social Discounting

The social rate of discount indicates the extent to which the society values future, anticipated net benefits relative to current net benefits. Generally, a benefit available in the future is thought to be worth less than that same benefit available today, and, for simplicity, the difference is assumed to be a constant factor.

Estimates of the actual social rate of discount are difficult to obtain. There are severe limitations to the use of such proxies as the market's long term interest rate on savings and individual savings behavior since, on the one hand, capital markets are imperfect and, on the other, the demonstratedly irrational decision-making of individual savers.[70/] Except under the most stringent of conditions, the social

68/ Hanson, Annex A., pp. 9-10.

69/ Sen, Marglin, and Dasgupta, p. 58.

70/ "The subjective time preference of the individual in private affairs is strongly influenced by the thought of the brevity and uncertainty of the individual life; when judging as a citizen, the individual assumes that the community,..., will be in existence when he is...in his grave." Landauer, Carl, "On the Social Rate of Discount: Comment," American Economic Review, December 1969, Vol. 59, No. 5, p. 917.

marginal productivity of capital, too, cannot equal the social rate of discount.

William J. Baumol in his article "On the Social Rate of Discount"[71/] "raises the intriguing problem of choosing a rate of interest for the public sector when risk or tax interposes a spread between the subjective rate of time preferences and the technical rate of opportunity cost between present and future consumption in the private sector."[72/] The subsequent debate[73/] focused on the difficulty of identifying the optimal social rate of discount. "The appropriate rate of discount for public projects is one which measures correctly the social opportunity cost." The problem lies in measuring correctly the social opportunity cost. Baumol states that "...there is an unavoidable indeterminancy in the choice of that rate,"[74/] and Carl Landauer concludes more strongly that "...the search for a unitary, optimal rate of social discount is a wild goose chase."[75/]

71/ Baumol, W. J., "On The Social Rate of Discount," American Economic Review, September 1968, 58, pp. 788-802.

72/ Usher, Dan, "On the Social Rate of Discount: Comment," American Economic Review, December 1969, Vol. 59, No. 5, pp. 925-929.

73/ Contributions to the Comments on Baumol's article were made by Alan Nichols, Estelle James, Carl Landauer, David Ramsey, Dan Usher, and William Baumol with his "Comment on the Comments"and appeared in the American Economic Review, Vol. 59, No. 5, December 1959, pp. 909-930.

74/ Baumol, W., p. 918.

75/ Landauer, C., p. 918.

Others[76/] venture to show that the appropriate interest rate on government projects lies between the sound rate of time preference and the opportunity cost of capital in the private sector.[77/]

The methodology for the social cost-benefit evaluation of small- to intermediate-scale irrigation projects elaborated in this thesis will treat, as the UNIDO methodology advises, the social rate of discount as an unknown of project formulation and evaluation, in the same manner as are redistribution weights and merit wants. In addition, the view that a risk premium on the discount rate on public projects should be excluded[78/] has been adopted.

As discussed above, the results of the SCB analysis will be presented using three measures of project efficiency: the benefit-cost ratio (SCB), the present net value (PNV), and the internal rate of return (IRR). None is a perfectly satisfactory comparative statistic.[79/]

As an investment decision indcator, the BCR must be used in conjunction with the PNV. Given a limited investment budget, the BCR, used as a comparison statistic between projects, can lead to misleading

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76/ Dan Usher and Alan Nichols.

77/ Usher, p. 925.

78/ Arrow, K. J., "Discounting and Public Investment Criteria," in Kneese, A. V. and S. C. Smith (eds.) Water Research, Baltimore, 1966 and Samuelson, P. A., "Principles of Efficiency: Discussion," American Economic Review, Proceedings, May 1964, pp. 93-96. Refer also to the section in this chapter on uncertainty and risk.

79/ For the following comparison, I have borrowed extensively from Earth Resources Survey Benefit-Cost Study, Vol. V. Approach and Methods of Analysis, prepared by Booz-Allen Applied Research Corporation, November 22, 1979.

results. For example, with a limited budget of $100 an investment decision must be made between a highway bridge costing $100, a pedestrian bridge costing $10, and a railway bridge costing $90. If the corresponding benefits are $120, $15, and $100, the BCR's accordingly are 1.20, 1.50, and 1.11. Using the BCR criteria above, the pedestrian bridge would be first selected, followed by the railway bridge. The combined BCR would be 1.15 with net benefits of $15. Alternatively, the highway bridge yields net benefits of $20 and a BCR of 1.2, and would have been selected according to a PNV criteria.[80/]

The present net value has the disadvantage of lending preference to large scale projects whose net benefit is accordingly large. The PNV statistic is best used, therefore, in relation to a budget constraint enabling the projects to be evaluated within the framework of established resources.

The social discount rate employed is critical to the selection of a project. Figure 5 illustrates a case in which project A had a greater PNV when the social rate of interest, i, is greater than 0 but less than 5, but where project B has the greater PNV where 1> 5.

The third SCB evaluation measures the IRR_{i*}, is defined by the rate of return, i, for which the PNV is zero. Points α and B on Figure 5

80/ Ibid.

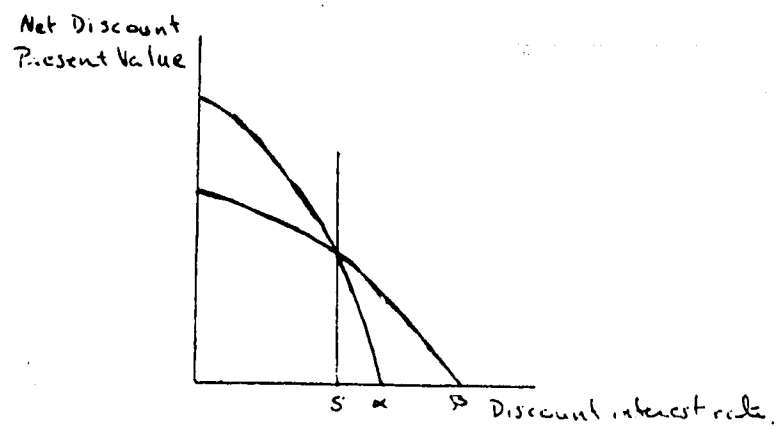

Figure 5.

"Hypothetically, alternative investments may be reached by their IRR with the rate of social time preferences (social discount rate) as the investment cut-off point (minimum acceptable IRR)."[82/] The IRR alone, however, does not provide an idea as to the relative magnitude of the net benefits and there may be more than one solution to the IRR equation. Also, conflicting answers may result from IRR and PNV criteria in the case of mutually exclusive investments. Figure 6 illustrates a case in which the IRR comparison criteria would indicate that project B should be selected (B > α) while according to PNV criteria with the social discount rate equal to S, project A would be selected (A > B).

82/ Ibid., p. N-3.

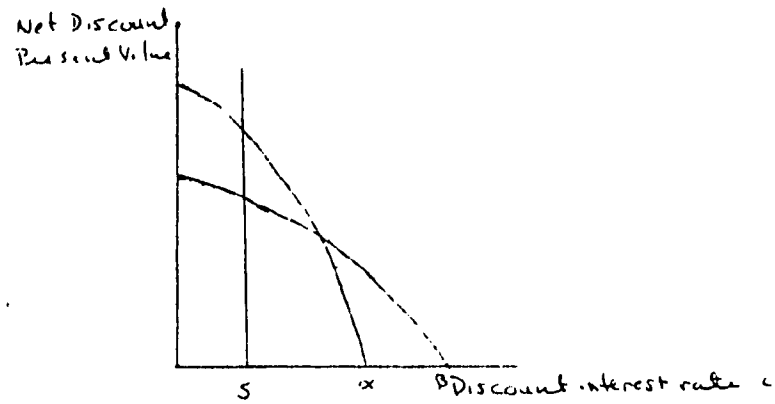

Figure 6.

The inherent complications in using the three SBC analysis coefficients of project comparison cannot satisfactorily be resolved. In the general evaluation case, toward which the methodology is directed, each of the three comparison coefficients will be presented.

Redistribution

The national income redistribution objective is an evaluation of the relative social importance of who receives project benefits and who pays the costs. For example, it may be properly argued that an additional unit of aggregate consumption accruing to an already wealthy person is of less value to the nation than that unit of aggregate consumption when it accrues to a poor person. Similiarly, a project located in an already wealthy region of the country may be worth less to the nation than a project in a poorer region.

The importance of equity effects have been indicated by Thomas Stevens in his work Equity and Water Resource Development.[83/] There are six reasons:

83/ Stevens, Thomas H. Equity and Water Resource Development. Ithaca: N.Y.: Cornell University Water Resources and Marine Sciences Center, March 1972.

> "First, society has preferences as to the distribution of benefits and costs from public expenditures...Second, some projects have been designed to distribute income but the effects are largely unknown...Third, although tax-transfer schemes may be a more efficient means of achieving a desired distribution, outright monetary transfers may be socially undesirable...Fourth, if a change in the distribution of income is a social goal...some tradeoffs between efficiency, equity, and other objectives must be made... Fifth, the support or opposition for a particular development will depend heavily upon who receives the benefits and who pays the costs. Finally, cost-sharing decisions are often made in the absence of empirical evidence on who pays initial costs and receives program benefits..."[84]

During the implementation of a project, net aggregate consumption benefits accrue to specific groups in the society-group most often classified by income. Accounting for the distribution of net benefits is conducted by weighting previously determined net benefits by distribution coefficients. In the case where aggregate consumption benefits are neutral as to their distribution, the net benefits accruing to each income group are weighted by an identical coefficient. When the distribution coefficients for each group are unequal, the benefits to one group have been considered more valuable to the nation than the net benefits received by a second group. For example, the net benefit received by those receiving from zero to 5000 dollars may be considered twice as valuable to the society as those net benefits received by those already earning more than $5000. In the first year, the benefits received by the low income groups would simply be multiplied by a factor of two. Considerable caution should be advised in estimating redistribution values. First, as a project proceeds persons will shift from one income category to another. Care must be taken to

estimate the rate and magnitude of such shifts. Second, the income brackets must be estimated in terms of real dollars, reflecting assumptions made for inflation in the analysis. Finally, it must be realized that the income redistribution objective may be achieved prior to the anticipated end of the program.

The actual procedure for determining the redistribution weights have been the subject of some discussion in the literature. One school has argued that these redistribution weights are determined through a political process. Arthur Maas illustrates how this political process has worked in the U.S. to establish values for the trade-off between efficiency and non-efficiency objectives such as income distribution. "There is a way to determine the trade-off--through the political process. For the federal government my studies indicate that there is a capacity in the legislative process to make the trade-off decision that can then govern the design of projects and programs."85/ This same approach, that of determining income redistribution coefficients through a political, planning-office process, is also that of the UNIDO Guidelines.

On the other hand, there is the school which evaluates income redistribution in the more restrictive framework of welfare theory. A. Myrick FreemanIII develops such a model which he claims to be a marked improvement over that proposed by Stephen Marglin. Freeman

85/ Arthur Maas. "Benefit-Cost Analysis: Its relevance to Public Investment Decisions," Quarterly Journal of Economics, May 1966, p. 210.

develops the general form of the project planning criteria to be

$$W = \sum_{i=1}^{n} \int_{y_{11}}^{y_{12}} Y_1^{-a}\, dY_i + \sum_{i=1}^{n} \int_{y_{11}}^{y_{12}} Y_j^{-a}\, dY_i \qquad \underline{86/}$$

where W is national welfare, Y_i is the income of the individuals affected by the project who have been divided into gainers, i=1, ...,n, and losers, j = 1, ..., m, a is a parameter determined by the planners.

Freeman's argument states that the Marglin method involves "some rather poorly defined subjective judgments regarding weights and opportunity costs. If subjective judgments are to be made concerning the weflare values of incomes to groups and the opportunity costs of achieving constraints, these judgments should be made explicit and within the framework of a well-defined welfare function."[87/] Freeman states that the advantage of his formulation is that "it explicitly takes into account the original levels of income of the beneficiaries as well as the way benefits are distributed within the group. But it also requires more information. Planners have to know the initial income distribution and how increments to income will be distributed. They also must be provided with a value for a."[88/]

86/ A. Myrick Freeman, III, "Income Distribution and Planning for Public Investment," The American Economic Review, June 1967, p. 502.

87/ Ibid., p. 499.

88/ Ibid., p. 503.

The methodology developed in this thesis adopts the income redistribution approach used by the UNIDO Guidelines. The determination of income redistribution coefficients is a responsibility of the planning body in collaboration with the national policy makers.

It may be the case that a nation might want to improve the regional distribution of income. Net benefits accuring to a poorer region may be a greater value than those accruing to a wealthier region. Accounting for this social objective is conducted in a manner congruent with income level groups.

Environmental Issues

Until very recently the evaluation of project impacts on environmental conditions have been left to descriptive comparison paragraphs to the main evaluative study. In a major study, specific to our primary interest in Sahelian irrigation projects, the Bechtel Overseas Corporation, for example, evaluated the environmental impacts of the Matam Irrigation Project in such general terms.[89/] The application of specific techniques to the evaluation of environmental impacts of projects conducted in the Sahel has been increasingly required.[90/] Primary environmental impacts of irrigation projects are on public health as it is thought the incidence of water borne diseases would increase, on water quality, on rodents and nuisance birds, and on natural vegetation.[91/]

89/ Bechtel Overseas Corporation Development of Irrigated Agriculture at Matam Senegal, Feasibility Study, December 1976.

90/ See Footnote 32.

91/ Bechtel Overseas Corporation, pp. 11-13-11-24.

Separate evaluation of the environmental impacts of projects may not be necessary. First, the quantifiable benefits and costs of environmental impacts have been included in the first-step estimation of net benefits. Second, the esthetic values often expressed for the maintained environment are, in fact, merit wants. The value to society of an innundated archealogical site is difficult to measure quantitatively outside the framework of merit wants--the values for which are established by the national planning office.

The value of the ecological-environmental account is to expand the perception of a project's impact to include more, not necessarily quantifiable, aspects. It is an argument for the holistic view rather than for one of strict profitability. The Water Resources Council adopts the following view: "...where the effects of a plan will be visibly evident, quantitative and qualitative description may be made in terms of established or accepted water and land classification or ecological criteria and related measure". For certain environmental effects, "the analysis should be supported by an appropriate descriptive-qualitative interpretation and evaluation of the effects of the plan on the relevant components of the environmental objective." Whether the environmental impact is quantifiable or not, "a frank expression of the state of knowledge and the limitation thereof, as well as the limitation of the analysis in each instance, is essential."[92/] This approach is assumed by the methodology prepared by this thesis.

92/ U.S. Water Resources Council, Standards for Planning Water and Land Resources, Washington, D.C., July 1970, pp. III-D-2,-3,-4.

Risk and Uncertainty

In this review of SCB methodology, it has been assumed that the estimated net social aggregate consumption benefits were attainable with a certainty probability of one. In reality, the probability of attaining the predicted net benefits is less than one.

Several points of view on how to treat risk and uncertainty of SCB analysis exist.[93/] The first is that point of view most forcefully argued by J. Hirschleifer.[94/] Perfect capital markets will reflect both time and risk, he argues. Consequently, public investments should be analyzed using discount rates derived from these markets.

A second school argues that a discount rate should be "equal to the private rate appropriate for investments with certain returns". Since the government invests in "a greater number of diverse projects and is able to pool risks to a much greater extent than private investors."[95/] This is a point of view sustained by Samuelson and Vickrey.[96/]

93/ This summary of uncertainty and risk analysis is adapted from Kenneth J. Arrow and Robert C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," The American Economic Review, Vol. 60, No. 3, June 1970, pp. 364-78.

94/ J. Hirshleifer, "Investment Decision under Uncertainty: Choice-Theoretic Approaches," Quarterly Journal of Economics, November 1965, pp. 509-36. "Investment Decisions Under Uncertainty: Applications of State Preference Approach," Quarterly Journal of Economics, May 1966, 80, pp. 252-77, and J. Hirschleifer, J.C. De Haven, and J. W. Milliman, Water Supply: Economics, Technology and Policy, Chicago, 1960.

95/ Arrow & Lind, p. 364.

96/ Samuelson, P. A. and W. Vickrey, "Discussion," American Economic Review Proceedings, May 1964, 59, pp. 88-96.

A third school, sustained by Eckstein and Marglin[97/] argues that risk should be established as a national paramter by the national planning agency.

Arrow and Lind share Hirschleifer's view that individual preferences should weigh upon the government's valuation of costs and benefits. In the case of risk, however, they conclude the government can ignore it.

> "It is demonstrated in the second section of thispaper that when the risks associated with a public investment are publically borne, the total cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investments. Similarly, the choice of the rate of discount should in this case be independent of considerations of risk....It is the risk-spreading aspect of government investment that is essential to this result."[98/]

The United States Water Resources Council acknowledges that perfect certainty cannot be assumed in the evaluation of projects. In some cases, uncertainty values can be calculated from observable data--such as rainfall, occurrence of disasters, etc. Where there is no readily available methodology for observing the incidences of uncertain behavior, no estimate of a value for uncertainty is possible. In such cases, the judgment of a planning agency would be required in evaluating the risks. The Water Resources Council states that the nature of the uncertainty problem should be fully developed in the text of a project evaluation.[99/]

97/ Eckstein, O., "A Survey of the Theory of Public Expenditure," and "Reply" Public Finances:Needs, Sources, and Utilization (Princeton: National Bureau of Economic Research, 1961), pp. 493-504. Marglin, S. "The Social Rate of Discount and the Optimal Rate of Investment," Quarterly Journal of Economics, February 1963, 77, pp. 95-111.

98/ Arrow and Lind, p. 366.

99/ United States Water Resources Council, Standards for Planning Water and Land Resources, (Washington, D.C., July 1970), pp. IV-11-IV-12.

Little and Mirrlees observe that the calculation of an expected present value is hardly easy but conclude that "the difficulties are not so bad as they seem!"[100/] They identify three areas of primary consideration: uncertainty about prices and quantities of inputs and outputs; uncertainty in adjustments to change; and project performance using expected prices in the design.

Deepah Lal includes in his Wells and Welfare, coefficients of uncertainty due to rainfall. In addition, he generates uncertainty coefficients which are due to "quality" in such technical areas as depth, yield, percolation rates, expected costs, supplemental irrigation, rates of return of the wells and which are due to the uncertainty of finding water. The probabilities of effective rainfall were established from historical data, from which, accompanied by an estimate of the impact of a change in the moisture index on yield, he calculated the expected increase in output and benefits due to irrigation. He was also able to estimate a probability for finding water by using survey research previously conducted. This provided the basis for calculating a mean expected rate of return and a variance due to hydrology surveys.[101/]

The methodology to be presented in this study will assume the point of view of the U.S. Water Resources Commission. Where the use of uncertainty weights seem appropriate in adding to the social value

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100/ Little and Mirrlees, Project Appraisal..., p. 320.

101/ Lal, p. 68.

and can be estimated (by using Monte Carlo simulation, for example) they will be. For other unobservable uncertainty issues, where appropriate, sensitivity analysis and model simulation techniques will be applied.[102/]

Sahelian Experience and Applications

The evaluation of irrigation projects in the Sahelian States of West Africa, where the vast majority of irrigation projects are of small- to intermediate-scale has not, generally, been the beneficiary of SCB analysis techniques. A recent exception to this is the Matam study published in December 1976.[103/] More typical of the available evaluations are those which emphasize, almost exclusively, commercial relationships and values. For example, there is the 1973 World Bank Namarigoungou (Niger) study[104/] and the WARDA (West African Rice Development Association) MacCarthy Island Pilot Irrigation Project in the Gambian Economy of February 1976.[105/]

102/ Model simulation will be a particular aid in resolving questions which uncertainty raises in the estimation of optimization behavior of farmers in the profitability analysis. See particularly A. A. Alchian, "Uncertainty, Evolution and Economic Theory," Journal of Political Economy, June, 1959.

103/ Bechtel Overseas Corporation.

104/ El Maghazi, M., and B. Kanchanalah, Projet d'Irrigation de Namarigoungou (Niger), Rapport 105 d'Identification. Aibdjou: IBRD, November 1973.

105/ Aw, D., W. K. Back, C.E. Vianen, The MacCarthy Island Pilot Irrigation Project in the Gambian Economy Case Study No. 2, WARDA February 1976.

SCB guidelines, such as the UNIDO and OECD methodologies, were initially designed for industrial projects and are now being applied to agricultural projects. Cline's study of large-scale irrigation projects in Brazil[106/] is a particularly good example of an application of SCB methods to the evaluation. More germane to the specific focus of this thesis is, of course, the already cited Wells and Welfare by Deepah Lal.[107/] Lal adapted the OECD methodology of Little and Mirrlees to the evaluation of small-scale irrigation projects in India.

Conclusion

It has been the objective of this paper to review the relevant theory and issues of social cost-benefit methodology. There is an extensive literature and this review is consequently cursory. It has shown, nonetheless, that analytical tools are available which will enable program designers and evaluators to draw more accurate conclusions about the worth of alternative projects. In addition, it is evident that the data needs of a SCB evaluation are greater than those needed for a commercial profitability evaluation. With these two thoughts in mind, further work will delineate the specific evaluation model and data needs for which this theory presentation provides the point of departure.

106/ Cline, William R., "Cost-Benefit Analysis of Irrigation Projects in Northeastern Brazil," American Journal of Agricultural Economics November, 1973, pp. 622-627.

107/