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9. ABSTRACT

Presents a model for quantifying, programming, and analyzing data on Senegalise agricultural supply and demand. Primarily for demonstration purposes, the model is expected to aid in the development of a more complex version. Cereal consumption in the cities, crop production in the Groundnut Basin and the Senegal River Valley, and government economic policy are examined. In addition to illustrating the process by which a short policy analysis is developed, the report includes detailed information on the model, the computer program, and the programming language and describes a graphic technique for presenting models.

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A TOOL FOR INTEGRATED AGRICULTURAL POLICY ANALYSIS IN THE SAHEL

Working Paper No. 4

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A TOOL FOR INTEGRATED AGRICULTURAL POLICY ANALYSIS IN THE SAHEL

INTRODUCTION

"Yesterday's projection will never really know, but tomorrow's recollection will surely show." Carol King and James Taylor, FOREVER MY LOVE

This paper presents a description of a preliminary model of agricultural supply and demand in Senegal. The purpose of the paper is to show how a simple understanding of Senegalese agriculture may be quantified with the data available, programmed for operation on a computer, and then used for policy analysis. The model is primarily for demonstration purposes and only a step towards constructing a more complex and useful model.

The model is being constructed for the Office of Sahel and Francophone West Africa of the U.S. Agency for International Development (AID). The long-term objective of the modeling process is to allow policy makers to project qualitatively the effect of various donor interventions befor implementation. An intermediate objective is to provide AID with an integrated explaination of a Sahelian socio-economic system which determines food supply and demand.

The rationale for the proposed relationships in this demonstration model are taken primarily from the literature on agriculture in Senegal and the Sahel. Other literature and expert opinion have been used. When necessary to fill obvious gaps in the literature, common sense reasoning has been utilized.

The model is not a complete statement of Senegalese agriculture. Four submodels have been included which describe crop production in the Groundnut Basin and the Senegal River Valley, cereal consumption in the citites, and government economic policy. The sectors do not reflect a complete description of the system. In addition, sectors for the Casamance Region and the eastern regions are presently omitted.

A description of the model is first presented, followed by policy analysis using the model.

A SUMMARY DESCRIPTION OF A MODEL OF AGRICULTURE IN SENEGAL

GOAL AND POLICY VARIABLES IN THE MODEL

A model is generally useful only when constructed to solve a particular problem. That is, before constructing the model it is first necessary to define the variables which we desire to affect, and the variables which we have in our power to change. The former we called goal variables, while the latter we call policy variables. These goal and policy variables that have been determined are listed in tables 1 and 2, respectively. The model is not yet at a stage where all of these variables are included.

THE SUBMODELS

The model is disaggregrated into sectors which represent different aspects of agricultural supply and demand in Senegal. These are: (1) the cities, (2) the Groundnut Basin, (3) the Senegal River Valley, (4) the government, (5) eastern Senegal, and (6) the Casamance Region. Each region can be discussed and treated separately as different submodels of the overall model. A general overview of the first four submodels follows. The model is explicitly described in annex A.

The Cities

Urban cereal demand depends on the number of urban people and the cereal demand per capita. The cereal demand per capita depends on the average price of cereals to consumers and on income per capita.

Demand is split between rice, wheat, millet, and sorghum based on relative prices, taste preferences, and availability. The availability of domestic cereals depends on available production in the rural regions. The availability of imported cereals depends on foreign exchange obtained from groundnut exports.

The Groundnut Basin

In the aggregate, land is first allocated for subsistence crop production. Demand for subsistence needs is based on the number of rural people, cereal requirements per capita, stock and seed requirements, and expected cereal yields. The amount of land planted is constrained by land, labor, and seed availability.

Income crops are then planted based on land and labor availability. Income crops are food crops for urban consumption and groundnuts for export. Land for income is split between these two crops depending on their relative expected revenues per hectare. Expected revenues will depend on groundnut band cereal prices and the amount of each crop sold.

TABLE 1

GOALS FOR SENEGAL[1]

Food Self-Sufficiency

1a. The population can be divided into six groups: average and above income urban, low income urban and rural children under six years and the average and above income urban, low income urban and rural people six years and older. Daily caloric consumption per capita should equal or exceed FAO standards for ninety percent of each population group for each month of the year. This consumption is measured after nutrition losses due to such causes as diarrheal diseases have been deducted.[2]

1b. There should be no donor food aid except to those drought years which occur with a frequency of once every seven years.[3]

1c. There should be no donor food aid to any economic sector which contributes to the achievement of the prior two goals.

Income

2a. Real average rural income per capita should increase gradually.

2b. The national income per capita distribution should narrow.

2c. Real average urban income per capita should not decrease.[4]

Health

3. Decrease or prevent an increase in the incidence of the major diseases: malaria, tuberculosis, trypanosomiasis, onchocerciasis, schistosomiasis, gastro-intestinal diseases in children, and measles.[5]

1/ These goals are meant as ultimate goals and not as means towards achieving other goals. They are taken unless indicated elsewhere, from the broader goals in the AID proposal to Congress for the Sahel Development Program. (AID, Proposal for a Long-Term Comprehensive Development Program for the Sahel, Part II, p 1a-3. There are no dates included since the purpose of a model which included these goal vairables would be to indicate approximately when, for different rates of donor aid, these goals could be achieved.

TABLE 1 continued

2/ Average daily caloric consumption per capita in Senegal was 2300 calories per capita in 1970, or ninety-seven percent of FAO's minimum requirements for Senegal. (FAO, The State of Food and Agriculture, 1974, p 145.) This would imply that, assuming a normal distribution of food consumption in Senegal, as much as fifty percent of the population might consume less than FAO requirements. FAO also estimates that for the total African population only seventy five percent of the people consume more than FAO requirements. This contrasts to ninety-seven percent of the people in the developed countries. (FAO, The State of Food and Agriculture, 1974, p 108.) The choice of ninety percent of Senegal is arbitrary except that it is a larger fraction than is presently the case.

3/ This frequency of drought of once in twenty years is often accepted by donors as a minimum standard for the capacity of a Sahelian country to meet its own emergency needs. Other donors argue for a Sahalian capacity to withstand droughts that occur with a frequency of only twice in every hundred years. (AID, Proposal for a Long-Term Comprehensive Development Program for the Sahel, Part II, p 2.)

4/ This has been included although it is actually a constraint since it is a sine qua non of political officials in the Sahel. It has been included as a goal since it relates directly to the other income goals.

5/ AID considers these the major diseases in Senegal. (AID, Development Assistance Program, 1976-1980, Central-West African Region, Section III, p. A-16.)

TABLE 2

DONOR AND NATIONAL POLICY INSTRUMENTS FOR SENEGAL 1/ 2/

Agriculture and Fishing Policies

Food and Cash Crops

1a. Aid for current crop production inputs (i.e. seeds, fertilizer, pesticides, etc.)

1b. Aid for crop production capital (i.e. plows, oxen, drying and storage facilities, etc.)

1c. Aid for development of water resources (i.e. irrigation facilities, land preparation equipment, etc.)

Livestock

2a. Aid for fire control and prevention (i.e. firebreaks, lookout towers, etc.)

2b. Aid for development of water resources (i.e. resevoirs, wells, levees, etc.)

2c. Aid for animal health services.

2d. Range management policies.

2e. Aid for forage production.

Infrastructure

3a. Aid for extension services to improve cultural practices.

3b. Aid to expand credit services.

3c. National agricultural policies (i.e. input subsidies, support prices, export taxes and subsidies, meat import restrictions, marketing, etc.)

3d. National transport policies (i.e. transportation subsidies, road construction and maintenance, etc.)

3e. Aid for research.

3f. Aid for improved factor and product marketing systems.

3g. Aid for industry (i.e. fertilizer production, agricultural processing, etc.).

TABLE 2 continued

Other Policies

4a. National income policies (i.e. taxes, price controls, etc.)

4b. National trade policies (i.e. import subsidies, exchange rates, custom duties, etc.)

4c. Aid for education.

4d. Aid for disease prevention services.

4e. Aid for nutrition improvement.

4f. Aid for family planning.

4g. Aid for urban development.

4h. Aid to industries such as mineral production, tourism, etc.

4i. Migration policies.

---

1. Aid is defined as the delivery of money, materials, commodities, or personnel assistance from a donor to a recipient country. Aid may be given as either a grant or a loan.

2. The policy variables will be disaggregated by the following regions in Senegal: the Senegal River Valley, the Groundnut Basin, the Casamance Region, eastern Senegal, and the cities.

Cereal and groudnut yields are determined by the rainfall, the relative amount of fallow land, and current inputs, e.g. fertilizer, pesticides, etc., per hectare. The amount of land planted per person depends on the agricultural capital stock, e.g. plows, oxen, etc., available to the farmers. Investment in current and capital inputs is the sum of funds available to the farmer plus development aid. Imports of fertilizer are limited by foreign exchange availability.

The Senegal River Valley

Crop production is primarily food crops. It is assumed that farmers follow the same decision rules as to land allocation for subsistence and income as indicated for the Groundnut Basin.

Cereal production is produced from irrigated or non-irrigated land. Non-irrigated crops include dryland and flood recession crops. The decision for a farmer to plant irrigated crops or not depends on a comparison of net revenues per hectare for each crop and relative work involved. Revenues depend on yield and price, while labor depends on hectares planted per active worker and whether the crop was double or single cropped.

The Government

All prices are determined outside the model, or exogenously. The model accounts for foreign exchange earned by groundnut exports and payed for cereal and fertilizer imports.

USING THE MODEL FOR POLICY ANALYSIS

The model, as described in annex A, was programmed on the AID computer in the computer language DYNAMO. The program is given in annex B. The computer language is briefly described in annex C.

The programmed model was operated on the computer to simulate events from 1970 to 1975 and to project events to 2000. The purpose of the historical simulation is to provide the user with some assurance that the model is sufficient to at least represent actual past behavior of Senegales agriculture. This historical representation does not assure validity of the model's projections. However, serious differences between model and actual behavior indicate deficiencies in the model. The purpose of the projection is to provide a base to measure the effects of policy interventions.

The historical and projected model behavior is first presented. The two sets of policies are tested to change the projected behavior. Finally, a relationship in the model is changed to indicate how the model may be used to identify research requirements.

HISTORICAL AND PROJECTED BEHAVIOR

The behavior of the model is shown in figures 1a and 1b. Only aggregate behavior for Senegal has been presented, although similar figures could be presented for each region in the model. The base projection is based on continuation of historical behavior for all variables determined outside the model, such as prices. No major regional development projects are assumed to affect the projection.

From 1970 to 1975, cereal consumption per capita fluctuated due to the drought. Cereal production was provided from primarily rainfed agriculture and imports, with relatively little coming from irrigated production.

From 1975 to 1990, rainfed cereal and groundnut production stabilize with fluctuations due to rainfall. The stabilization of rainfed crop production has several causes.

Population pressure in the Groundnut Basin causes an increased demand for income and food. Farmers, able to achieve greater production faster by increasing land, decrease the amount of fallow land. This causes a slow decline in cereal yields which means farmers must plant more land for subsistence needs and less for income. As income revenues decline, less revenues are available for fertilizer and there is a further decline in yields.

As groundnut production reaches a maximum, so do groundnut exports and revenues. This limits imports of cereals and fertilizer. The abrupt decline in groundnut production in the 1990's is due to the inability of the country to buy fertilizer. Thus urban cereal consumption falls due to declining cereal imports and growing urban population.

POLICY ANALYSIS

Two sets of policies have been chosen to demonstrate the output of the model. There are many other policies that could have been chosen, and many combinations of all these policies.

FIGURE 1a

HISTORICAL AND P JECTED BEHAVIOR

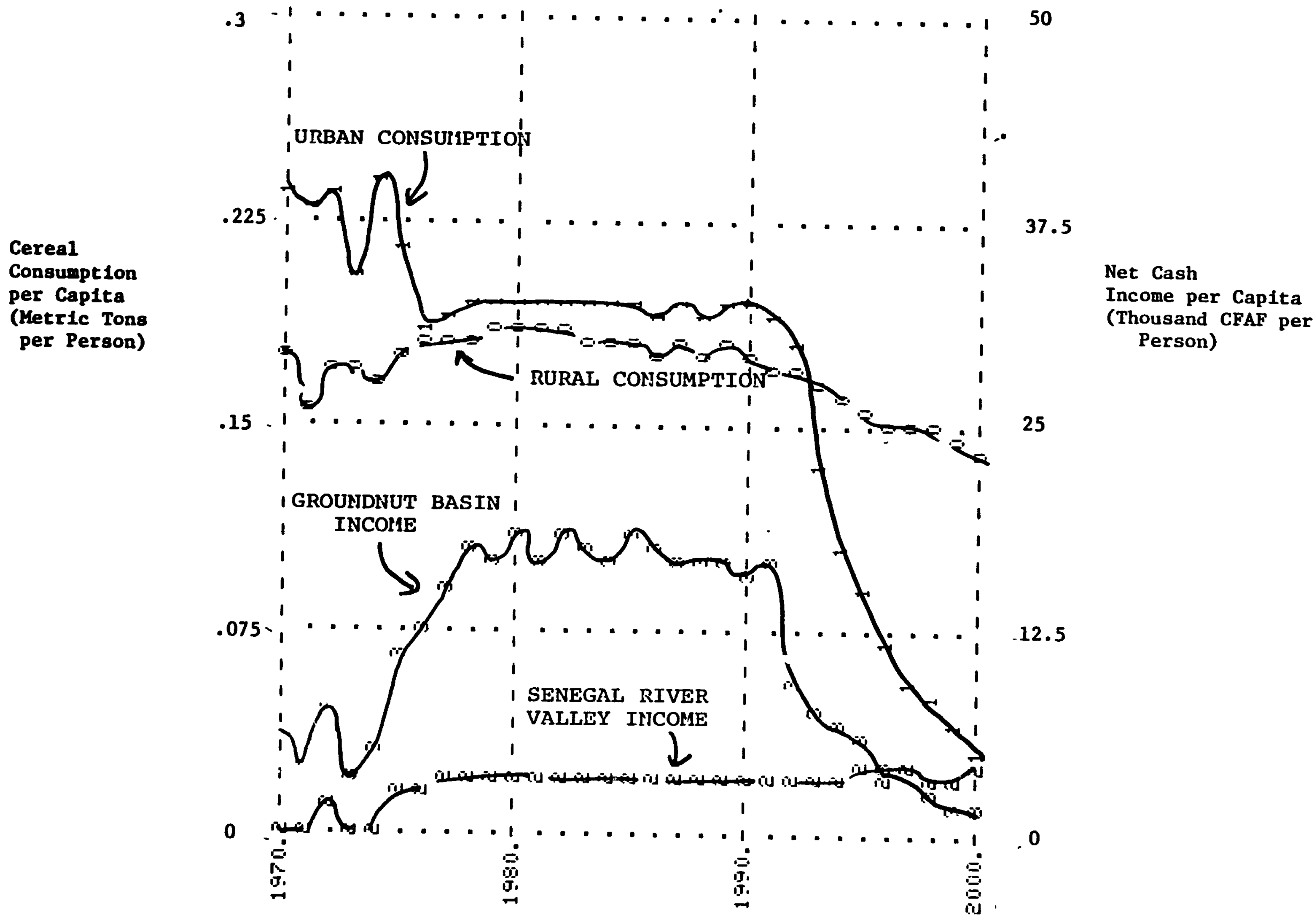
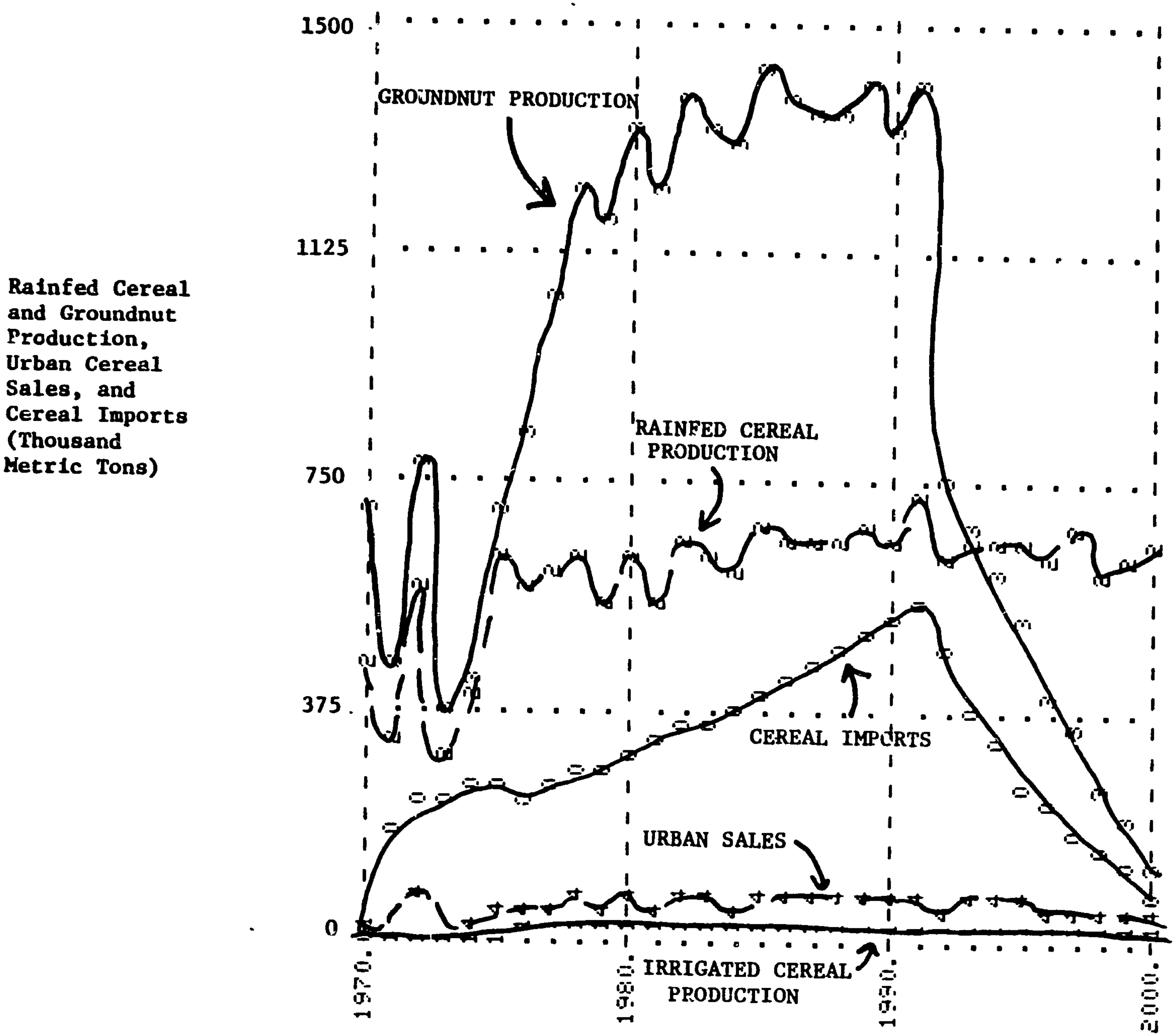


FIGURE 1b
HISTORICAL AND PROJECTED BEHAVIOR



Rainfed Crop Production Strategy

The first policy set is based on increasing rainfed cereal production. Four policies are implemented:

a. Changing urban preference for rice and wheat such that rice, wheat, millet, and sorghum are viewed as qualitative substitutes. The will require primarily solutions such as new techniques for converting millet into high quality commercial products;

b. Increasing the price of millet and sorghum to the farmers by 5 percent per year to a maximum of 2.5 times the present price;

c. Increasing the price of cereal imports by 2 percent per year; and

d. Decreasing to one year the delay in achieving technologically possible crop yields based on available inputs. This will require an effective trained extension staff, or equivalent means to insure technology transfer to farmers.

The results of these policies are shown in figure 2.

Irrigated Crop Production Strategy

The second policy set is based on increasing irrigated cereal production. Two policies are implemented:

a. Investing 400 million dollars from 1977 to 2000 in irrigation facilities valued at 2680 dollars per hectare. In the model 2100 and 3000 dollars per hectare represent respectively irrigation with (1) partial water control and pumping stations, and (2) full water control.

b. Decreasing to one year the delay in achieving technologically possible crop yields based on available imputs.

The results of these policies are shown in figure 3.

IDENTIFYING RESEARCH REQUIREMENTS

A model can be used to indicate research requirements. This can be done by taking model relationships for which definitive data are not available and varying them over a range of possible values. If these changes do not effect the model projections, then there will be no need to be concerned about the relationship's specific form. If there is a major effect which would indicate a change in policy recommendations, then research is necessary to better define the relationship. The following is an example of such a relationship. There are others in the mode.

FIGURE 2
DOMESTIC RAINFED CEREAL PRODUCTION STRATEGY

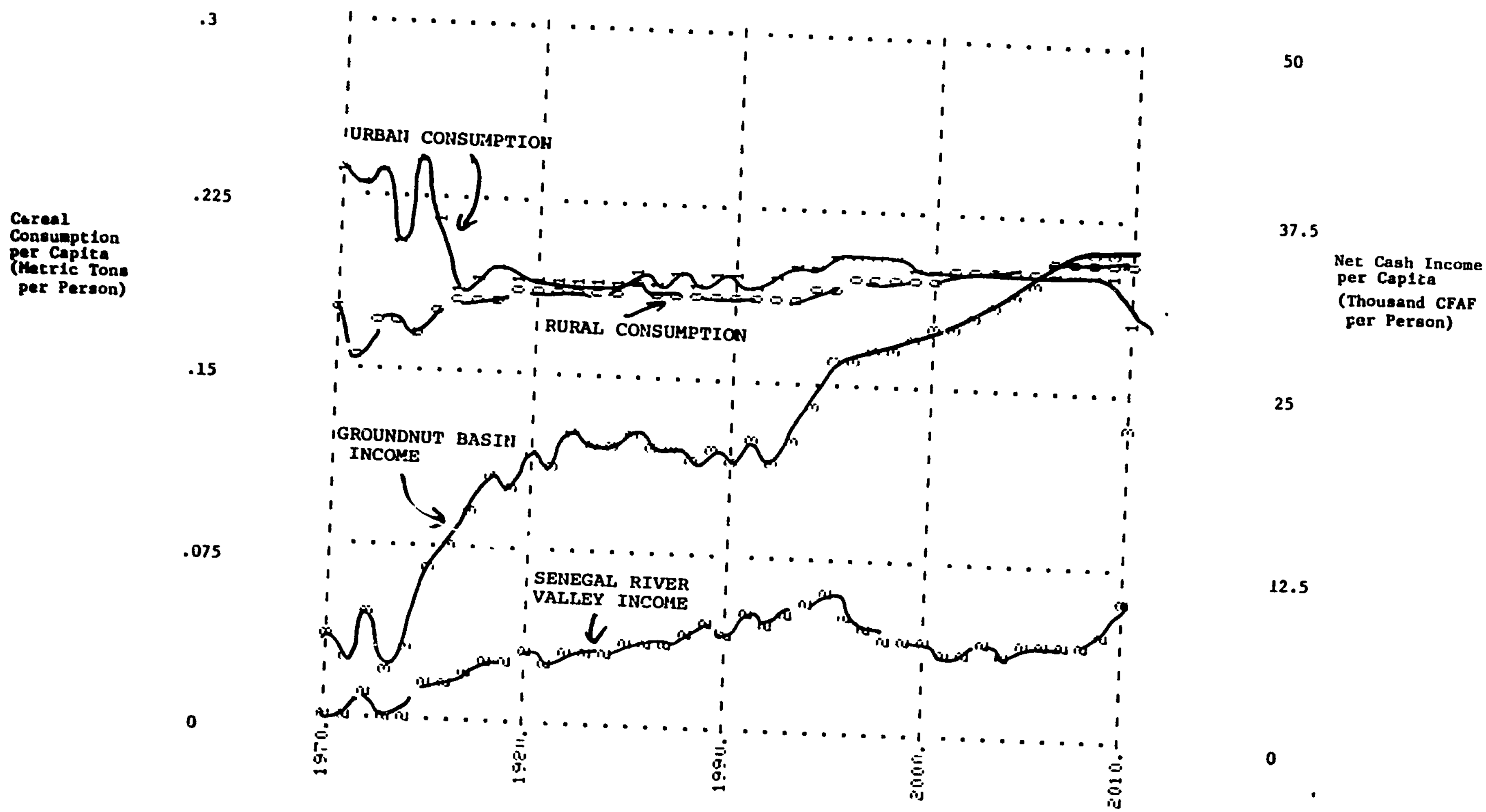
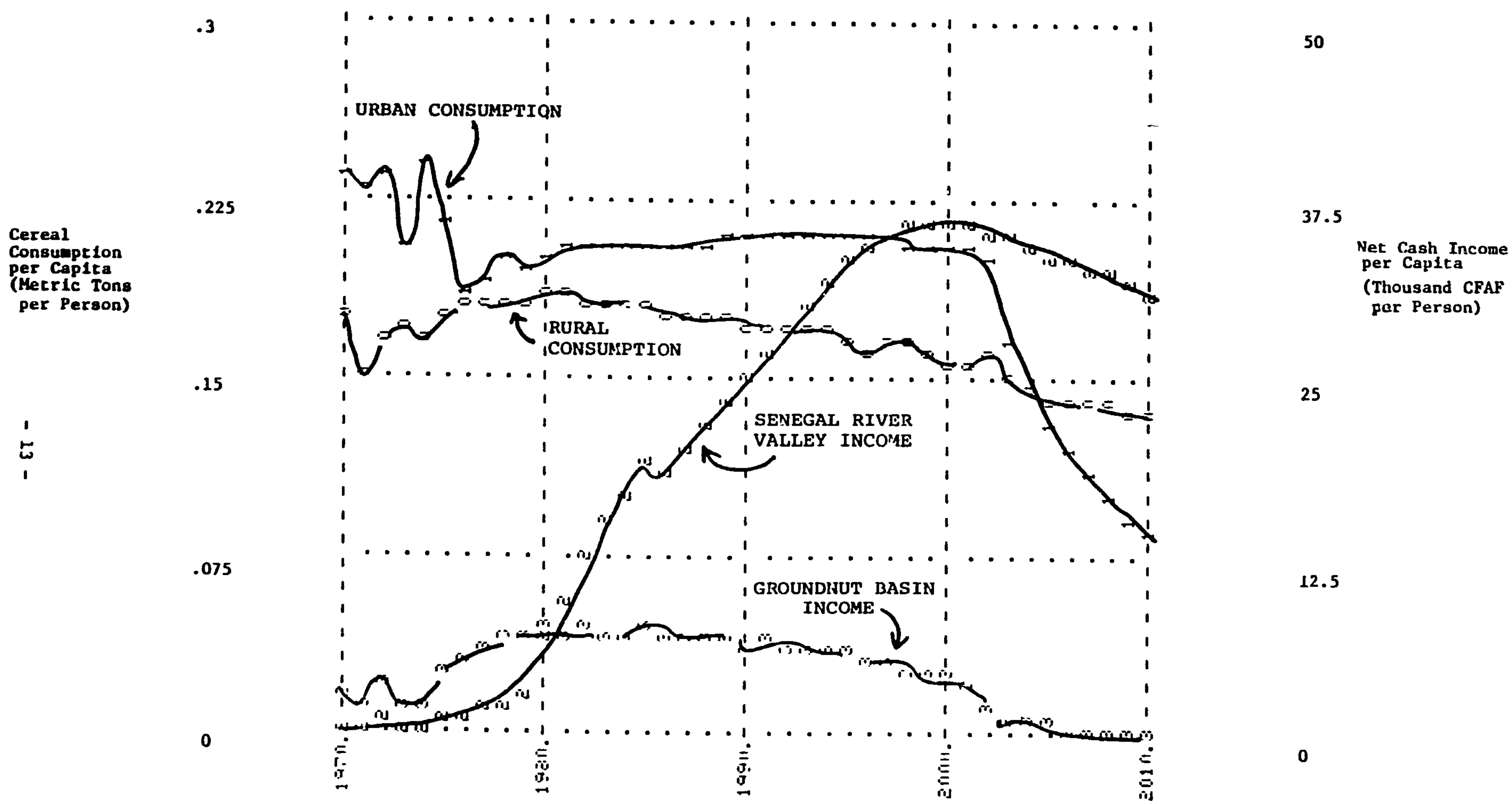
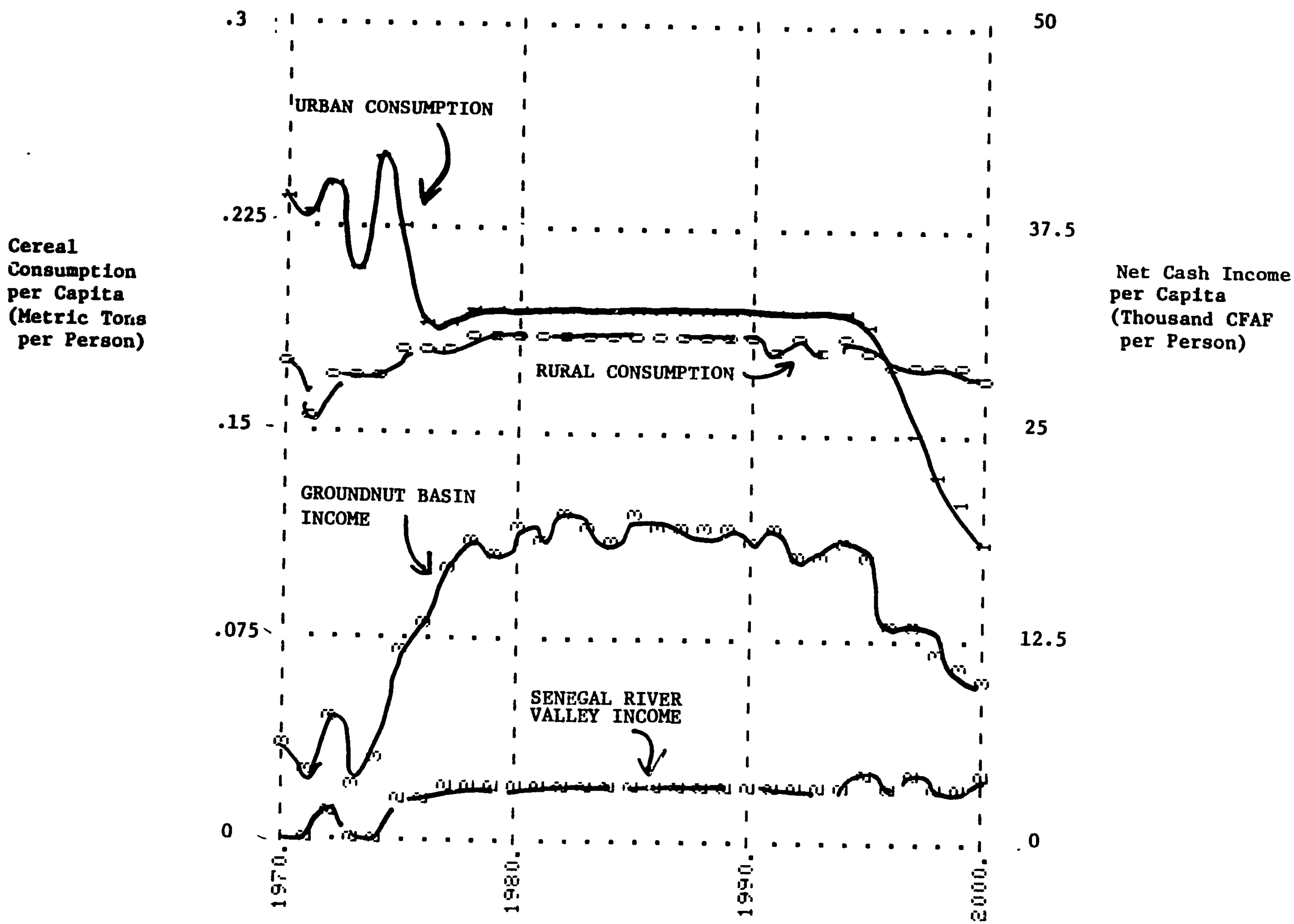


FIGURE 3
IRRIGATED CEREAL PRODUCTION STRATEGY



In the model there is an estimate of the mineral content of the soil in the Groundnut Basin. There is no definitive data on what this value should be. It is possible to choose many values for the soil fertility depending on expert analysis. The effect of increasing this estimate by a factor of 3 is shown in Figure 4.

FIGURE 4
EFFECT OF AN INCREASE IN THE ESTIMATE OF
THE MINERAL CONTENT OF SOIL IN GROUNDNUT BASIN



ANNEXES

ANNEX A

DETAILED DESCRIPTION OF MODEL

The model has four distinct subsectors which are: (1) an urban sector, (2) a Groundnut sector, (3) a Senegal River Valley sector, and (4) a government budget sector. Each sector will be described. The explanation of the equations have been simplified. For more precise definitions, consult the program listing in annex B. An index of variable definitions is given at the end of this annex.

URBAN SECTOR

Total urban cereal demand is equal to the product of urban population and urban cereal demand per capita. If,

$URPOP_t$ = urban population (people)

$URDPC_t$ = urban cereal demand per capita (metric tons per person)

$URDEM_t$ = total urban cereal demand (metric ton)

then,

$$URDEM_t = (URPOP_t)(URDPC_t)$$

Urban demand for domestic millet and sorghum is determined by the (1) total urban cereal demand, (2) the fraction of urban cereal demand supplied by rice and wheat, (3) desired additions to urban stocks of millet and sorghum, and (4) shortfalls in rice and wheat supply. Urban demand for rice and wheat is similarly determined. If,

$URDDP_t$ = urban demand for domestic millet and sorghum in year t (metric tons) (In following definitions of variables with a subscript t, the phase "in year t" will be omitted.)

$URCIM1_t$ = urban demand for rice and wheat (metric tons)

$URIF_t$ = fraction of urban cereal demand supplied by rice and wheat (dimensionless)

$URDDAS_t$ = desired additions to urban millet and sorghum stocks (metric tons)

$URDIAS_t$ = desired additions to urban rice and wheat stocks (metric ton)

$URISHT_t$ = shortfall in rice and wheat supply (metric ton)

$URDSHT_t$ = shortfall in domestic millet and sorghum supply (metric ton)

then,

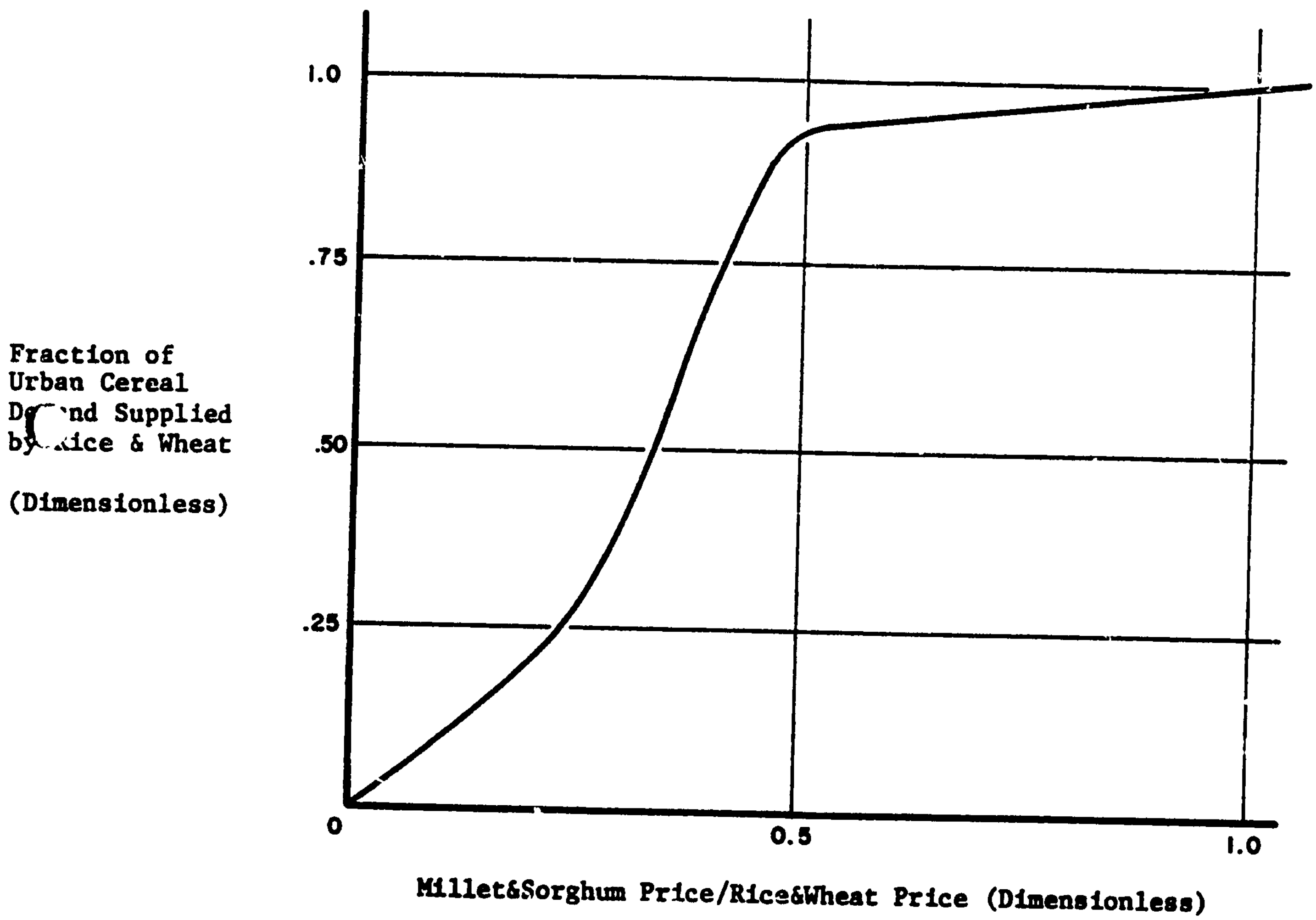
$$URDDP_t = (URDEM_t)(1-URIF_t) + URDDAS_t + URISHT_t$$

$$URCIM1_t = (URDEM_t)(URIF_t) + URDIAS_t + URDSHT_t.$$

The fraction of urban cereal demand supplied by rice and wheat (URIF) is a function of the price of wheat and rice and the price of millet and sorghum. The ratio of cereal prices determines the fraction supplied by imports. In addition. equal prices do not imply an equal preference for the different cereals. Rice and wheat are preferred for taste and convenience of preparation. Thus, urban consumers are willing to pay a premium for such cereals. The relationship which determines the fraction is given in figure A1.

Figure A1

THE RELATIONSHIP BETWEEN THE
FRACTION OF URBAN CEREAL DEMAND SUPPLIED BY RICE AND WHEAT AND
THE RATIO OF RICE AND WHEAT TO MILLET AND SORGHUM PRICES



<u>Urban demand for imported rice and wheat</u> is determined by the (1) urban demand for rice and wheat, (2) fraction of urban rice and wheat demand supplied by imports, and (3) shortfalls in domestic rice and wheat supply. <u>Urban demand for domestic rice and wheat</u> is similarly determined. If,

$URIRD_t$ = urban demand for imported rice and wheat (metric ton)

$URDRD_t$ = urban demand for domestic rice and wheat (metric ton)

$URRF_t$ = fraction of urban rice and wheat demand supplied by imports (dimensionless)

$URDRSH_t$ = shortfall in domestic rice and wheat supply (metric ton)

$URIRSH_t$ = shortfall in imported rice and wheat supply (metric ton)

then,

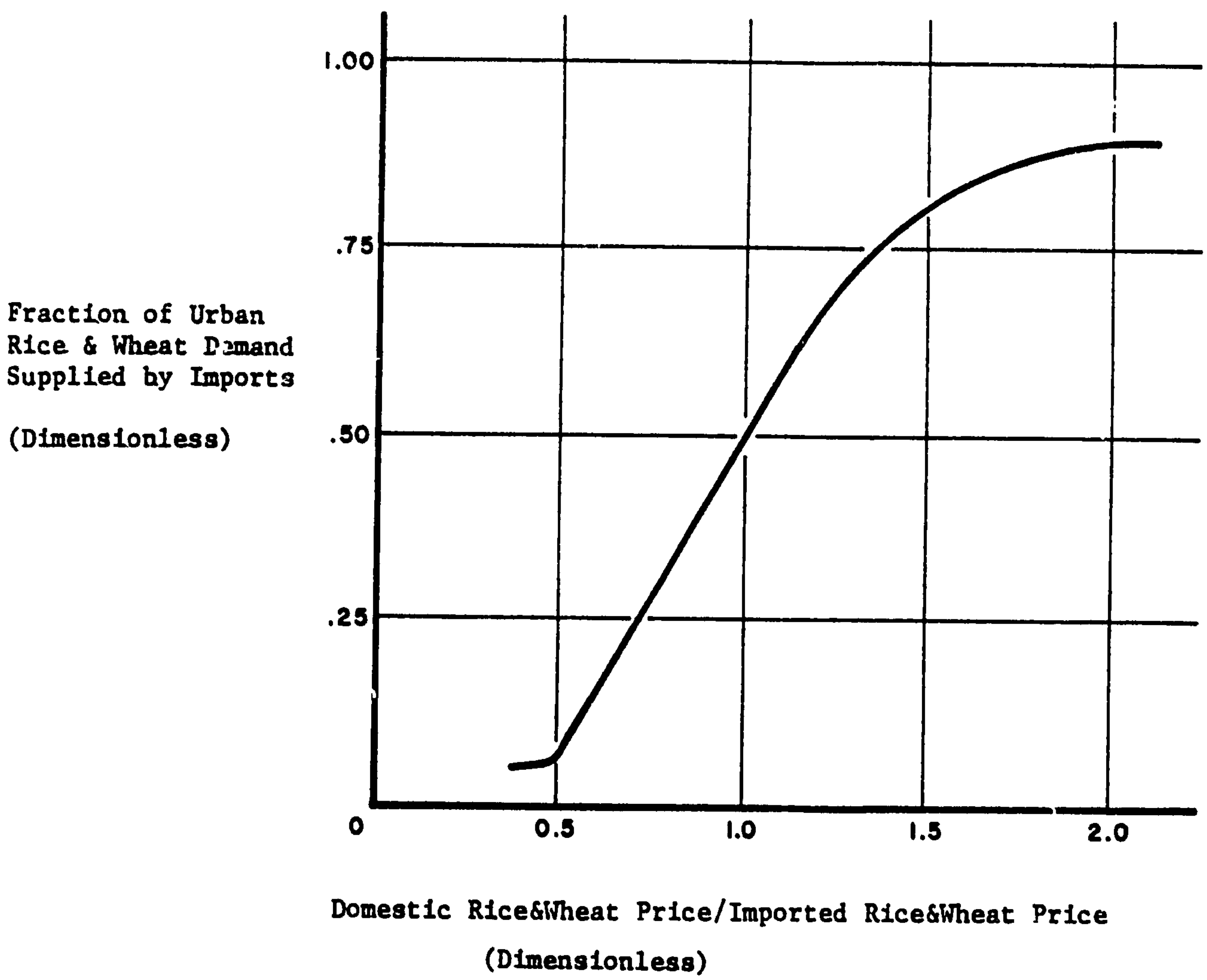
$$URIRD_t = (URCIM1_t)(URRF_t) + URDRSH_t$$

$$URDRD_t = (URCIM1_t)(1-URRF_t) + URIRSH_t.$$

The fraction of urban rice and wheat demand supplied by imports (URRF) is a function of the price of imported rice and wheat and the price of domestic rice and wheat. The ratio of the cereal prices determines the fraction supplied by imports. There is assumed to be no preference shown for either imported or domestic rice or wheat. Thus equal prices imply an equal preference for each type of cereal. The relationship which determines the fraction is given in figure A2.

FIGURE A2

THE RELATIONSHIP BETWEEN THE FRACTION OF URBAN RICE AND WHEAT DEMAND SUPPLIED BY IMPORTS AND THE RATIO OF IMPORTED AND DOMESTIC RICE AND WHEAT PRICES



Urban imports of rice and wheat may be no larger than the amount which can be bought from foreign exchange received from groundnut exports. The maximum cereal imports is set equal to the amount of revenues from groundnut exports divided by the imported cereal price. An exception to this rule is made during the drought. Extra foreign exchange is assumed available from other exports, international debt, drawing down exchange reserves, etc. for emergency purposes. If,

$FXOS_t$ = emergency foreign exchange reserves (CFAF)

then,

$URCIMP_t$ = urban imports of rice and wheat (metric ton)

$GOVGR_t$ = groundnut revenues from exports (CFAF)

$URIMP_t$ = imported rice and wheat price (CFAF per metric ton)

$IMAX_t$ = maximum urban imports of rice and wheat (metric ton)

then,

$$URCIMP_t = URIRD_t, \text{ such that } URCIMP_t \leq IMAX_t$$

$$IMAX_t = GOVGR_t / URIMP_t.$$

Millet and sorghum stocks for urban consumption is increased by millet and sorghum production sold for income in the Groundnut Basin and in the Senegal River Valley and decreased by urban consumption of these cereals. If,

$URDSK_t$ = domestic cereal stocks for urban consumption (metric ton)

$GCPIS_t$ = Groundnut Basin millet and sorghum production sold for income (metric ton)

$SNCPIS_t$ = Senegal River Valley millet and sorghum production sold for income (metric ton)

$URDCON_t$ = Urban consumption of millet and sorghum (metric ton)

then,

$$URDSK_t = URDSK_{t-1} + GCPIS_t + SNCPIS_t - URDCON_t.$$

Rice and wheat stocks for urban consumption is increased by cereal imports, rice production sold for income in the Senegal River Valley, donor aid of rice and wheat, and decreased by urban consumption of these cereals. All commercial imports commercial sales, and aid shipments of rice and wheat shown in Table A1 are assumed destined for urban areas. If,

$URISK_t$ = rice and wheat stocks for urban consumption (metric ton)

$SICPQ_t$ = Senegal River Valley rice production sold for income (metric ton)

$URICON_t$ = urban consumption of rice and wheat (metric ton)

TABLE A1

CEREAL IMPORTS

and COMMERCIAL CEREAL SALES IN SENEGAL

Thousand Metric Tons

YEAR[1]	COMMERCIAL IMPORTS		FOOD AID		OFFICIAL COMMERCIAL SALES	
	Wheat and Rice	Other Cereals[2]	Wheat and Rice	Other Cereals[2]	Paddy Rice	Millet
1969	292.8	38.6	11.2	18.2	38.0	10,472
1970	219.0	0.2	12.6	9.6	692.0	346
1971	299.5	28.9	0.0	2.8	599.0	2,866
1972	265.3	10.4	0.0	1.0	653.0	N.A.
1973	250.6	26.4	46.8	61.6	N.A.[3]	N.A.
1974	222.6	33.5	7.6	49.5	N.A.	N.A.
1975	217.6	5.0	6.2	0.0	N.A.	N.A.
1976	235.0	0.0	0.0	2.4	N.A.	N.A.

1/ Calendar year for imports and crop year for sales.
2/ Millet, sorghum, and maize.
3/ N.A. denotes not available

Sources: AID, Proposal for a PL 480 Title I - Program in Senegal, 1976, Annex I, p 52-533; Direction de la Statistique, Bulletin Statistique et Economic Mensuel; ONCAD.

$CUAID_t$ = donor aid of rice and wheat (metric ton)

then,

$$URISK_t = URISK_{t-1} + URCIMP_t\ SICPQ_t - URICON_t + CUAID_t.$$

Desired additions to millet and sorghum stock is assumed equal to one-half of the difference between desired and actual stocks. Desired stocks is assumed to equal one-quarter of urban consumption. If,

$URDDSK_t$ = desired urban millet and sorghum stock (metric ton)

then,

$$URDDAS_t = (URDDSK_t - URDSK_t)/2$$

$$URDDSK_t = (URDEM_t)(1-URIF_t) + URISHT_t.$$

Desired additions to urban rice and wheat is determined similar to the urban demand for millet and sorghum. If,

$URDISK_t$ = desired urban rice and wheat stock (metric ton)

then,

$$URDIAS_t = (URDISK_t - URISK_t)/2$$

$$URDISK_t = (.25)\ (URDEM_t)(URIF_t) + URDSHT_t).$$

Urban consumption of millet and sorghum and rice and wheat are determined by the (1) total urban cereal demand, (2) the fraction of urban cereal demand supplied by rice and wheat, (3) shortfalls in cereal supply, and (4) the cereal stock multipliers. If,

$URDCSM_t$ = urban millet and sorghum stock multiplier (dimensionless)

$URICSM_t$ = urban rice and wheat stock multiplier (dimensionless)

then,

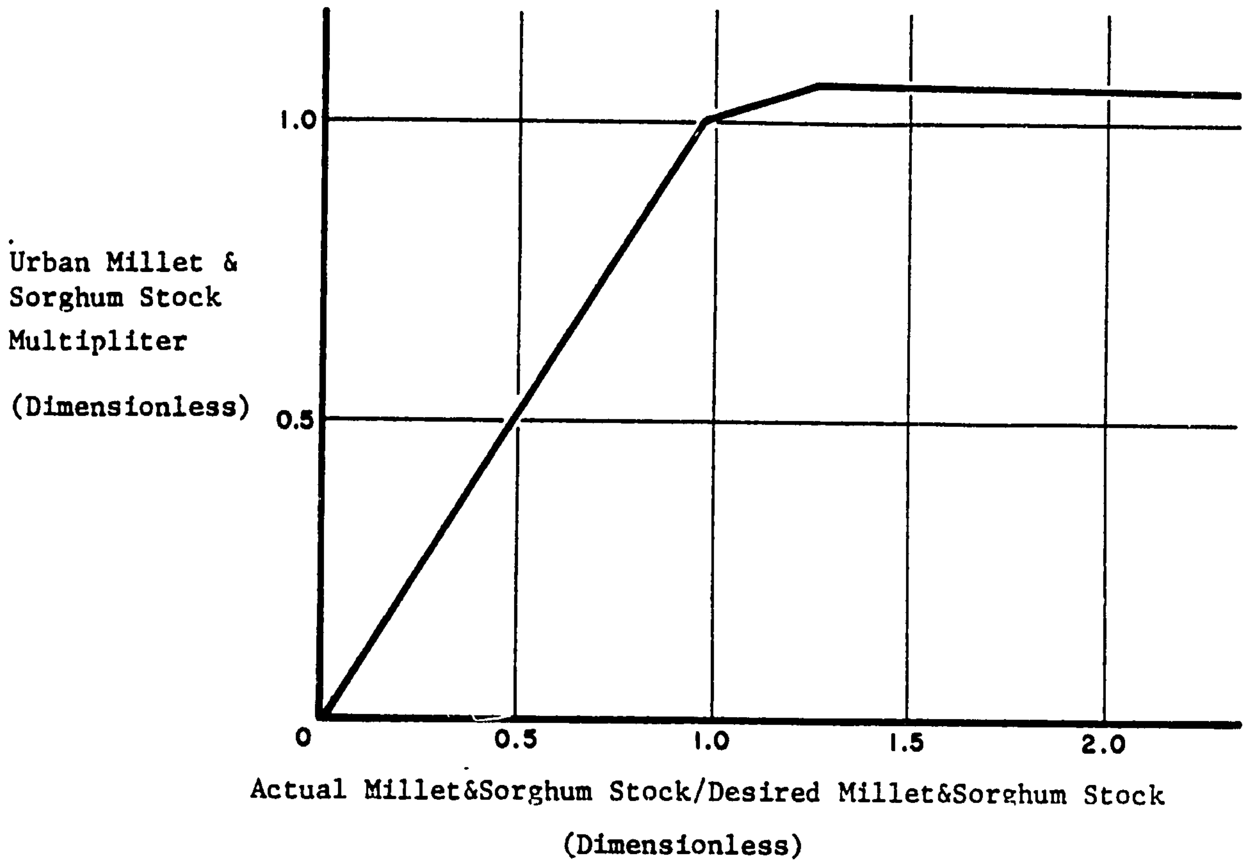
$$URDCON_t = (URDCSM_t)((URDEM_t)(1-URIF_t) + URISHT_t)$$

$$URICON_t = (URICSM_t)((WRDEM_t)(URIF_t) + URDSHT_t).$$

The urban millet and sorghum (URDCSM) and rice and wheat stock multiplier (URICSM) are determined by the actual and desired stocks of each stock. The millet and sorghum multiplier is presented in Figure A3.

FIGURE A3

THE RELATIONSHIP BETWEEN THE
URBAN MILLET AND SORGHUM STOCK MULTIPLIER AND THE
RATIO OF ACTUAL AND DESIRED CEREAL STOCKS



The fraction of domestic millet and sorghum production bought by the urban sector is equal to the quotient of total urban demand for these cereals divided by the domestic production for sale, up to a maximum of one. The fraction of domestic ric and wheat production bought by the urban sector is equal to the quotient of total urban demand for these cereals divided by the total production for sale, up to a maximum of one. If,

$URTM_t$ = fraction of domestic millet and sorghum production bought by the urban sector (dimensionless)

$URTMR_t$ = fraction of domestic rice and wheat production bought by the urban sector (dimensionless)

$TOTCPS_t$ = domestic production of millet and sorghum for sale

then,

$$URTM_t = URDDP_t / (TOTCPS_t), \text{ such that } URTM_t \leq 1$$

$$TOTCPS_t = GCPIS_t + SNCPIS_t$$

$$URTMR_t = URDRD_t / SICPQP_t \text{ such that } URTMR_t \leq 1$$

Urban population is increased by the urban population growth rate. The urban population is defined to be the ten largest cities: Dakar, Kaolak, Thies, Saint-Louis, Ziguinchor, Rufisque, Diourbel, Louga, Mbour and Tambacounda. The combined population of these cities were approximately 30 percent of the total Senegal population in 1973. The average urban growth rate was approximately 5 percent per year.[1/] The 1970 urban population was assumed to be 30 percent of the total 1970 Senegal population, or 1,126,200 people. If,

URG_t = urban population growth (people per year)

URGR = urban population growth rate (dimensionless)

then,

$$URPOP_t = URPOP_{t-1} + URG_t$$

$$URG_t = (URPOP_t)(URGR)$$

$$URGR = .05.$$

Urban cereal demand per capita is determined by the perceived average urban cereal price and perceived urban income per capita. As the urban cereal price increases (or decreases), the cereal demand per capita will decrease (or increase). As urban income per capita increases (or decreases), the cereal demand per capita will increase (or decrease). The magnitude of the effect will depend on the price and income elasticities of demand. The price elasticity has been assumed to be -.2 and the income elasticity is assumed to be .2. Each elasticity may be changed as data become available.

$URPACP_t$ = perceived average urban cereal price (CFAF per metric ton)

$URPIC_t$ = perceived income per capita index (dimensionless)

URIELA = income elasticity of demand (dimensionless)

URPELA = price elasticity of demand (dimensionless)

URCON = constant (CFAF per person)

then,

$$URDPC_t = (URCON)(URPACP_t^{\ URPELA})(URPIC_t^{\ URIELA})$$

$$URPELA = -.2$$

$$URIELA = .2$$

Urban cereal consumption per capita from 1965 through 1968 was approximately .250 metric tons per person per year.[2/] This consumption seems to have declined with higher food prices in the 1970's.[3/]

1/ Nelson, H., et.al., Area Handbook for Senegal, American University, 1974, p. 63.
2/ Dione, J., Le Deficit Cerealier au Senegal, University Laval, Quebec, 1975, p. 48.
3 AID, Proposal for a PL 480 Title I Program in Senegal, Dakar, 1976, Annex I, p. 10.

Perceived average urban cereal price and the perceived income per capita index are exponentially weighted moving averages of past values of average urban cereal prices and of the income per capita index.

Average urban cereal price is equal to the average of domestic cereal and imported cereal prices, weighted by the amounts of each type of cereal consumed in the cities. If,

$URACP_t$ = average urban cereal price (CFAF per metric ton)

$URARP_t$ = urban rice and wheat price (CFAF per metric ton)

$URDCP_t$ = urban domestic millet and sorghum price (CFAF per metric ton)

then,

$$URACP_t = (URDCP_t)(TOTCPS_t) + (URARP_t)(URCIMP_t + SICPQ_t)))/(TOTCPS_t + URCIMP_t + SICPQ_t)$$

The urban rice and wheat price is a weighted average of imported and domestic prices. The urban domestic millet and sorghum price is a weighted average of Groundnut Basin and Senegal River Valley cereal. The imported rice and wheat price is exogenous in the model. Prior to November, 1974, urban consumer prices for imported rice were 50-60 CFAF per kilogram. On this date, the price for rice was raised to 100 CFAF per kilogram and lowered to 80 CFAF in April, 1976.1/ The urban domestic cereal price is determined by the average cereal price paid to farmers and the government percentage price mark-up to consumers. These prices are given in table A2. This mark-up is assumed to be 25 percent.2/ The price of domestic rice is increased by 51 percent due to the 66 percent loss of weigh. by milling. This preliminary model ignores the prices paid and received by private traders which vary from the government prices. If,

GOVDM = government price mark-up for domestic cereals (dimensionless)

$URIMPC_t$ = urban price of imported cereals (CFAF per metric ton)

$SICPF_t$ = Senegal River Valley price of rice to farmers (CFAF per metric ton)

$GCPF_t$ = Groundnut Basin price of millet and sorghum to farmers (CFAF per metric ton)

$SNCPF_t$ = Senegal River Valley price for millet and sorghum to farmers (CFAF per metric ton)

then

$$URARP_t = (URIMPC_t)(URCIMP_t) + (SICPF_t)(GOVDM/.66)(SICPQ_t)/(URCIMP_t + SICPQ_t)$$

$$URDCP_t = (GCPF_t)(GCPIS_t) + (SNCPF_t)(SNCPIS_t)(GOVDM)/(GCPIS_t + SNCPIS_t)$$

$$GOVDM = 1.25$$

1/ ibid, pp. 8, 33.
2/ Comments on an expert on agriculture in Senegal (1.27).

TABLE A2

Cereal and Groundnut Prices to Farmers

CFAF Per Kilogram

YEAR	Millet: Fleuve Region	Millet: Other Regions	Rice	Groundnut[1/]
1969	18	17	21	17.95
1970	18	17	21	18.40
1971	18	17	21	21.17
1972	18	17	21	23.28
1973	18	18	21	22.87
1974	23	23	35	29.76
1975	32	32	41.50	41.50

1/ Average price to cooperatives.
Source: Societe Africaine, Le Senegal en Chiffres, 1976, pp. 100-101, 115.

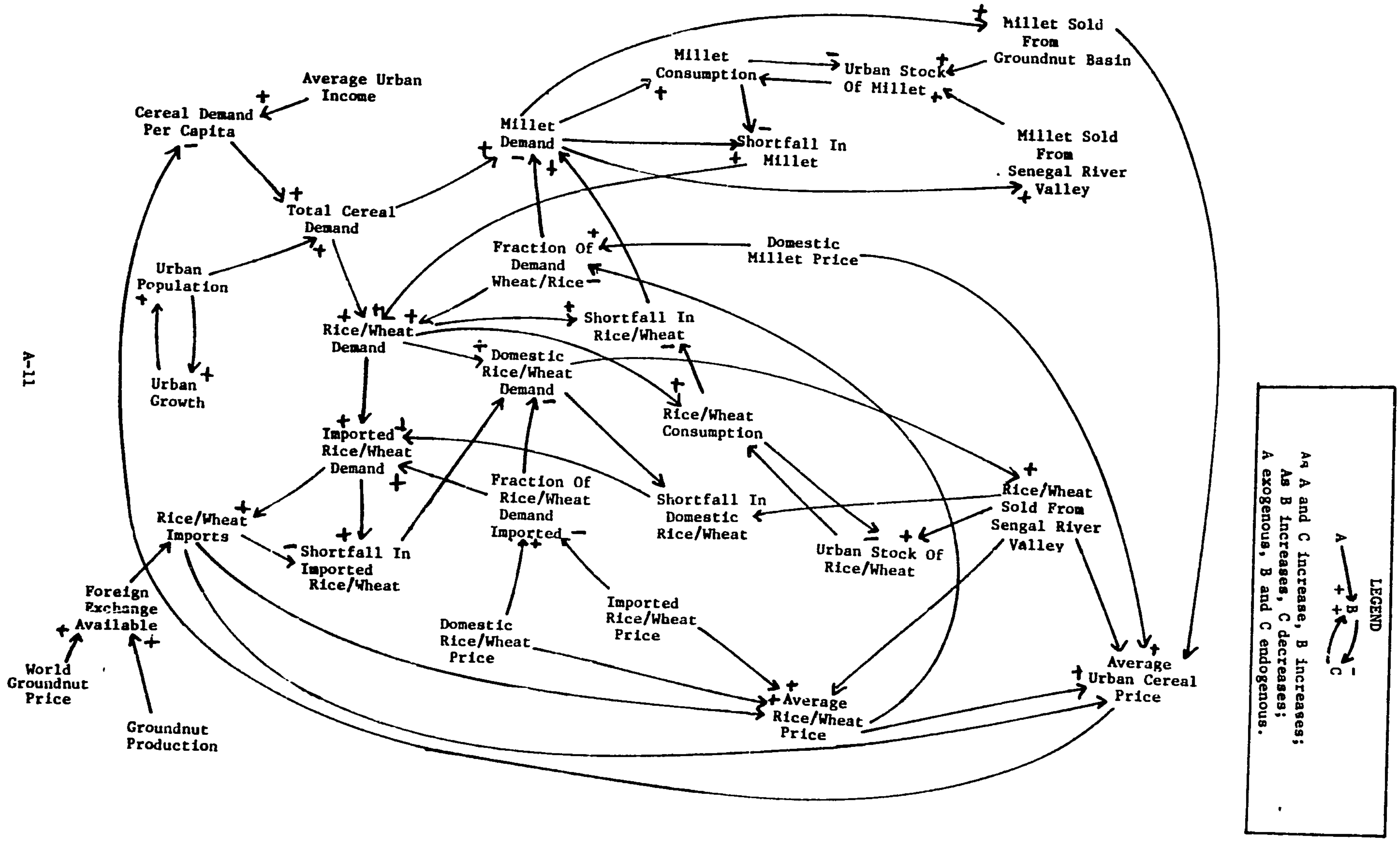
The urban income per capita index (URPEC) is exogenous in the model and is assumed equal to the index of minimum hourly wage rates for industrial workers. The index increases at approximately 2.8 percent per year from 1970 to 1974 and 60 percent from 1974 to 1975.[1/]

The relationships in this sector are presented in figure A4. This graphical technique is explained in Annex D.

1/ PL 480, op. ct., p. 44.

FIGURE A4

CAUSAL RELATIONSHIPS IN THE URBAN SECTOR



GROUNDNUT BASIN SECTOR

Groundnut Basin (GB) cereal production for income is determined by cereal land planted, income cereal yield, and the percentage seed use and wastage.[1] The fraction for seed use and wastage is assumed to be the sum of 10 percent for losses[2] and 10 percent for seed use. If,

$GCLI_t$ = Groundnut Basin (GB) cereal land planted for income (hectares)

$GCPI_t$ = GB cereal production for income (metric ton)

GCY_t = GB income cereal yield (metric tons per hectare)

GSLR = GB fraction for seed use and wastage (dimensionless)

then,

$$GCPI_t = (GCLI_t)\ (GCY_t)\ (1-GSLR)$$

$$GSLR = .20$$

Cereal land planted for income is equal to the product of land planted for income times the fraction of income land planted to cereals. Groundnut land planted is equal to the remainder of the GB income land planted. If,

$GGLI_t$ = GB groundnut land planted (hectares)

$GLPI_t$ = GB land planted for income (hectares)

$GCFP_t$ = fraction of GB income land planted to cereals (dimensionless)

then,

$$GCLI_t = (GLPI_t)\ (GCFP_t)$$

$$GGLI_i = (GLPI_t)\ (1-GCFP_t)$$

Table A3 gives production data for cereals and groundnuts in the Groundnut Basin.

The fraction of income land planted to cereals (GCFP) is determined by a comparison of perceived cereal and groundnut revenues per hectare. This relationship is presented in figure A5.

1/ The Groundnut Basin is assumed to comprise the Regions of Thies, Diourbel and Sine-Saloum.

2/ Dione, op. cit, p. 19.

TABLE A3

MILLET AND GROUNDNUT PRODUCTION
IN THE GROUNDNUT BASIN[1/]

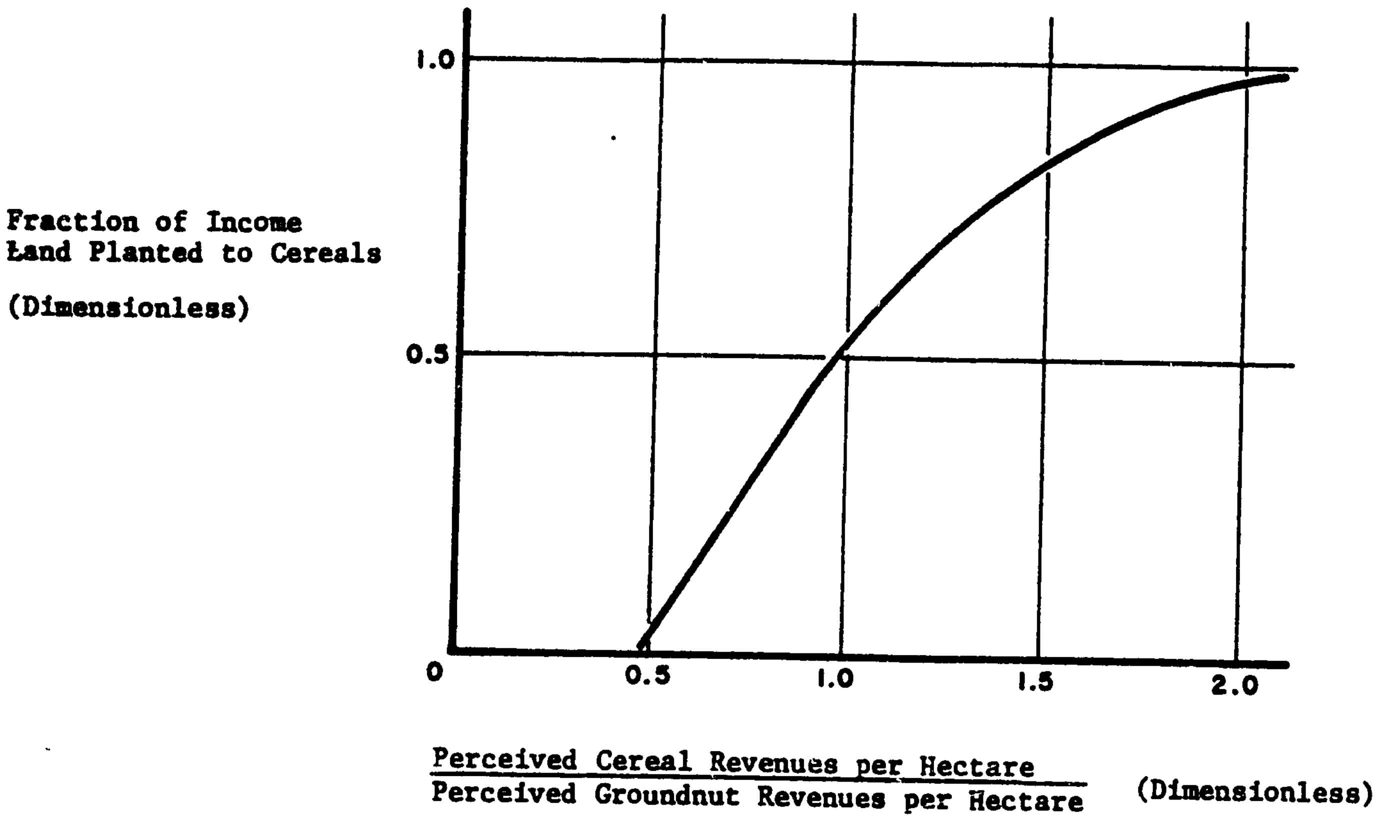
	MILLET			GROUNDNUTS		
YEAR	Area Thousand Hectares	Yield Metric Tons Per Hectare	Production Thousand Metric Tons	Area Thousand Hectares	Yield Metric Tons Per Hectare	Production Thousand Metric Tons
1969/1970	638	.543	379	777	.856	665
1970/1971	626	.385	241	761	.585	450
1971/1972	681	.570	388	876	.940	823
1972/1973	573	.361	207	623	.688	428
1973/1974	988	.430	425	862	.610	526
1974/1975	904	.670	606	995	.912	808

1/ The Groundnut Basin is assumed to comprise the Regions of Thies, Diourbel and Sine-Saloum.

Source: Societe Africaine, Le Senegal en Chiffres, 1976, pp. 101-102, 113-114.

FIGURE A5

THE RELATIONSHIP BETWEEN THE
FRACTION OF INCOME LAND PLANTED TO CEREALS AND THE
RATIO OF PERCEIVED CEREAL AND GROUNDNUT REVENUES PER HECTARE



Perceived cereal and groundnut revenues per hectare are exponentially weighted averages of past values of actual cereal and groundnut revenues per hectares. This includes the assumption that actual revenues per hectare do not immediately change farmer's production decisions.

Cereal revenue and groundnut revenue per hectare are equal to the product of (1) prices received by farmer times (2) the crop yield. Cereal and groundnut prices to farmers are exogenous in the model and presented in Table A2. Cereal revenues also depend upon the fraction of production bought by the urban sector. If,

$GCRH_t$ = GB cereal revenue per hectare (CFAF per hectare)

$GGRH_t$ = GB groundnut revenue per hectare (CFAF per hectare)

$GCPF_t$ = GB cereal price to farmer (CFAF per metric ton)

$GGPF_t$ = GB groundnut price to farmer (CFAF per metric ton)

then,

$$GCRH_t = (GCPF_t)\ (GCY_t)\ (URTM_t)$$

$$GGRH_t = (GGPF_t)\ (CGY_t)$$

Groundnut production is determined by (1) groundnut land planted, (2) groundnut yield, (3) seed use and wastage, and (4) on-farm consumption. On-farm consumption varies and was approximately five percent in 1973/74.[1/]

$GGPI_t$ = GB groundnut production (metric ton)

GGY_t = GB groundnut yield (metric ton per hectare)

GCC = GB groundnut on-farm consumption (dimensionless)

then,

$GGPI_t = (GGLI_t)(GGY_t)(1-GSLR)(1-GCC)$

GCC = .05.

Land planted for income is determined by the land available after subsistence crop land has been deducted, and the available labor. The total land in the Groundnut Basin (i.e., the Thies, Diourbel, and Sine-Saloun Regions) is 6,409,000 hectares and total cropped area is approximately 1,800,000 hectares.[2/] It is assumed based on the national average, that 30 percent of the total land is arable.[3/] This would leave about six percent of the land fallow. If,

GTAL = GB total arable land (hectare)

$GCLS_t$ = GB cereal land planted for subsistence (hectare)

$GMPLP_t$ = GB maximum labor available (hectare)

then,

$GLPI_t = GTAL - GCLS_t$, such that $GLPI_t \leq GMPLP_t - GCLS_t$

GTAL = 1,922,700.

The maximum labor available is determined by the population active in agriculture and maximum land planted per active person. The percent of the population active is assumed to be 40 percent.[4/] If,

$GPOP_t$ = GB rural population (people)

PACT = fraction of population active (dimensionless)

$GMLPP_t$ = GB maximum land planted per person (hectare per person)

then,

$GMPLP_t = (GPOP_t)(PACT)(GMLPP_t)$

GMLPP = 2.4

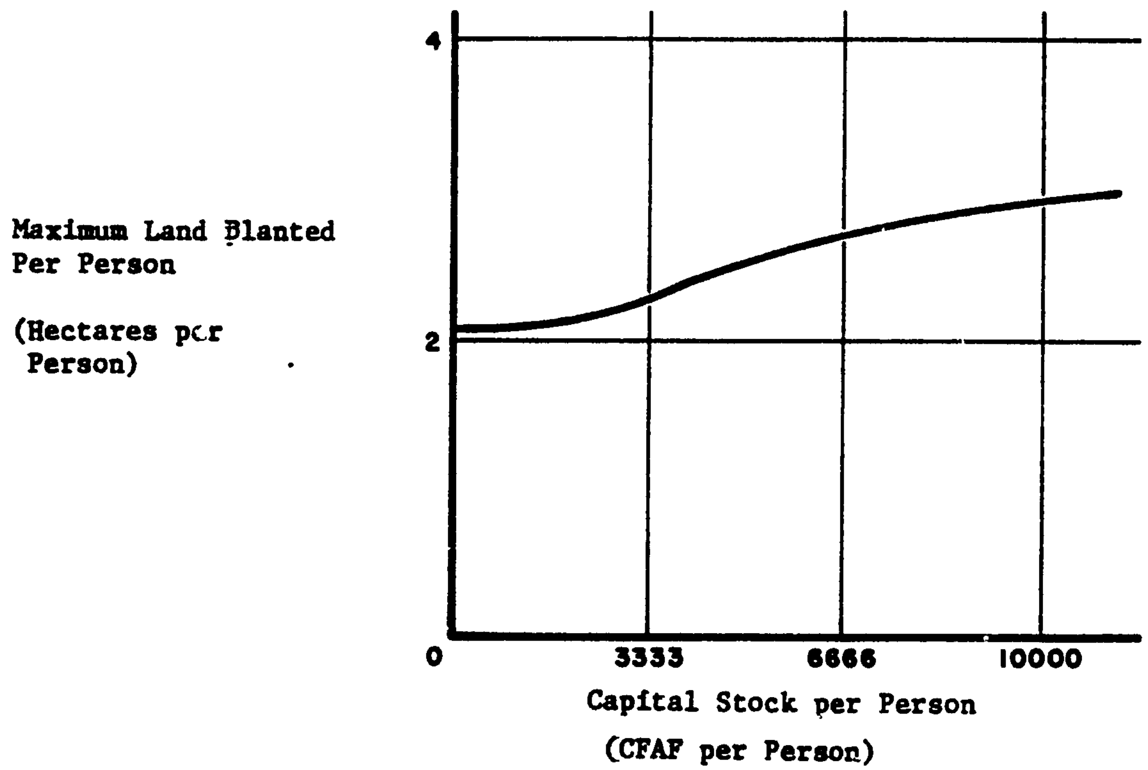
PACT = 0.4.

1/ Societe Africaine, Le Senegal en Chiffres, 1976, p. 111.
2/ Official statistics (2).
3/ Nelson, op cit., p. 266.
4/ AID, Development Assistance Program, FY 1975, March 1975, pp. A-22, A-23.

The maximum land planted per person (GMLPP) is determined by the amount of capital e.g. plows, seeders, oxen, etc. utilized per person.[1] Presently the land planted per person is approximately 2.4 hectares per person.[1] The relationship between land planted per person and capital stock per person is shown in figure A6. This relationship includes the assumption that, excluding the use of tractors or other energy intensive equipment, that farmers presently have approximately 25 percent of their maximum requirements for capital equipment. Further, it is assumed that the maximum land planted per person can be increased by only 50 percent. Both of these assumptions can be easily changed as data become available.

FIGURE A6

THE RELATIONSHIP BETWEEN THE
MAXIMUM LAND PLANTED PER PERSON AND THE
CAPITAL STOCK PER PERSON



The agricultural capital stock is increased by investment and decreased by depreciation. Agricultural capital investment is assumed to equal 60 percent of total agricultural investment, based on the data in table A4. Depreciation is based on an average lifetime of capital of 10 years.[2] The amount of capital in 1970 is estimated to be CFAF 2,200 million, based on table A4. If,

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1/ Official Statistics (2.4.1)
2/ AID, Senegal Cereals Project, Project Proposal, p. 104

TABLE A4

VOLUME AND VALUE OF AGRICULTURAL INPUTS IN SENEGAL

	1960 - 1970			1973			Unit Value[1/]
	Volume	Value (Million CFAF)	Percent of Total Value (Percent)	Volume	Value (Million CFAF)	Percent of Total Value (Percent)	
Fertilizer (Metric Tons)	311,613	3,739	44	37,035	444	36	CFAF12,000/Metric Ton
Fungicide (Metric Tons)	646	248	3	100	0	0	CFAF384,000/Metric Ton
Equipment (Units)							
Seeders	125,112	1,555	19	11,146	139	11	CFAF12,430/Unit
Hoes	146,612	1,129	13	19,491	150	12	CFAF7,700/Unit
Liftels	19,409	82	1	3,004	13	1	CFAF4,200/Unit
Plows	13,851	346	4	5,982	150	12	CFAF25,000/Unit
Carts	39,899	1,085	13	8,363	227	19	CFAF27,200/Unit
Oxen Pair	7,474	219	3	3,243	95	8	CFAF29,300/Unit
Total Value - Fertilizer and Fungicide	-	3,987	47	-	444	36	
Total Value - Equipment	-	4,416	53	-	774	64	
Total Value	-	8,403	100	-	1,218	100	

1/ 1974 unit value.
Source: ONCAD; AID, Senegal Cereals Project, Project Proposal, p. 103.

$GCAPSK_t$ = GB agricultural capital stock (CFAF)

$GCAPI_t$ = GB agricultural capital investment (CFAF)

$GAVREV_t$ = GB total agricultural investment (CFAF)

GCRIF = GB fraction of total investment allocated to current inputs (dimensionless)

$GCAPD_t$ = GB agricultural capital depreciation (CFAF)

GLTC = GB average lifetime of capital (years)

then,

$$GCAPSK_t = GCAPSK_{t-1} + GCAPI_t - GCAPD_t$$

$$GCAPI_t = (GAVREV_t)\ (1-GCRIF)$$

$$GCAPD_t = GCAPSK_t\ /\ GLTC$$

$$GLTC = 10$$

$$GCRIF = .40$$

The <u>agricultural capital stock per person</u> is the quotient of the agricultural capital stock divided by the total population. If,

$GCAPH_t$ = GB agricultural capital stock per person (CFAF)

then,

$$GCAPH_t = GCAPSK_t\ /\ GPOP_t$$

<u>Total agricultural investment</u> is equal to an exponentially weighted average of past values of the indicated total agricultural investment. This includes the delays in ordering and receiving new quantities of agricultural inputs. The <u>indicated total agricultural investment</u> is equal to 35 percent of farmer's receipts from groundnut and cereal sales. This fraction is based on the fraction of the current value of crop output allocated to inputs. The range is from 47 percent for 80,000 farms in the North Groundnut Basin to 23 percent for 20,000 farms in the South Groundnut Basin.[1/] If,

$GAVRVI_t$ = GB indicated total agricultural investment (CFAF)

$GRAF_t$ = GB fraction of farmer's revenues available for investment (dimensionless)

GCR_t = GB farmer's revenues from cereal sales (CFAF)

GGR_t = GB farmer's revenues from groundnut sales (CFAF)

1/ Official Statistics (2.4.1-5).

Then, $GAVRVI_t = (GRAF_t)\ (GCR_t + GGR_t)$

$$GCR_t = (GCPF_t)\ (GCPIS_t)$$

$$GGR_t = (GGPF_t)\ (GGPI_t)$$

$$GRAF_t = .35.$$

Groundnut Basin population is increased by population growth. The rural population growth rate from 1970 for GB is assumed to be approximately 1.5 percent per year with a 1971 population of 1,745,401 people. 1/ If,

GG_t = GB rural population growth (people per year)

$GPGR$ = GB rural population growth rate (dimensionless)

then,

$$GPOP_t = GPOP_{t-1} + GG_t$$

$$GG_t = (GPOP_{t-1})\ (GPGR)$$

$$GPGR = .015.$$

The cereal land planted for subsistence is determined by the desired cereal production for subsistence, the available labor, the expected cereal yield, the fraction of seed use and wastage, and available seed. The available seed is assumed equal to available stocks at a seeding rate of approximately 10 percent of desired production. If,

$GDCPS_t$ = GB desired cereal production for subsistence (metric ton)

$GECY_t$ = GB expected cereal yield (metric tons per hectare)

$GCSK_t$ = GB farmers cereal stocks (metric ton)

then,

$$GCLS_t = (GDCPS_t)\ (GECY_t)\ (1-SLR) \text{ such that}$$

$$GCLS_t \leq GMPLP_t$$

$$\text{and } GCLS_t \leq (GCSK_t)\ (10)/GECY_t.$$

Desired cereal production for subsistence is equal to the sum of desired subsistence cereal consumption plus desired additions to stock. If,

$GDSSC_t$ = GB desired subsistence cereal consumption (metric ton)

$GDASK_t$ = GB desired addition to cereal stocks (metric ton)

then,

$$GDCPS_t = GDSSC_t + GDASK_t.$$

1/ Societe Africaine, op. cit., pp. 22-23.

Desired subsistence cereal consumption is equal to the product of population times desired cereal consumption per capita. Cereal consumption per capita for rice, millet/sorghum, wheat, and maize varied between 158 to 240 kilograms per person per year from 1972 to 1976.1/ In this model it is assumed to be 175 kilograms. If,

$GDPC$ = GB desired cereal consumption per capita (metric ton per person)

then,

$$GDSSC_t = (GPOP_t)\ (GDPC)$$

Desired additions to cereal stock are equal to 10 percent of the difference between farmers' desired and actual cereal stocks. Desired cereal stocks are assumed to equal one-half year's cereal consumption. If,

$GDCSK_t$ = GB desired cereal stock (metric ton)

then,

$$GDASK_t = (GDCSK_t - GCSK_t)/10$$

$$GDCSK_t = (.50)\ (GDSSC_t).$$

Cereal stocks are (1) increased by cereal production for subsistence, unsold cereal production for income, and donor aid shipments, and (2) decreased by cereal consumption. Cereal consumption is equal to the product of population and cereal consumption per capita. If,

$GCPS_t$ = GB cereal production for subsistence (metric ton)

$GCPIN_t$ = GB unsold cereal production for income (metric ton)

$GASSC_t$ = GB cereal consumption (metric ton)

$GCAID_t$ = GB donor cereal aid (metric ton)

GPC_t = GB cereal consumption per capita (metric ton per person)

then,

$$GCSK_t = GCSK_{t-1} + (GCPS_t - GASSC_t + GCPIN_t + GCAID_t)$$

$$GASSC_t = (GPC_t)\ (GPOP_t).$$

Desired cereal consumption per capita is an exponentially weighted average of past values of cereal consumption per capita. This assumes that desired consumption is based on recent consumption trends.

Cereal consumption per capita depends on inventory coverage and on desired cereal consumption per capita. Actual consumption will increase above (decrease

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1/ PL 480, op. cit., Appendix I, p. 16.

below) desired consumption as the inventory coverage increases above (decreases below) one. Inventory coverage is equal to the quotient of cereal stocks divided by desired cereal stocks. If,

$GCOV_t$ = GB inventory coverage (year)

then,

$$GCOV_t = GCSK_t \; / \; GDCSK_t.$$

Cereal production for subsistence is determined by land planted, the cereal yield, and the fraction for seed use and wastage. If,

GCY_t = GB cereal yield (metric ton per hectare)

then,

$$GCPS_t = (GCLS_t) \; (GCY_t) \; (1-GSLR).$$

The fraction of land fallow is an exponentially weighted average of past values of the indicated fraction of land fallow. This includes the assumption that the farmer only slowly changes his decision to set a certain amount of his land fallow. The indicated fraction of land fallow is the residual fraction of land after cereal land for subsistence and desired land planted for income have been subtracted from total arable land. If,

$GPLFI_t$ = GB indicated fraction of land fallow (dimensionless)

then,

$$GPLFI_t = (GTAL - GCLS_t - GLPI_t)/GTAL.$$

Sold cereal production for income is equal to cereal production for income less any shortfall between desired and actual cereal production for subsistence. Sold production is also effected by the amount demanded by the urban sector. Unsold cereal production for income is equal to production for income not sold. Thus,

$$GCPIS_t = (GCPI_t - (GDCPS_t - GCPS_t) \; (URTM_t)$$

$$GCPIN_t = GCPI_t - GCPIS_t.$$

Aid shipments are equal to the share of total Senegal aid shipments of millet, sorghum, and maize to the GB. Total aid shipments are exogenous in the model and presented in Table A1. The GB share of this grain aid is assumed to be 85 percent, to indicate the high priority the GB, especially the northern area, was assigned for relief.1/

The groundnut and cereal yield are determined by the natural soil fertility, the rainfall, and agricultural investment per hectare on each type of land planted. An initial groundnut yield for 1970 is set at .900 metric ton per hectare and an initial cereal yield at .625 metric ton per hectare based on the data in table A3. If

GGYN = GB 1970 groundnut yield (metric ton per hectare)

1/ Nelson, op. cit., p. 270.

$GGIYM_t$ = GB groundnut yield multiplier due to agricultural investment (dimensionless)

$GCIYM_t$ = GB cereal yield multiplier due to agricultural investment (dimensionless)

GWM_t = GB rainfall multiplier (dimensionless)

$GAVNFM_t$ = GB natural soil fertility multiplier (dimensionless)

$GGFMM_t$ = GB multiplier for groundnut inorganic fertilizer use (dimensionless)

$GCFMM_t$ = GB multiplier for cereal inorganic fertilizer use (dimensionless)

then,

$$GGY_t = (GGYN)(GWM_t)(GGIYM_t)((GAVNFM_t) + (1-GGFMM_t))$$

$$GCY_t = (GCYN)(GWM_t)(GCIYM_t)((GAVNFM_t)(GCFMM_t) + (1-GCFMM_t))$$

Groundnut yields have shown a decline from 1960 to 1974, while millet and sorghum yields have maintained an average level. Fertilizer applied per hectare of groundnut rose from 1961 to 65, dropped dramatically in 1967, has maintained an average level since. Fertilizer applied per hectare of millet has generally risen since 1960. This data is summarized in figure A7. Experts feel that groundnut yield may be declining due to soil depletion or misapplication of current inputs. At least, under current conditions, these yields may have reached their ceiling.1/

The natural soil fertility multiplier is set equal to the current natural soil fertility divided by an estimate of the 1970 natural soil fertility. The natural soil fertility is increased by inorganic fertilizer applications and natural mineral additions from fallow and decreased by crop production. The 1970 natural soil fertility estimate is based on estimates of (1) the total amount of arable land, (2) the amount of phosphorous, potassium, and calcium per hectare removed by groundnut crops, and (3) the number of crops that could be supported by the present soil without additional fertilization. The amount of the above fertilizer removed by groundnuts is 73 kilograms per hectare.2/ Nitrogen is not included since groundnuts fix their own nitrogen and free nitrogen leaches from the soil relatively quickly.3/ The number of crops is estimated at 10 years, based on a common Sahelian practice of cropping land 5 years without fertilizer and laying it fallow for around 17 years.4/ If,

$GAVNF_t$ = GB natural soil fertility (kilograms of minerals)

$GARNA_t$ = GB inorganic fertilizer application not removed by crops (kilograms)

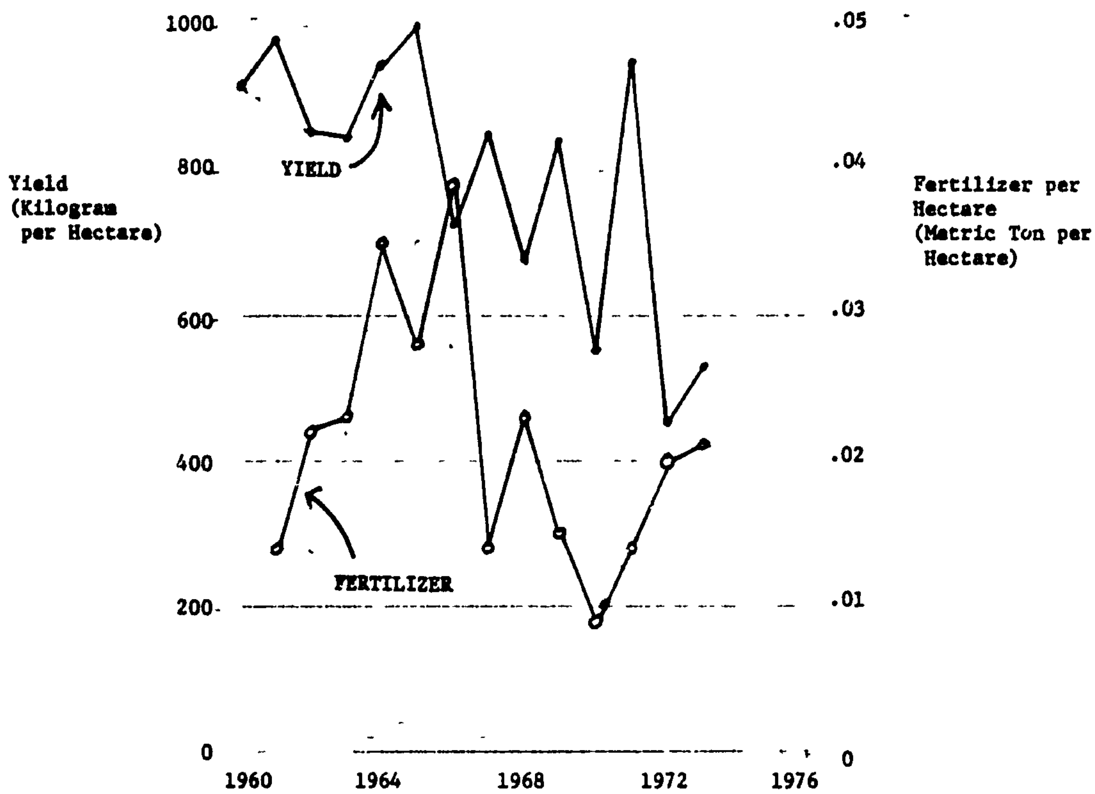
$GNLNA_t$ = GB natural mineral additions from fallow (kilograms)

GNR_t = GB mineral removal by crops (kilograms)

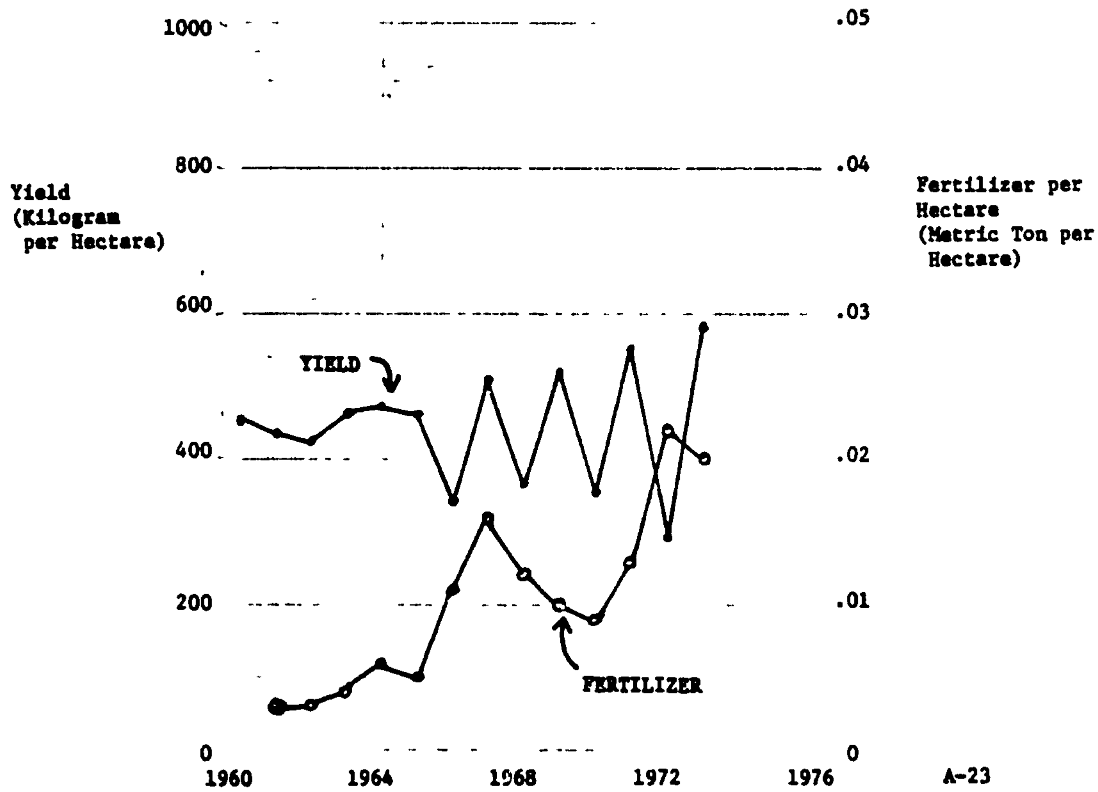
1/ Comments of an expert on agriculture in Senegal (3.3.2)
2/ Senegal Cereals, op. cit., p. 35.
3/ Senegal Cereals, op. cit., p. 36.
4/ Conversation with AID Officer, David Weisenborne, June 22, 1976.

FIGURE A7
Crop Yields and Fertilizer Application in Sine Saloum

a. Groundnuts



b. Millet/Sorghum



SOURCE: Official Statistics (3.18)

GGNL = GB annual mineral withdrawal by groundnut crop (kilograms per hectare)

then,

$GAVNFM_t$ = $GAVNF_t/((GTAL)(GGNL)(10)$

$GAVNF_t$ = $GAVNF_{t-1} + GARNA_t + GNLNA_t - GNR_t$

GGNL = 73.

Inorganic fertilizer application not removed by crops is determined by farmer's investment on current inputs, the percent of that investment spent on fertilizer, the percent assumed removed by crops, and the price of fertilizer. It is assumed that approximately 95 percent of the value of current input is composed of fertilizer, as shown in table A4. The price of fertilizer to the farmer is set at CFAF 12 per kilogram.[1/] There is assumed to be a 71 percent government subsidy on imported fertilizer.[2/] It is also assumed that 95 percent of the fertilizer applied is removed by the crops for which they were intended. The amount of fertilizer bought can be no larger than the amount of foreign exchange received from groundnut exports less exchange expended on cereal imports. If,

$GFRCF_t$ = GB fertilizer price to farmers (CFAF per kilogram)

$GFRCI_t$ = GB fertilizer import price (CFAF per kilogram)

GOVFS = government fertilizer subsidy (percent)

$GOVGRS_t$ = government foreign exchange surplus (CFAF)

GFPCU = GB fertilizer percent of current investment (dimensionless)

GPFNR = GB percent of fertilizer not removed (percent)

$GFERTI_t$ = GB fertilizer application indicated (CFAF)

$GFERT_t$ = GB fertilizer applied (CFAF)

then,

$GARNA_t$ = $(GFERT_t)(GFPCU)(GPFNR)/(GFRCF_t)$

$GFERT_t$ = $GFERTI_t$ such that $GFERTI_t/GFRCF_t \leq GOVGRS_t/GFRCI_t$

GFPCU = .95

GPFNR = .05

Natural mineral addition from fallow is determined by the amount of arable land and the percent of that land fallow. It is assumed that, based on a traditional fallow cycle of 15 years fallow to 5 years cropped, one-fifteenth of the mineral withdrawal by groundnuts for five years is added annually by one acre of fallow.[3/] Thus,

$GNLNA_t$ = $(GTAL)\ (GPLP_t)(1/15)\ (5)\ (GGNL)$.

Minerals removed by crops depends on the types of crops, the land planted to each crop, the amount of fertilizer used, and the amount of minerals in the soil.

1/ Senegal Cereals, op. cit., p. 103.
2/ Senegal Cereals, op. cit., p. 45.
3/ Weisenborne, op. cit.

It is assumed that 73 and 50 kilograms per hectare of phosphorous, potassium, and calcium are removed by groundnut and millet crops respectively. The assumption is made that for fertilizer applications above these amounts, no are removed from the soil. If fertilizer application is below this amount, then crops remove the necessary residual from minerals in the soil. The assumption is also made that as the amount of minerals in the soil approaches zero, the amount of minerals removed approaches zero in a linear fashion. If,

GCNL = GB annual mineral withdrawal by cereal crop (kilogram per hectare)

then,

$$GNR_t = (GAVNFM_t)((GGFMM_t)(GGNL)(GGLI_i) + (GCFMM_t)(GCNL)(GCCI_t + GCLS_t)))$$

$$GCNL = 50.$$

The multipliers for groundnut and for millet inorganic fertilizer use are determined by the fertilizer applied per crop and the amount of minerals removed per crop. The value of fertilizer for millet is reduced by the value of 100 kilograms per hectare of urea for required nitrogen addition.1/ Thus,

$$GGFMM_t = 1-(GGFIH_t \ / \ GGNL) \text{ such that } GGFMM_t \geq 0$$

$$GCFMM_t = 1-((GCFIH_t - (100)\ (GFRCF_t))/GCNL \text{ such that } GCFMM \geq 0.$$

1/ Senegal Cereals, op. cit., p. 38.

The groundnut and cereal yield multiplier due to agricultural investment are determined by fertilizer and capital investment for each crop. If,

$GGIYMR_t$ = GB groundnut yield multiplier from fertilizer investment (dimensionless)

$GCIYMR_t$ = GB cereal yield multiplier from fertilizer investment (dimensionless)

$GGIYMP_t$ = GB groundnut yield multiplier from capital investment (dimensionless)

$GCIYMP_t$ = GB cereal yield multiplier from capital investment (dimensionless)

then,

$$GGIYM_t = (GGIYMP_t)\ (GGIYMR_t)$$

$$GCIYM_t = (GCIYMP_t)\ (GCIYMR_t).$$

The groundnut and cereal yield multiplier from fertilizer investment (GGIYMR and GCIYMR) depend on the fertilizer investment per hectare for each crop. This relationship is shown in figure A8. Fertilizer investment on groundnut hectare and cereal hectare depend on the amount of fertilizer applied to each crop. If,

$GGFIH_t$ = GB fertilizer investment per groundnut hectare (kilogram per hectare)

$GCFIH_t$ = GB fertilizer investment per cereal hectare (kilogram per hectare)

then,

$$GGFIH_t = ((GFERT_t)\ (GFPCU)\ (GGR_t/GAVREV_t)/(GFRCF_t)\ (GGLI_t))$$

$$GGFIH_t = ((GFERT_t)\ (GFPCU)\ (GCR_t/GAVREV_t))/((GFRCF_t)\ (GCLS_t + GCLI_t)).$$

The groundnut and cereal yield multiplier from capital investment (GGIYMP and GCIYMP) depend on the capital investment per hectare. This relationship is presented in figure A9. If,

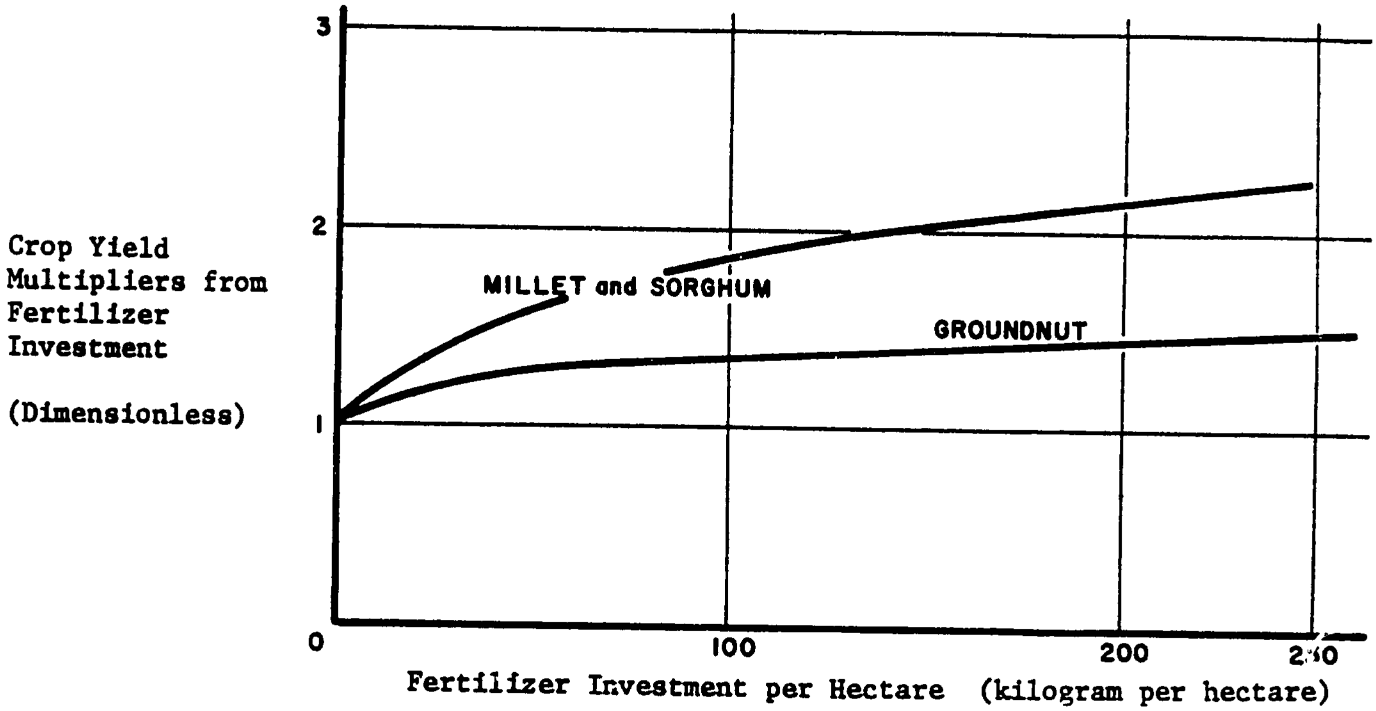
$GCAPHH_t$ = GB capital stock per hectare (CFAF per hectare)

then,

$$GCAPHH_t = GCAPSK_t/(GGLI_t + GCLI_t + GCLS_t).$$

FIGURE A8

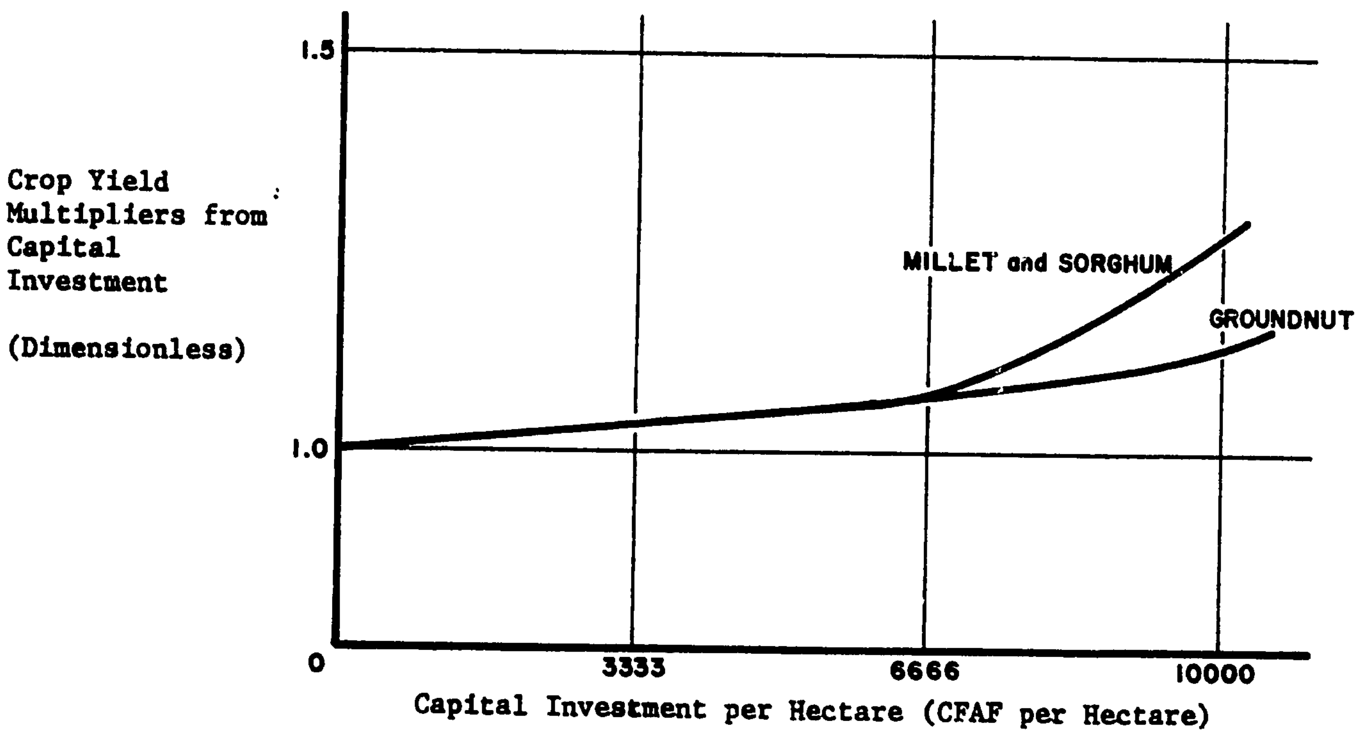
THE RELATIONSHIP BETWEEN THE CROP YIELD MULTIPLIERS FROM FERTILIZER INVESTMENT AND THE FERTILIZER INVESTMENT PER HECTARE



Source: AID, Senegal Cereals Project, Project Proposal.

FIGURE A9

THE RELATIONSHIP BETWEEN THE CROP YIELD MULTIPLIERS FROM CAPITAL INVESTMENT AND THE CAPITAL INVESTMENT PER HECTARE



Source: AID, Senegal Cereals Project, Project Proposal.

The rainfall multiplier (GWM) is equal to the index of rainfall in the GB. index is given in table A5. After 1973, the index is assumed to be normally distributed with mean 1, and .05 standard deviation.

TABLE A5

Rainfall in Groundnut Basin[1/]

Year	Amount Millimeters	Index (1969=1)
1969	823.9	1
1970	528.5	.64
1971	754	.92
1972	448.1	.54
1973	387	.47

1/ Average for the Regions of Diourbel and Sine-Saloun.
Source: Societe Africaine, Le Senegal en Chiffres, 1976, p. 113.

SENEGAL RIVER VALLEY SECTOR

Senegal River Valley (SR) irrigated cereal production for income is determined by the irrigated land planted for income per crop, the irrigated crop yield, the cropping intensity, and the fraction for seed use and wastage. Non-irrigated cereal production for income is determined by the non-irrigated land planted for income, crop yield, and seed use and wastage. Table A6 gives cereal production data in the Senegal River Valley. [1/] If,

$SICPI_t$ = Senegal River Valley (SR) irrigated cereal production for income (metric ton)

$SNCPI_t$ = SR non-irrigated cereal production for income (metric ton)

$SILI_t$ = SR irrigated cereal land for income per crop (hectare)

$SICY_t$ = SR irrigated cereal yield (metric ton per hectare)

$SICI_t$ = SR irrigated cereal cropping intensity (crops per year)

$SNLI_t$ = SR non-irrigated cereal land for income (hectares)

$SNCY_t$ = SR non-irrigated cereal yield (metric ton per hectare)

SSLR = SR fraction for seed use and wastage (dimensionless)

then,

$$SICPI_t = (SILI_t)(SICY_t)(SICI_t)(1-SSLR)$$

$$SNCPI_t = (SNLI_t)(SNCY_t)(1-SSLR)$$

$$SSLR = 0.2$$

1/ PL 480, op. ct., p. 44

FIGURE A10

CAUSAL RELATIONSHIPS IN THE GROUNDNUT BASIN SECTOR

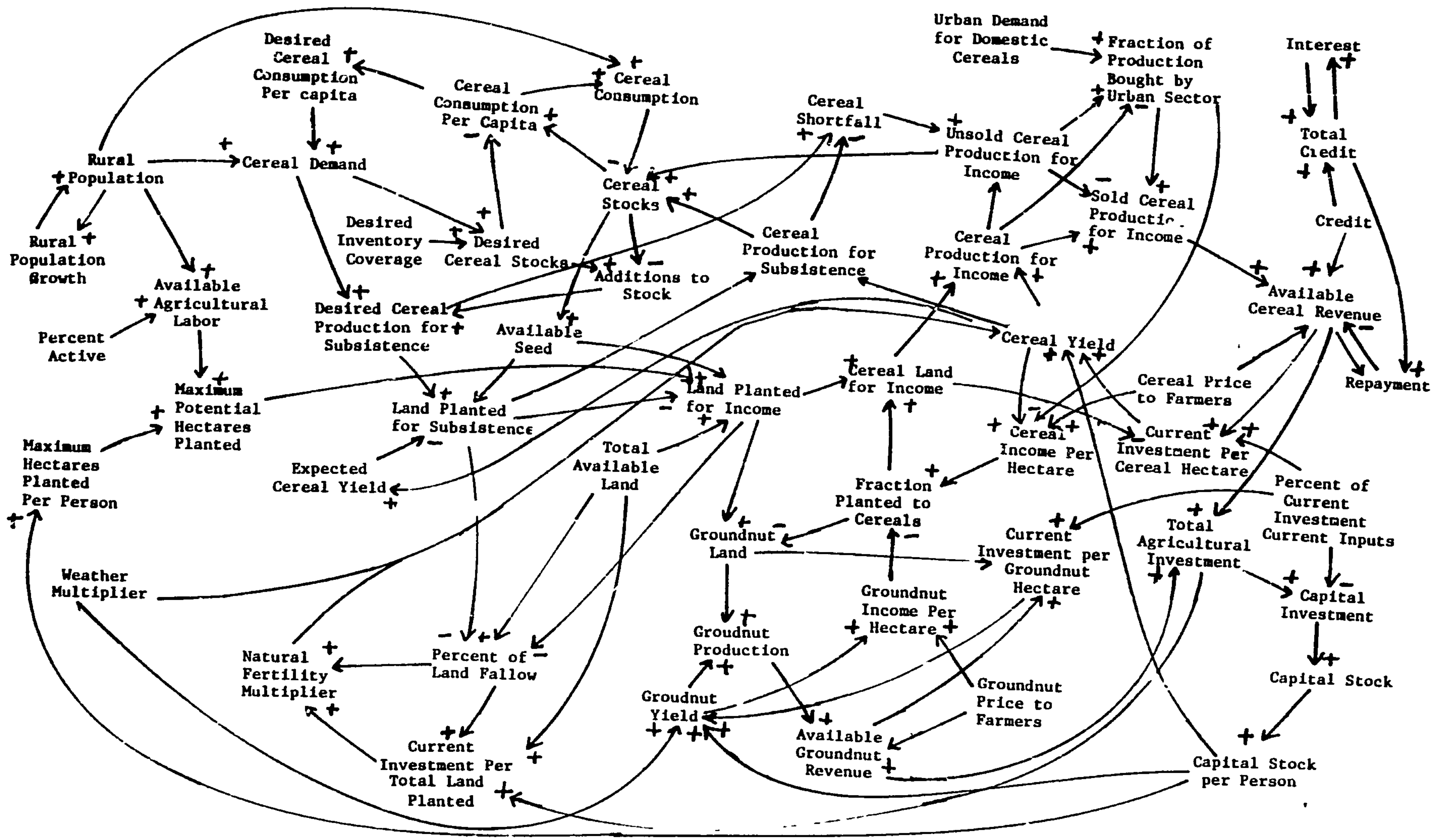


TABLE A6

Cereal Production Data in the Senegal River Valley[1/] [2/]

Crop Year	Area Thousand Hectare	Yield Metric Ton per Hectare	Production Thousand Metric Ton
1969	120.5	.446	53.7
1970	128.4	.787	101.1
1971	111.1	.489	54.3
1972	141.6	.589	83.5
1973	60.9	.126	7.7
1974	N.A.[3/]	N.A.	37.2[4/]
1975	N.A.	N.A.	70.42[4/]

1/ The Senegal River Valley is assumed to comprise the Fleuve Region.
2/ Paddy rice, millet, sorghum and maize.
3/ N.A. denotes not available.
4/ Data excludes maize production.
Source: Official statistics (2); Societe Africaine, Le Senegal en Chiffres, Dakar, 1976. pp. 100-101.

Irrigated cereal land for income per crop is determined by the land available after subsistence crop land has been deducted, and by the available labor. If,

$SILA_t$ = SR irrigated land available (hectare)

$SICLS_t$ = SR irrigated cereal land for subsistence per crop (hectare)

$SIMPLP_t$ = SR maximum irrigated labor available (hectare)

then,

$$SILI_t = SILA_t - SICLS_t \text{ such that } SILI_t \leq SIMPLP_t - SICLS_t.$$

Irrigated land available is determined by investiment in irrigation facilities. There are approximately 9085 hectares of irrigated cereals presently planted. Irrigation development costs from 1964 to 1973 were approximately $1728 pe_ hectare. This is 432 CFAF per hectare at CFAF 250 per U.S. dollar. It is assumed that new irrigation hectares will be added at a rate of CFAF 250 million per year from 1967 until 1990. Depreciation of irrigation equipment is assumed over an average lifetime of 30 years.[1/] If,

SIC_t = SR total investment in irrigation facilities (CFAF)

$SICG_t$ = SR investment rate in irrigation facilities (CFAF)

$SICDR_t$ = SR depreciation rate of irrigation facilities (CFAF)

$SLIC_t$ = SR average irrigation investment per hectare (CFAF per hectare)

then,

$$SIC_t = SIC_{t-1} + (SICG_t - SICDR_t)$$

1/ Official Statistics (1.32).

$SICDR_t$ = SIC_t / 30

$SILA_t$ = SIC_t / $SLIC_t$

$SICG_t$ = 250,000,000

$SLIC_t$ = 432,000.

Irrigated cereal land for subsistence per crop is determined by the desired irrigated cereal production for subsistence, the available labor, the irrigated cereal yield, the cropping intensity, the fraction of seed use and wastage, and available seed. The available seed is assumed equal to available stocks at a seeding rate of approximately 10 percent of desired production. If,

$SIDCPS_t$ = SR desired irrigated cereal production for subsistence (metric ton)

$SICSK_t$ = SR irrigated cereal stock (metric ton)

then

$SICLS_t$ = $SIDCPS_t$ / (($SICY_t$) ($SICI_t$) (1-SSLR)) such that

$SICLS_t \leq SIMPLP_t$, and

$SICLS_t \leq$ (($SICSK_t$) (10))/$SICY_t$.

Maximum irrigated and non-irrigated labor available are determined by the population active in irrigated and non-irrigated agriculture and the maximum irrigated and non-irrigated land planted per active person. The maximum land planted per person for irrigated land is assumed to be .66 and for non-irrigated to be 1.6.1/ If,

$SNMPLP_t$ = SR maximum non-irrigated labor available (hectare)

$SIPOP_t$ = SR irrigated agriculture population (people)

$SNPOP_t$ = SR non-irrigated agriculture population (people)

SILP = SR maximum irrigated land planted per person (hectare per person)

SNLP = SR maximum non-irrigated land planted per person (hectare per person)

then,

$SIMPLP_t$ = ($SIPOP_t$) (PACT) (SILP)

$SNMPLP_t$ = ($SNPOP_t$) (PACT) (SNLP)

1/ AID, Matam Project, Project Proposal, pp. 53-54; Official Statistics (2.4.6-7).

SILP = .66

SNLP = 1.6.

The irrigated and non-irrigated agriculture population is determined by the total population and the fraction of labor allocated to irrigated production. The Senegal River Valley population (i.e. the Fleuve Region) is increased by population growth. The rural population growth rate from 1970 for SR is assumed to be approximately 1.6 percent per year with a 1971 population of 307,887 people.[1] If,

$SPOP_t$ = SR rural population (people)

$SPIF_t$ = SR fraction of labor allocating to irrigated production (dimensionless)

SG_t = SR rural population growth (people per year)

SGR = SR rural population growth rate (dimensionless)

then,

$SIPOP_t = (SPOP_t)(SPIF_t)$

$SNPOP_t = (SPOP_t)(1-SPIF_t)$

$SPOP_t = SPOP_{t-1} + SG_t$

$SG_t = (SPOP_{t-1})(SGR)$

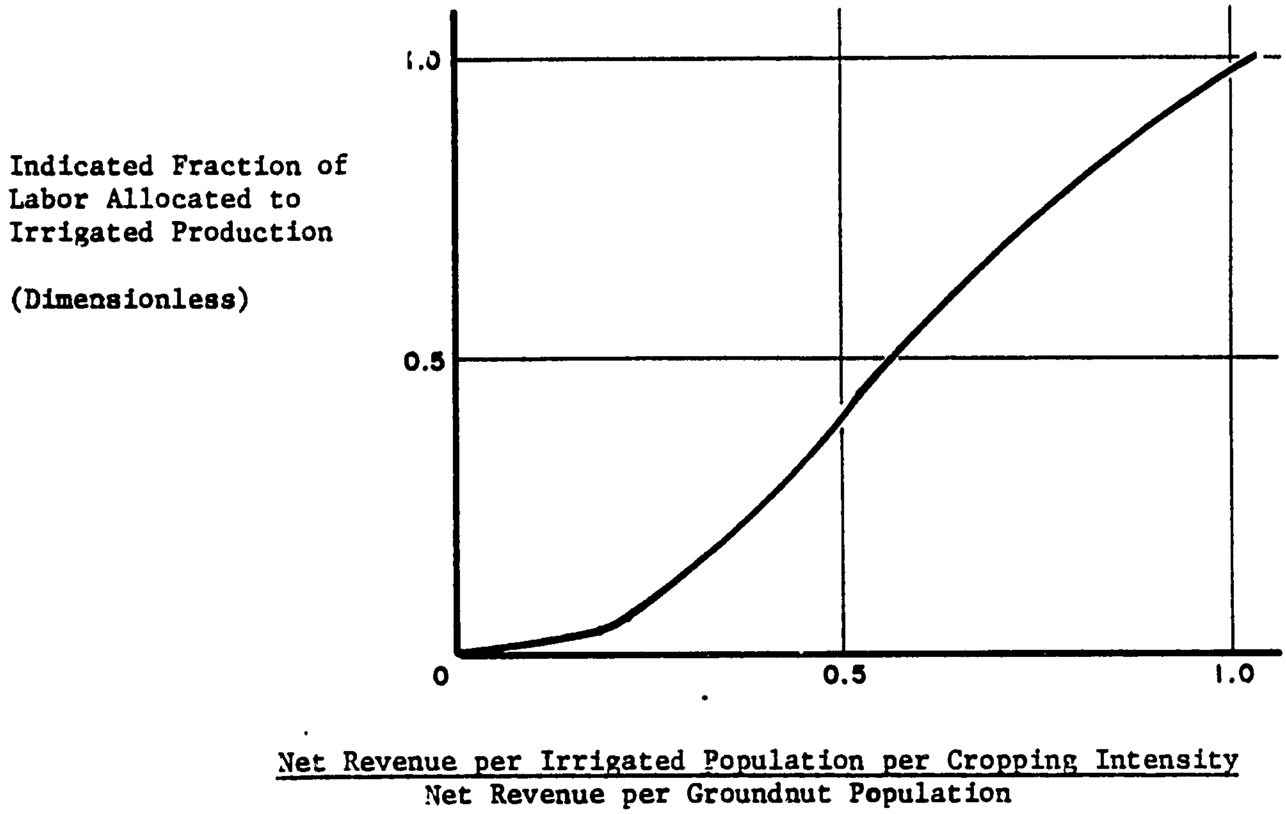
$SGR = .016.$

The fraction of labor allocated to irrigated production (SPIF) is determined by an exponentially weighted average of the indicated fraction of labor allocated to irrigated production. This reflects the slowness of farmers to change from their traditional practices. The indicated fraction of labor allocated to irrigated production (SIF) is determined by the ratio of net revenue per irrigated population per cropping intensity to net revenue per Groundnut Basin population. The relationship assumes that the majority of farmers will choose not to farm irrigated land due to the extra work involved with more than one crop unless they are financially compensated.[2] In the current model it is assumed, for example, that double cropping will require twice the compensation needed for a single crop. Irrigated crop hectare is also constrained by irrigated land availability. The relationship is shown in figure A11.

1/ Societe Africaine, op. cit., pp. 22-23.
2/ Matam, op. cit., p. 19, 59.

FIGURE A11

THE RELATIONSHIP BETWEEN THE INDICATED FRACTION OF LABOR ALLOCATED TO IRRIGATED PRODUCTION AND THE RATIO OF NET REVENUE PER IRRIGATED POPULATION PER CROPPING INTENSITY AND THE NET REVENUE PER GROUNDNUT BASIN POPULATION



Net revenue per irrigated population and per non-irrigated population is determined by the amount of crop yield, the cereal price to farmers, the cost per hectare, associated population. It is assumed that irrigated cereals will be primarily rice and that non-irrigated cereals will be primarily millet. Prices for these cereals are exogenously determined in the model and are given in Table A2. Irrigated cereal costs per hectare are assumed to be CFAF 26,000 per hectare. Irrigated costs are assumed to be composed of production costs (e.g. fertilizer, pesticides, etc.) and maintenance and operation costs for the irrigation facilities. In 1974, production costs were approximately 57 percent of such costs.1/ Non-irrigated cereal costs are assumed to be zero. If,

$SIRP_t$ = SR net revenue per irrigated population (CFAF per person)

$SNRP_t$ = SR net revenue per non-irrigated population (CFAF per person)

$SICPF_t$ = SR irrigated cereal price to farmers (CFAF per metric ton)

$SNCPF_t$ = SR non-irrigated cereal price to farmers (CFAF per metric ton)

$SICH_t$ = SR irrigated cereal costs per hectare (CFAF per hectare)

1/ Official Statistics (1.33)

then,

$$SIRP_t = (SICI_t)((SICY_t)(SILI_t)(SICPF_t) - (SILI_t + SICLS_t)(SICH_t)) / SIPOP_t$$

$$SNRP_t = (SNCY_t)(SNLI_t)(SNCPF_t) / SNPOP_t.$$

The irrigated cereal cropping intensity (SICI) and irrigated cereal yield (SICY) are determined by average irrigation investment per hectare. The annual relationship is shown in table A7.

Non-irrigated cereal land for subsistence and for income and subsequent variables is determined in a similar fashion as for irrigated cereal land. However, the land is also determined by the amount of flow in the Senegal River since much of the non-irrigated land is flood-recession land. The river flow multiplier for 1970 through 1974 is based on an index of cereal land planted between those years. After 1974, the index is assumed to have a normal distribution with mean 1, and .05 standard deviation.

The relationships for this sector are shown in figure A12.

GOVERNMENT SECTOR

Groundnut export revenues are determined by the export groundnut price and groundnut production. The export groundnut price (GGPE) is based on values in table A8. If,

$$GOVGR_t = GGPI_t * GGPE_t.$$

Government foreign exchange surplus is equal to the difference between groundnut export revenues and cereal import expenditures. If,

$URCIMV_t$ = cereal import expenditure (CFAF)

then,

$$URCIMV_t = (URIMP_t)(URCIMP_t)$$

$$GOVGRS_t = GOVGR_t - URCIMV_t.$$

TABLE A7

IRRIGATED CROPPING INTENSITY, YIELDS, AND INVESTMENT PER HECTARE

Maximum Crop Yields Kilogram per Hectare	Cropping Intensity Crops per Year	Investment per Hectare Thousand Dollars per Hectare	Description of Irrigation Facility
400[1]	1	none	Traditional (flood recession)
900[2]	1	1,200-1,500	Partial Water Control (controlled flooding of polders)
1,500[2]	1	900-2,100	Partial Water Control (with pumps)
4,000[2]	2[3]	2,000-3,000	Full Water Control
NA[4]	NA	2,000-3,000	Underground Watch

1/ Millet.

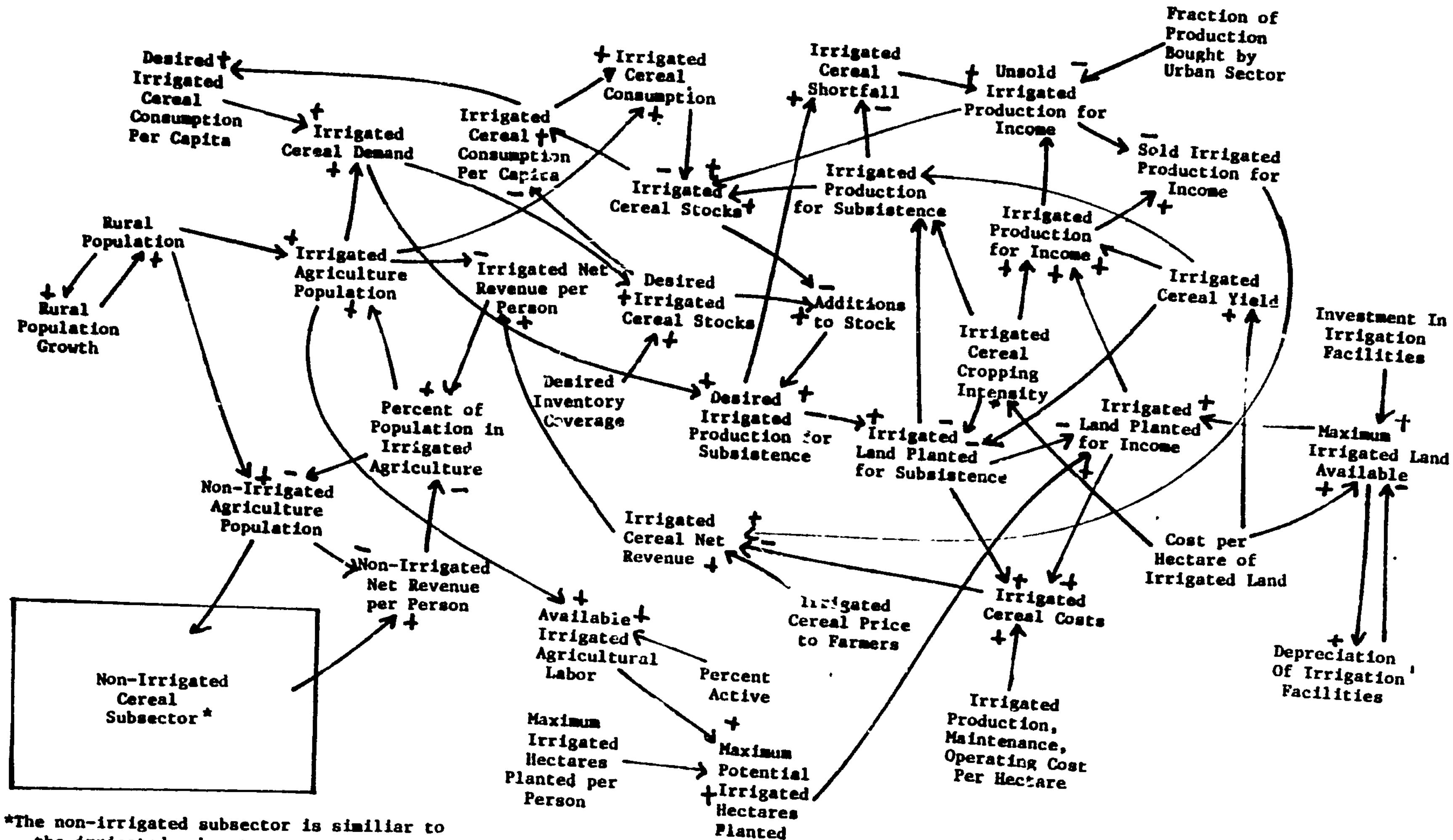
2/ Rice.

3/ Depending on water availability during dry season.

4/ NA denotes not available.
Source: Official Statistics (2.3.3-5).

FIGURE A12

CAUSAL RELATIONSHIPS IN THE SENEGAL RIVER VALLEY SECTOR



*The non-irrigated subsector is similiar to the irrigated subsector.

Table A8

GROUNDNUT PRODUCTION AND EXPORT REVENUES

Crop Year	Production Marketed Thousand Metric Tons	Export Value Million CFAF	Export Unit Value Of Marketed Production CFAF per Kilogram
1969	598	19,100	32
1970	595	22,400	38
1971	400	16,400	41
1972	755	29,300	39
1973	392	20,100	51
1974	440	38,500	88

Source: Societe Africaine, *Le Senegal en Chiffres*, 1976

Subsector	Variable Name	Variable Definition	Page Defined
Urban	$IMAX_t$	maximum urban imports of rice and wheat (metric ton)	A-4
	GOVDM	government price mark-up for domestic cereals (dimensionless)	A-9
	$TOTCPS_t$	domestic production of millet and sorghum for sale	A-7
	$URACP_t$	average urban cereal price (CFAF per metric ton)	A-9
	$URARP_t$	urban rice and wheat price (CFAF per metric ton)	A-9
	$URCIM1_t$	urban demand for rice and wheat (metric ton)	A-1
	$URCIMP_t$	urban imports of rice and wheat (metric ton)	A-4
	$URDCON_t$	urban consumption of millet and sorghum (metric ton)	A-6
	$URDCP_t$	urban domestic millet and sorghum price (CFAF per metric ton)	A-9
	$URDCSM_t$	urban millet and sorghum stock multplier (dimensionless)	A-1
	$URDDAS_t$	desired additions to urban millet and sorghum stocks (metric tons)	A-6
	$URDDP_t$	urban demand for domestic millet and sorghum (metric tons)	A-1
	$URDDSK_t$	desired urban millet and sorghum stock (metric ton)	A-6
	$URDEM_t$	total urban cereal demand (metric ton)	A-1
	$URDIAS_t$	desired additions to urban rice and wheat stocks (metric ton)	A-6
	$URDISK_t$	desired urban rice and wheat stock (metric ton)	A-6
	$URDPC_t$	urban cereal demand per capita (metric tons per person)	A-8
	$URDRD_t$	urban demand for domestic rice and wheat (metric ton)	A-3
	$URDSK_t$	domestic cereal stocks for urban consumption (metric ton)	A-4
	URG_t	urban population growth (people per year)	A-8

INDEX OF VARIABLE DEFINITIONS (cont'd)

Subsector	Variable Name	Variable Definition	Page Defined
	URGR	urban population growth rate (dimensionless)	A-8
	$URICON_t$	urban consumption of rice and wheat (metric ton)	A-6
	$URICSM_t$	urban rice and wheat stock multiplier (dimensionless)	A-6
	URIELA	income elasticity of cereal demand	A-8
	$URIF_t$	fraction of urban cereal demand supplied by rice and wheat (dimensionless)	A-1
	$URIRD_t$	urban demand for imported rice and wheat (metric ton)	A-3
	$URISK_t$	rice and wheat stocks for urban consumption (metric ton)	A-6
	URPELA	price elasticity of demand (dimensionless)	A-8
	$URPOP_t$	urban population (people)	A-8
	URRF	fraction of urban rice and wheat demand supplied by imports (dimensionless)	A-3
	$URTM_t$	fraction of domestic rice and wheat production bought by the urban sector (dimensionless)	A-7
	$URTMR_t$	fraction of domestic rice and wheat production bought by the urban sector (dimensionless)	A-7
Groundnut Basin	$GARNA_t$	GB(Groundnut Basin) inorganic fertlizer application not removed by crops (kilograms)	A-24
	$GASSC_t$	GB cereal consumption (metric ton)	A-20
	$GAVNF_t$	GB natural soil fertility (kilograms of minerals)	A-24
	$GAVNFM_t$	GB natural soil fertility multiplier (dimensionless)	A-24
	$GAVRVI_t$	GB indicated total agricultural investment (CFAF)	A-19
	$GCAPD_t$	GB agricultural capital depreciation (CFAF)	A-18
	$GCAPH_t$	GB agricultural capital stock per person (CFAF)	A-18

bsector	Variable Name	Variable Defination	Page Defined
	$GCAPHH_t$	GB capital stock per hectare (CFAF per hectare)	A-26
	$GCAPI_t$	GB agricultural capital investment	A-18
	$GCAPSK_t$	GB agricultural capital stock (CFAF)	A-18
	GCC	GB groundnut on-farm consumption (dimensionless)	A-15
	$GCFMM_t$	GB multiplier for cereal inorganic fertilizer use (dimensionless)	A-25
	$GCFP_t$	fraction of income land planted to cereals (dimensionless)	A-12
	$GCIYM_t$	GB cereal yield multiplier due to agricultural investment (dimensionless)	A-26
	$GCIYMP_t$	GB cereal yield multiplier from capital investment (dimensionless)	A-26
	$GCIYMR_t$	GB cereal yield multiplier from fertilizer investment (dimensionless)	A-26
	$GCIYM_t$	GB cereal yield multiplier due to agricultural investment (dimensionless)	A-26
	$GCLI_t$	GB cereal land planted for income (hectare)	A-12
	$GCLS_t$	GB cereal land planted for subsistence (hectare)	A-19
	GCNL	GB annual mineral withdrawal by cereal crop (kilogram per hectare)	A-25
	$GCOV_t$	GB inventory coverage (year)	A-21
	$GCPI_t$	GB cereal production for income (metric ton)	A-12
	$GCPIN_t$	GB unsold cereal production for income (metric ton)	A-21
	$GCPIS_t$	Groundnut Basin millet and sorghum production sold for income (metric ton)	A-21
	$GCPS_t$	GB cereal production for subsistence (metric ton)	A-21

INDEX OF VARIABLE DEFINITIONS (cont'd)

Subsector	Variable Name	Variable Definition	Page Defined
	GCR_t	GB farmer's revenues from cereal sales (CFAF)	A-19
	$GCRH_t$	GB cereal revenue per hectare (CFAF per hectare)	A-14
	GCRIF	GB fraction of total investment allocated to current inputs	A-18
	$GCSK_t$	GB farmers cereal stocks (metric ton)	A-20
	GCY_t	GB cereal yield (metric ton per hectare)	A-22
	$GDASK_t$	GB desired addition to cereal stocks (metric ton)	A-20
	$GDCPS_t$	GB desired cereal production for subsistence (metric ton)	A-19
	$GDCSK_t$	GB desired cereal stock (metric ton)	A-20
	$GDSSC_t$	GB desired subsistence cereal consumption (metric ton)	A-20
	$GFERT_t$	GB fertilizer applied (CFAF)	A-24
	GFPCU	GB fertilizer percent of current investment (dimensionless)	A-24
	GG_t	GB rural population growth (people per year)	A-19
	GGFIH	GB fertilizer investment per groundnut hectare (kilogram per hectare)	A-26
	$GGFMM_t$	GB multiplier for groundnut inorganic fertilizer use (dimensionless)	A-25
	$GGIYM_t$	GB groundnut yield multiplier due to agricultural investment (dimensionless)	A-26
	$GGIYMP_t$	GB groundnut yield multiplier from capital investment (dimensionless)	A-26
	$GGIYMR_t$	GB groundnut yield multiplier from fertilizer investment (dimensionless)	A-26
	$GGLI_t$	GB groundnut land planted (hectared)	A-12
	$GGNL_t$	GB annual mineral withdrawal by ground-crop (kilogram per hectare)	A-24
	$GGPI_t$	GB groundnut production (metric ton)	A-15
	GGR_t	GB farmer's revenues from groundmut sales (CFAF)	A-19

INDEX OF VARIABLE DEFINITIONS (cont'd)

INDEX OF VARIABLE DEFINITIONS (cont'd)

Subsector

ANNEX B

COMPUTER PROGRAM FOR MODEL

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*  SENEGAL MODEL VERSION IE
NOTE **************
NOTE MACRO SECTOR *
NOTE **************
NOTE
NOTE  MAX. POTENTIAL LAND PLANTED MACRO
MACRO MPLP(POP,ACT,MLPP)
A MPLP.K=POP.K*ACT*MLPP.K
MEND
NOTE
NOTE  SUBSISTENCE CEREAL LAND PLANTED MACRO
MACRO CLS(ASSC,CSK,PC,PCT,MPLP,POP,ECY,CI,DPC,DCPS,YRS,SLR)
A $CLS1.K=MIN(DCPS.K/(ECY.K*CI*(1-SLR.K)),MPLP.K)
A CLS.K=MIN($CLS1.K,CSK.K*10/ECY.K)
A DCPS.K=MAX($DSSC.K+$DASK.K,0)
A $DSSC.K=POP.K*DPC.K
A $DASK.K=($DCSK.K-CSK.K)/10
A $DCSK.K=$DSSC.K*YRS.K
R ASSC.KL=PC.K*POP.K
A PC.K=TABHL(PCT,$COV.K,0,2,.25)*DPC.K
A $COV.K=CSK.K/$DCSK.K
MEND
NOTE
NOTE INCOME LAND PLANTED MACRO
MACRO LI(LI,MPLP,AL,PLF)
A $LI1.K=MAX(MPLP.K-LI.K,0)
A $LI2.K=MIN($LI1.K,(AL.K*(1-PLF.K))-LI.K)
A LI.K=MAX($LI2.K,0)
MEND
NOTE
NOTE  URBAN IMPORTED/DOMESTIC CEREAL SUPPLY/DEMAND MACRO
MACRO CON(PCT,DEM,IF,CSK,SHT,OSHT,IN,DIN,YRS)
A $CON1.K=TABHL(PCT,CSK/$DCSK,0,2,.25)*$DCON.K
R CON.KL=$CON1.K
A $DCON.K=(DEM.K*IF.K)+OSHT.K
A IN.K=MAX(0,DIN.K)
A DIN.K=$DCON.K+$DASK.K
A $DASK.K=($DCSK.K-CSK.K)/2
A $DCSK.K=(YRS.K)($DCON.K)
A SHT.K=MAX(0,(DEM.K*IF.K)-$CON1.K)
MEND
NOTE **************
NOTE URBAN SECTOR *
NOTE **************
A UYRS.K=TABHL(UYRST,TIME.K,1975,1990,5)
T UYRST=.25/.25/.25/.25
A UPDEM.K=URDPC.K*URPOP.K
L URPOP.K=URPOP.J+(DT)*(URG.JK)
N URPOP=1126200
R URG.KL=URPOP.K*URGR.K
```

```
00510 A URGR.K=TABHL(URGRT,TIME.K,1975,2000,5)
00520 T URGRT=.05/.05/.05/.05/.05/.05
00540 A IMAX.K=(GOVGR.K+(FXOS.K*.8))/URIMP.K
00550 A URCIMV.K=URIMP.K*URCIMZ.K
00560 L URISK.K=URISK.J+(DT)(URCIMP.JK-URICON.JK+CUAID.JK+SICPO.JK)
00570 N URISK=2E5
00580 L URDSK.K=URDSK.J+(DT)(TOTCPS.JK-URDCON.JK)
00590 N URDSK=3E4
00600 R URICON.KL=CON(GPCT,URDEM.K,URIF,URISK.K,URIST,URDSHT,URCIM1
00610 X ,URIDEM,UYRS.K)
00630 R URDCON.KL=CON(GPCT,URDEM.K,1-URIF,URDSK.K,URDST,URISHT,URDIMP
00640 X ,URDDEM,UYRS.K)
00650 A URISHT.K=SMOOTH(URIST.K,.25)
00660 N URIST=0
00670 A URDSHT.K=SMOOTH(URDST.K,.25)
00680 N URDST=0
00690 A URIRD.K=(URCIM1.K*URRF.K)+URDRSH.K
00700 A URCIMZ.K=MIN(IMAX.K,URIRD.K)
00701 R URCIMP.KL=URCIMZ.K
00710 A URIRS.K=MAX(0,(URCIM1.K*URRF.K)-IMAX.K)
00720 A URIRSH.K=SMOOTH(URIRS.K,.25)
00730 N URIRS=0
00740 A URDRD.K=(URCIM1.K*(1-URRF.K))+URIRSH.K
00750 A URDRS.K=MAX(0,(URCIM1.K*(1-URRF.K))-SICPO1.K)
00760 A URDRSH.K=SMOOTH(URDRS.K,.25)
00770 N URDRS=200E3
00780 A URTMR.K=TABHL(URTMRT,URDRD.K/(SICPQP.K+1),0,1,1)
00790 T URTMRT=0/1
00800 A URRF.K=TABHL(URIF2T,URDR.K,.5,2,.25)
00810 A URDR.K=SMOOTH(URDR1.K,.5)
00820 N URDR1=1
00830 A URDR1.K=((SICPF.K*GOVDM.K)/.66)/URIMPC.K
00840 A URAPP.K=((URIMPC.K*URCIMP.JK)+((SICPF.K*GOVDM.K/.66)*SICPO.JK))
00850 X /(URCIMP.JK+SICPO.JK)
00860 A URACP.K=((URDCP.K*TOCPS.K)+(URAPP.K*(URCIMP.JK+SICPO.JK)))/
00861 X (TOCPS.K+URCIMP.JK+SICPO.JK)
00862 A URDIP1.K=URDCP.K/URAPP.K
00870 A URPC.K=(URICON.JK+URDCON.JK)/URPOP.K
00880 A URTM.K=TABHL(URTMT,URDDEM.K/(TOTCPI.K+1),0,1,1)
00890 T URTMT=0/1
00900 A URIF1.K=TABHL(URIF1T,URDIR.K,0,1,.25)
00910 T URIF1T=0/.35/.85/.9/.95
00920 A URIF2.K=TABHL(URIF2T,URDIR.K,.5,2,.25)
00930 T URIF2T=.10/.235/.50/.71/.815/.8675/.90
00940 A URIF.K=(URIF1.K*FRAC.K)+(URIF2.K*(1-FRAC.K))
00950 A FRAC.K=TABHL(FRACT,TIME.K,1975,1990,5)
00960 T FRACT=1/1
00980 A URDIR.K=SMOOTH(URDIR1.K,.5)
00990 N URDIR1=1
01020 A URPACP.K=SMOOTH(URACP.K,URPD)
01030 N URACP=URACPI
01040 C URACPI=40000
01050 A URIC.K=TABHL(URICT,TIME.K,1970,1975,1)*URIGM.K
01060 T URICT=1/1.03/1.06/1.09/1.12/1.79
01070 A URPIC.K=SMOOTH(URIC.K,URPD)
01080 N URIC=URICI
01090 C URICI=1
01100 C URPD=.5
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A URDCP1.K=((GCPF.K)*(GCPIS1.K/TOCPS.K)+
X (INCPF.K)*(INCPM1.K/TOCPS.K))*GOVDM.K
A URDCP.K=MAX(URDCP1.K,MIN(GCPF.K,INCPF.K))
A URDPC.K=URCN.K*EXP(URPELA*LOGN(URPACP.K))*EXP(URIELA*LOGN(URPIC.K))
C URPELA=-.2
C URIELA=.2
A URCN.K=.225/(EXP(URPELA*LOGN(UPACPI))*EXP(URIELA*LOGN(URICI)))
NOTE ************************
NOTE GROUNDNUT BASIN SECTOR *
NOTE ************************
A PYRS.K=TABHL(PYRST,TIME.K,1975,1990,5)
T PYRST=.5/.5/.5/.5
A GCLI.K=CLI(GASSC,GCSK,GPC,GPCT,GMPLP,GPOP,GECY,GCI,GDPC,GDCPS,PYRS.K
X ,GILR.K)
A GLPI.K=LI(GCLS.K,GMPLP,GTAL.K,GPLF.K)
A GSLP.K=GSUR+GWR
C GSUR=.1
C GWR=.1
A GMPLP.K=MPLP(GPOP,PACT,GMLPP)
A GCPIG.K=GCLI.K*GCY.K
A GCPI.K=GCPIG.K*(1-GSLP.K)
A GCPIPS.K=MAX(GCPI.K-MAX(GDCPS.K-GCPS1G.K,0),0)
A GCPFS.K=GCPIPS.K/(GCPI.K+1)
A GCPIS1.K=GCPIPS.K*URTM.K
A GCPIN1.K=GCPI.K-GCPIS1.K
R GCPIN.KL=GCPIN1.K
A GGPIG.K=GGLI.K*GGY.K
A GGPI.K=GGPIG.K*(1-GSLP.K)*(1-GCC)
A GGPIS.K=MIN(GGPI.K,GGPWM.K)
A WMGTM.K=TABHL(WMGTMT,GGPWM.K/(GGPI.K+1),0,1,1)
T WMGTMT=0/1
C GCC=.05
A GCFP.K=TABHL(GCFPT,GPCP.K/GPGP.K,.50,2,.25)*GGEDI.K
T GCFPT=.05/.235/.50 .71 .815 .8675/.9
A GGLI.K=(1-GCFP.K)*GLPI.K
A GCLI.K=GCFP.K*GLPI.K
A GTAL.K=GTALI
C GTALI=2235E3
L GCSK.K=GCSK.J+(DT)(GCPS.JK-GASSC.JK+GCPIN.JK+(CPAID.JK*GCAF.J))
N GCSK=(GPOPI*.175)*PYRS
A GDPC.K=SMOOTH(GPC.K,10)
N GPC=.175
A GPLFI.K=MAX((GTAL.K-GMPLP.K)/GTAL.K,GPLFMN.K)
A GPLFMN.K=TABHL(GPLFNT,TIME.K,1970,2000,5)
T GPLFNT=0/0/0/0/0/0/0
A GPLF.K=SMOOTH(GPLFI.K,3)
N GPLFI=GPLFII
C GPLFII=.15
A GCPS1G.K=GCLS.K*GCY.K
A GCPS1.K=GCPS1G.K*(1-GSLR.K)
R GCPS.KL=GCPS1.K
A GCP.K=GCPS1G.K+GCPIG.K
N GCPS1=300E3
L GPOP.K=GPOP.J+(DT)*(GG.JK)
N GPOP=GPOPI
C GPOPI=1719607
R GG.KL=GPOP.K*GPPGR.K
A GPPGR.K=TABHL(GPPGRT,TIME.K,1975,2000,5)
T GPPGRT=.015/.015/.015/.015/.015/.015
A GMLPPM.K=TABHL(GMLPPT,GCAPH.K,0,9990,3330)
T GMLPPT=.85/.9/1.06/1.15
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01720 A GMLPRM.K=TABHL(GMLPRT,GFH.K,0,2500,500)
01730 T GMLPRT=1/1/1/.9/.9/.9
01740 A GMLPPI.K=2.4*GMLPPM.K*GMLPRM.K
01750 A GMLPP.K=SMOOTH(GMLPPI.K,1)
01760 N GMLPPI=2.4
01770 A GCAPHI.K=GCAPSK.K/GPOP.K
01780 A GCAPH.K=SMOOTH(GCAPHI.K,1)
01790 N GCAPHI=GCAPHN
01800 C GCAPHN=4896
01810 C GCI=1
01820 C GCYN=.625
01830 A GCY.K=GCIYM.K*GCYN*((GAVNFM.K*GCFMM.K)+(1-GCFMM.K))*GWM.K
01840 A GECY.K=SMOOTH(GCY.K,GCYPD)
01850 N GCY=GCYN
01860 C GCYPD=2
01870 C GGYN=.900
01880 A GGY.K=GGIYM.K*GGYN*((GAVNFM.K*GGFMM.K)+(1-GGFMM.K))*GWM.K
01890 L GAVNF.K=GAVNF.J+(DT)(GARNA.JK+GNLNA.JK-GNR.JK)
01900 N GAVNF=GTALI*GFYRS*GGNL
01910 C GFYRS=10
01920 A GAVNFM.K=TABHL(GAVNMT,GAVNF.K/(GTALI*GFYRS*GGNL),0,1,.25)
01930 T GAVNMT=0/.25/.5/.75/1
01940 R GARNA.KL=(GFERT.K*.97*.05)/12
01950 R GNR.KL=GAVNFM.K*((GGFMM.K*GGNL*GGLI.K)+(GCFMM.K*GCNL*(GCLI.K+GCLS.K)))
01960 A GGFMM.K=TABHL(GGFMMT,(GGFIH.K*.95)/(GGNL*12),0,1,1)
01970 T GGFMMT=1/0
01980 A GCFMM.K=TABHL(GCFMMT,(GCFIH.K*.95)/((GCNL+66)*12),0,1,1)
01990 T GCFMMT=1/0
02000 R GNLNA.KL=(GTAL.K*GPLF.K)*(.3)*(5*GGNL)
02010 C GGNL=73
02020 C GCNL=50
02030 A GPP.K=(1-GRAF.K)*((GCPIS1.K*GCPF.K)+(GGPIS.K*GGPF.K)-REP1.K)/GPOP.K
02040 A GGCRI.K=GRAF.K*GCPIS1.K*GCPF.K/DCG.K
02050 A GGCR.K=DELAY1(GGCRI.K,GTUD)
02060 N GGCRI=100E6
02070 A GGGRI.K=GRAF.K*GGPIS.K*GGPF.K/DCG.K
02080 A GGGR.K=DELAY1(GGGRI.K,GTUD)
02090 N GGGRI=2E9
02100 A GTUD.K=TABHL(GTUDT,TIME.K,1970,2000,5)
02110 T GTUDT=1/1/1/1/1/1/1
02120 A GRAF.K=TABHL(GRAFT,TIME.K,1970,1990,5)
02130 T GRAFT=.04/.15/.15/.15/.15
02140 L GCRED.K=GCRED.J+(DT)(LEND.JK+INT.JK-REP.JK)
02150 N GCRED=0
02160 A LEND1.K=TABHL(LEND1T,TIME.K,1975,2000,5)*1E6
02170 T LEND1T=0/0/0/0/0/0
02180 R LEND.KL=LEND1.K
02190 R INT.KL=GCRED.K*(0.0)
02200 A REP1.K=MIN(GCRED.K*.10,GGGR.K+GGCR.K)
02210 R REP.KL=REP1.K
02220 L GCAPSK.K=GCAPSK.J+(DT)(GCAPI.JK-GCAPD.JK)
02230 N GCAPSK=8.42E9
02240 R GCAPD.KL=GCAPSK.K*.04
02250 R GCAPI.KL=(GAVREV.K*(1-GCRIF.K))+((LEND1.K+GIAID.K)*(1/DCG.K)
02260 X *(1-GIFCR.K))
02270 A GFERTI.K=(GAVREV.K*GCRIF.K)+((LEND1.K+GIAID.K)*(1/DCG.K)*GIFCR.K)
02280 A GFERT.K=MIN(GOVGRS.K,GFERTI.K)
02290 A GOVGRS.K=(GOVGR.K+FXOS.K+GOVICA.K)-URCIMV.K
02300 A GAVREV.K=GGCR.K+GGGR.K-REP1.K
02310 A GCRIF.K=TABHL(GCRIFT,TIME.K,1970,2000,5)
02320 T GCRIFT=.35/.35/.35/.35/.35/.35/.35
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02330 A SFH.K=GFEPT.K/(GLPI.K+GCLI.K+1)
02340 A GCFIH.K=((GFEPT.K◆GGCR.K/GAVREV.K)+(LEND1.K+GIAID.K)◆(1/DCS.K)◆GIFCR.K
02350 X ◆GCAIDF.K)/(GCLI.K+GCLI.K+1)
02360 A GGFIH.K=((GFEPT.K◆GGGR.K/GAVREV.K)+(LEND1.K+GIAID.K)◆(1/DCG.K)◆GIFCR.K
02370 X ◆(1-GCAIDF.K))/(GGLI.K+1)
02380 A GCIYMI.K=GCIYMP.K◆GCIYMP.K◆GCTCM.K
02390 A GCIYM.K=SMOOTH(GCIYMI.K,GDEVD.K)
02400 N GCIYMI=1
02410 A GCIYMP.K=TABHL(GCYMPT,GCFIH.K,0,2500,500)
02420 T GCYMPT=1/1.3/1.6/1.8/1.9/2.1
02430 A GCIYMP.K=TABHL(GCYMPT,GCAPH.K,0,9990,3330)
02440 T GCYMPT=1/1.03/1.05/1.27
02450 A GCTCM.K=TABHL(GCTCMT,TIME.K,1970,2000,5)
02460 T GCTCMT=1/1/1/1/1/1/1
02470 A GGIYMI.K=GGIYMP.K◆GGIYMP.K◆GGTCM.K
02480 A GGIYM.K=SMOOTH(GGIYMI.K,GDEVD.K)
02490 N GGIYMI=1
02500 A GDEVD.K=TABHL(GDEVDT,TIME.K,1970,2000,5)
02510 T GDEVDT=7/7/7/7/7/7/7
02520 A GGIYMP.K=TABHL(GGYMRT,GGFIH.K,0,2500,500)
02530 T GGYMPT=1/1.08/1.15/1.15/1.15/1.15
02540 A GGIYMP.K=TABHL(GGYMPT,GCAPH.K,0,9990,3330)
02550 T GGYMPT=1/1.03/1.06/1.15
02560 A GGTCM.K=TABHL(GGTCMT,TIME.K,1970,2000,5)
02570 T GGTCMT=1/1/1/1/1/1/1
02580 A GPCR.K=SMOOTH(GCRH.K,GPD)
02590 N GCRH=GCYN◆17E3
02600 A GPGR.K=SMOOTH(GGRH.K,GPD)
02610 N GGRH=GGYN◆18.4E3
02620 C GPD=4
02630 A GCRH.K=GCY.K◆GCPF.K◆URTM.K
02640 A GGRH.K=GGY.K◆GGPF.K◆WMGTM.K
02650 NOTE ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
02660 NOTE GOVERNMENT SECTOR ◆
02670 NOTE ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
02680 A GCPF.K=TABHL(GCPFT,TIME.K,1970,1975,1)◆1000◆DCPGM.K
02690 T GCPFT=17/17/17/18/23/32
02700 A GGPF.K=TABHL(GGPFT,TIME.K,1970,1975,1)◆1000◆DGPGM.K
02710 T GGPFT=18.4/21.17/23.28/22.87/29.76/41.50
02720 A GGEDI.K=TABHL(GGEDIT,TIME.K,1970,2000,5)
02730 T GGEDIT=1/1/1/1/1/1/1
02740 A SNCPF.K=TABHL(SNCPT,TIME.K,1970,1975,1)◆1000◆DCPGM.K
02750 T SNCPT=18/18/18/18/23/32
02760 A SICPF.K=TABHL(SICPT,TIME.K,1970,1975,1)◆1000◆DICPGM.K
02770 T SICPT=21/21/21/21/35/41.5
02780 A URIMP.K=TABHL(URIMPT,TIME.K,1970,1976,1)◆1000◆ICCPGM.K
02790 T URIMPT=90/90/90/90/90/90/90
02800 A URIMPC.K=URIMP.K◆GOVIS.K
02810 A GOVISA.K=MAX(0,URIMP.K◆(GOVIS.K-1))
02820 A GOVIS.K=TABHL(GOVIST,TIME.K,1970,1976,1)◆ICPGM.K
02830 T GOVIST=.55/.55/.55/.55/.55/1/1.6
02840 A GOVDM.K=TABHL(GOVDMT,TIME.K,1970,1973,1)
02850 T GOVDMT=1.25/1.25/1.25/1.25
02860 A GOVGR1.K=GGPIS.K◆(GGPF.K◆1.25)
02870 A GOVGR.K=SMOOTH(GOVGR1.K,1)
02880 N GOVGR1=21E6
02890 A FXOS.K=TABHL(FXOST,TIME.K,1970,1976,1)◆1E9
02900 T FXOST=0/10/15/25/15/12/0
02910 A DCG.K=TABHL(DCGT,TIME.K,1970,1976,1)◆DCGM.K
02920 T DCGT=1/1/1/1/1/1.33/1.67
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02930 A DCPGM1.K=EXP(B.K◆LOGN(DCPGMI))
02940 C DCPGMI=1.0
02950 A DCPGM.K=MIN(DCPGMX,DCPGM1.K)
02951 A DICPGM.K=EXP(B.K◆LOGN(DICPGI))
02952 C DICPGI=1.0
02960 C DCPGMX=2.6
02970 A DGPGM.K=TABHL(DGPGMT,TIME.K,1970,2000,5)
02980 T DGPGMT=1/1/1/1 1/1 1
02990 A DCGM.K=EXP(B2.K◆LOGN(DCGMI))
03000 C DCGMI=1
03010 A ICPGM.K=EXP(B2.K◆LOGN(ICPGMI))
03020 A ICCPGM.K=EXP(B2.K◆LOGN(ICCPGI))
03030 C ICCPGI=1
03040 C ICPGMI=1.0
03050 A URIGM.K=EXP(B.K◆LOGN(1.0))
03060 A SRWMM.K=EXP(B.K◆LOGN(1))
03070 A B.K=RAMP(1,1975)
03080 A B2.K=RAMP(1,1976)
03090 NOTE ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
03100 NOTE SENEGAL RIVER VALLEY SECTOR ◆
03110 NOTE ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
03120 A SNSLP.K=.2
03130 A SISLR.K=.47
03140 A SICLS.K=CLS(SIASSC,SIC[illegible]IMPLP,SIPOP,SICY,SICI,SIDPC,SIDCPS
03150 X ,RYRS.K,SISLR.K)
03160 A SNCLS1.K=CLS(SNASSC,SNC[illegible]MPLP,SNPOP,SENCY,SNCI,SNDPC
03170 X ,SNDCPS,RYRS.K,SNSLP.K)
03180 A SNCLS.K=SNCLS1.K◆CLIP(GFLM.K,1,SNCLS1.K,70E3)
03190 A SILI.K=LI(SICLS.K,SIMPLP,SILA.K,0)
03200 A SNLI1.K=LI(SNCLS1.K,SNMPLP,1E9,0)
03210 A SNLI.K=MIN(SNLI1.K◆GFLM.K,((SNCSK.K◆10/SENCY.K)-SNCLS1.K))
03220 A SIPOP.K=SPOP.K◆SPIF.K
03230 A SNPOP.K=SPOP.K◆(1-SPIF.K)
03240 A SIMPLP.K=MPLP(SIPOP.K,PACT,SILP)
03250 A SNMPLP.K=MPLP(SNPOP.K,PACT,SNLP)
03260 A SICPSG.K=SICLS.K◆SICY.K◆SICI.K
03270 A SICPS1.K=SICPSG.K◆(1-SISLR.K)
03280 R SICPS.KL=SICPS1.K
03290 A SICP.K=SICPSG.K+SICPIG.K
03300 A SICPIG.K=SILI.K◆SICY.K◆SICI.K
03310 A SICPI.K=SICPIG.K◆(1-SNSLR.K)
03320 A SICPOP.K=MAX(SICPI.K-MAX(SIDCPS.K-SICPSG.K,0),0)
03330 A SICPO1.K=SICPOP.K◆URTMR.K
03331 R SICPO.KL=SICPO1.K
03340 A SICIN1.K=SICPI.K-SICPO1.K
03350 R SICPIN.KL=SICIN1.K
03360 L SICSK.K=SICSK.J+(DT)(SICPS.JK-SIASSC.JK+SICPIN.JK)
03370 N SICSK=(SPOPI◆SIFI◆.175)◆RYPS
03380 A SIDPC.K=SMOOTH(SIPC.K,10)
03390 N SIPC=.175
03400 A SNCPSG.K=SNCLS.K◆SNCY.K
03410 A SNCPS1.K=SNCPSG.K◆(1-SNSLR.K)
03420 R SNCPS.KL=SNCPS1.K
03430 A SNCP.K=SNCPSG.K+SNCPIG.K
03440 A SNCPIG.K=SNLI.K◆SNCY.K
03450 A SNCPI.K=SNCPIG.K◆(1-SNSLR.K)
03460 A SNCPOP.K=MAX(SNCPI.K-MAX(SNDCPS.K-SNCPSG.K,0),0)
03470 A SNCPO1.K=SNCPOP.K◆URTM.K
03480 A SNCIN1.K=SNCPI.K-SNCPO1.K
03490 R SNCPIN.KL=SNCIN1.K
03500 L SNCSK.K=SNCSK.J+(DT)(SNCPS.JK-SNASSC.JK+SNCPIN.JK+(CRAID.JK
03510 X ◆(1-GCAF.J)))
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03520 N SNCSK=(SPOPI*(1-SIFI)*.175)*PYPS
03530 A SNDPC.K=SMOOTH(SNPC.K,10)
03540 N SNPC=.175
03550 A SICI.K=TABHL(SICIT,SLIC.K,270E3,670E3,200E3)
03560 T SICIT=1/1/2
03570 A SIF1.K=TABHL(SIF1T,(SIPP.K/SICIM.K)/(GPP.K+1),0,1,.2)
03580 A SICIM.K=TABHL(SICIMT,SICI.K,1,2,1)
03590 T SICIMT=1/2
03600 T SIF1T=0/.1/.25/.5/.75/1
03610 A SIF.K=MIN(SIF1.K,(SILA.K/SILP.K)/(SPOP.K*PACT))
03620 A SPIF.K=SMOOTH(SIF.K,SISPD)
03630 N SIF=SIFI
03640 A SIFI.K=(SICII/433E3)/(SPOPI*PACT*SILP.K)
03650 C SISPD=.75
03660 A SPP.K=((SIRP.K*SIPOP.K)+(SNPP.K*SNPOP.K))/(SIPOP.K+SNPOP.K)
03670 A SIPP.K=(SICI.K*((SICPO1.K*SICPF.K)-((SILI.K+SICLS.K)*(SICH.K+SICDPH.K
03680 X ))))/SIPOP.K
03700 A SICH.K=TABHL(SICHT,TIME.K,1970,1975,5)*1000*DCGM.K
03710 T SICHT=25/26
03720 A SNRP.K=MAX((SNCPO1.K*SNCPF.K ...
03730 A SILP.K=TABHL(SILPT,TIME.K,1975,1...
03740 T SILPT=.65/.66
03750 A SNLP.K=TABHL(SNLPT,TIME.K,1975,1985,10)
03760 T SNLPT=1.6/1.6
03770 A SILA.K=SIC.K/SLIC.K
03780 A SILAFU.K=(SICLS.K+SILI.K)/SILA.K
03790 A SLIC.K=TABHL(SLICT,TIME.K,1975,1990,5)*1000
03800 T SLICT=433/433/433/433
03810 L SIC.K=SIC.J+(DT)*(SICG.JK-(SICDR.JK*SICSW.K))
03820 N SIC=SICII
03830 C SICII=3930E6
03840 A SICG1.K=TABHL(SICG1T,TIME.K,1975,2000,5)*1E6
03850 T SICG1T=250/250/250/250/250/250
03860 R SICG.KL=SICG1.K
03870 R SICDR.KL=SIC.K/30
03880 A SICDRH.K=(1-SICSW.K)*(SIC.K/30)/(SICLS.K+SILI.K)
03881 A SICSW.K=CLIP(0,1,TIME.K,SICSWD)
03890 C SICSWD=2010
03900 L SPOP.K=SPOP.J+(DT)*(SG.JK)
03910 N SPOP=SPOPI
03920 C SPOPI=303380
03930 R SG.KL=SPOP.K*SGR.K
03940 A SGR.K=TABHL(SGRT,TIME.K,1975,2000,5)
03950 T SGRT=.015/.016/.016/.016/.016/.016
03960 A SICYI.K=TABHL(SICYT,SLIC.K,270E3,670E3,200E3)
03970 T SICYT=1.0/1.5/3.5
03980 A SICY.K=SMOOTH(SICYI.K,SDEVD.K)
03990 A SDEVD.K=TABHL(SDEVDT,TIME.K,1970,2000,5)
04000 T SDEVDT=7/7/7/7/7/7/7
04010 A SENCY.K=SMOOTH(SNCY.K,SCYPD)
04020 N SNCY=SNCYN
04030 C SCYPD=10
04040 C SNCI=1
04050 A SNCY.K=SNCYN*GWM.K
04060 C SNCYN=.500
```

```
04070 NOTE **************
04080 NOTE MISC. SECTOR *
04090 NOTE **************
04100 A TOTPC.K=((TOTRPC.K)*(GPOP.K+IPOP.K)+(URPC.K)*(URPOP.K))/POP.K
04110 A TOTRPC.K=((GPOP.K*GPC.K)+(SIPOP.K*SIPC.K)+(SNPOP.K*SNPC.K))/
04120 X (GPOP.K+IPOP.K)
04130 A POP.K=URPOP.K+GPOP.K+SPOP.K
04140 A TOTPCP.K=GCP.K+SNCP.K
04150 A GFLM.K=CLIP(GWM3.K,GFLM1.K,TIME.K,1976)*(1-STEP(.5,DF1)
04160 X +STEP(.5,D2))
04170 A GFLM1.K=TABHL(GFLM1T,TIME.K,1970,1975,1)
04180 T GFLM1T=1 .9/1 .5/.6/.95
04190 A GWM3.K=MIN(GWM2.K,1)
04200 A GWM.K=CLIP(GWM2.K,GWM1.K,TIME.K,1976)*(1-STEP(.5,DR1)
04210 X +STEP(.5,D2))
04220 C DR1=2500
04230 C DF1=2500
04240 C D2=2500
04250 A GWM1.K=TABHL(GWM1T,TIME.K,1970,1975,1)
04260 T GWM1T=.74 .5/.9 .47 .53 .9
04270 A GWM2.K=NORMRN(1,.05)
04280 T GPCT=0 .25/.5/.75 1/1.05 1.05 1.05 1. 1
04290 A TOCPS.K=MAX(GCPIS1.K+SNCPO1.K,1)
04300 R TOTCPS.KL=TOCPS.K
04310 A TOTCPI.K=MAX(GCPIPS.K+SNCPOP.K,0)
04320 C PACT=.45
04330 R CRAID.KL=TABHL(CRAIDT,TIME.K,1970,1990,1)*1000
04340 T CRAIDT=9.9 31.7/11.4/88/83/5/2.4/0/0/0/0/0/0 0/0/0/0/0/0/0/0
04350 A GCAF.K=.95
04360 R CUAID.KL=TABHL(CUAIDT,TIME.K,1970,1990,1)*1000
04370 T CUAIDT=12.6 0/0 46.8/7.6/6.2/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0
04380 A SIAIDI.K=TABHL(SIAIDT,TIME.K,1970,2000,5)*1E6
04390 T SIAIDT=0/0/0/0 0/0 0
04400 A SIAID.K=DELAY1(SIAIDI.K,GTUD.K)
04410 A SIFCR.K=TABHL(SIFCRT,TIME.K,1970,2000,5)
04420 T SIFCRT=.9/.9/.9/.9/.9/.9/.9
04430 A SCAIDF.K=TABHL(GCADFT,TIME.K,1970,2000,5)
04440 T GCADFT=1/1/1/1/1/1/1
04450 A GGPWM.K=(GGPWMX)*GPWMM.K
04460 C GGPWMX=5000E3
04470 NOTE **********************
04480 NOTE MODEL CONTROL SECTOR *
04490 NOTE **********************
04500 C DT=.10
04510 C LENGTH=1990
04520 N TIME=1970
04530 C PLTPER=0
04540 C PRTPER=0
04550 PLOT TOTRPC,URPC(0,.3)/CPP,GPP(0,50E3)
04560 PLOT URCIMP,ICP,TOTRCP,GGPIS,TOTCPS(0,1500E3)
04570 PRINT GCLS,GCLI,GGLI,GECY,GCY,GPLF,URTM,GCPFS
04580 RUN REFERENCE
READY
```

ANNEX C

THE PROGRAMMING LANGUAGE FOR THE MODEL

The relationships discussed in annex A, once mathematically represented, were simulated on the AID computer with the programming language DYNAMO.[1/] DYNAMO is primarily used to compile and execute simulation models where the behavior of the system depends more on aggregate flows between variables than upon discrete events. These types of models are called continuous simulation models. Typically there are many closed feedback relationships in such systems. DYNAMO orders the relationships in the form of recursive difference equations, simulates the system behavior on the computer, and prints the simulated values of the model variables.[2/]

The major advantages of DYNAMO are: (1) it is an efficient way to simulate large continuous simulation models with many feedback relationships; (2) it allows the inclusion of behavioral relationships, through specified equations or numerical approximations; (3) it allows the inclusion of physical or information delays between variables through specified equations or numerical approximations; (4) it provides easy to read graphical and tabular output; and (5) it provides easy to use rerun capability for sensitivity and policy tests.

DYNAMO, though a convenient tool for simulation, is not an all-purpose language. It would not be possible, for instance, to program a linear programming model in DYNAMO.

1/ Pugh, Alexander, Dynamo User's Manual, MIT Press, Cambridge, 1976.

2/ A difference equation is an equation whose variables can take different values depending on time. A recursive set of equations means that it is possible, by starting with the initial value of any endogenous variable and the values of all exogenous variables, to proceed iteratively to calculate the values of all other endogenous variables.

ANNEX D

AN EXPLANATION OF A GRAPHICAL TECHNIQUE FOR PRESENTING MODELS

A technique, called a casual influence diagram, presents variables that have been identified in a system, their interrelationships, and the effects of changes in value or intensity. The technique is illustrated with a simple model of dust generation in the Sahel.[1]

The author's hypothesis is that plant cover is determined by the amount of annual rainfall and the northern reach of the monsoon. As the amount of rainfall increases or as the monsoon [illegible] further north, the plant cover increases.

The amount of dust generation is determined by the amount of plant cover and the wind. As plant cover increases, dust generation is decreased. As wind increases, dust generation increases.

The amount of rainfall and the northern reach of the monsoon are determined by climatic changes and the amount of dust generation. As more dust is generated, the amount of rainfall decreases and the monsoon does not reach as far north.

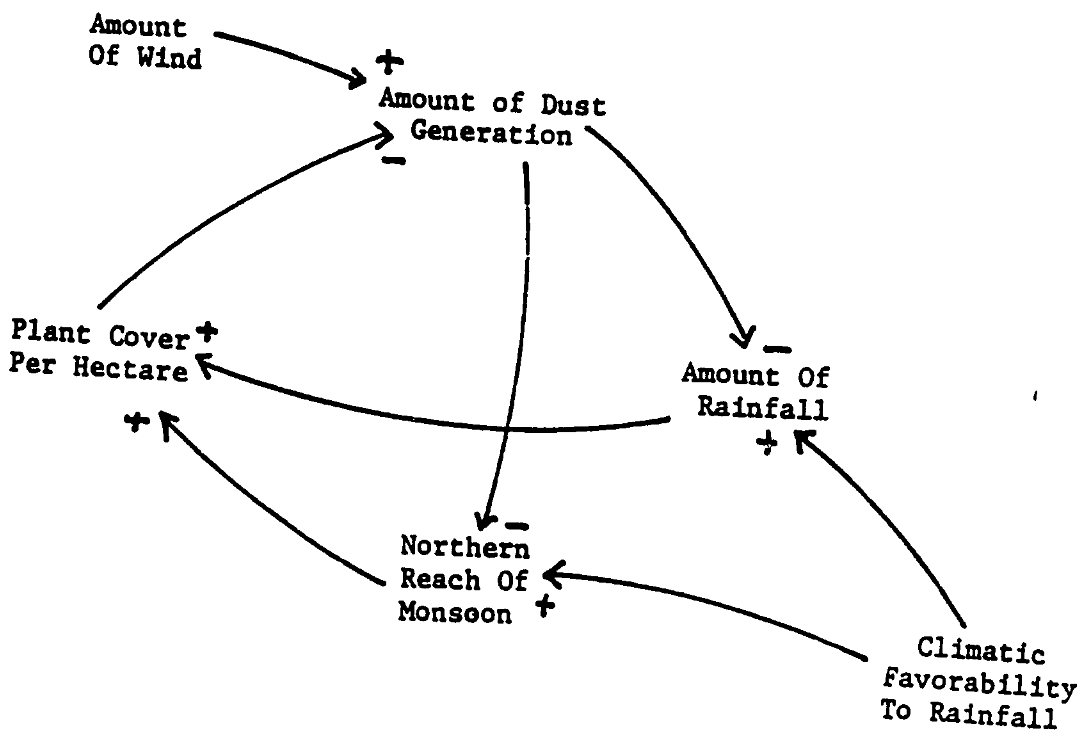
This hypothesized model indicates that droughts tend to "feed on themselves." If a monsoon does not produce much rain and does not reach as far north as normal, plant cover decreases and more dust is generated. The extra dust increases the severity of the drought.

This model is presented in Figure D1. The arrows indicate the direction of effect. The sign at the head of an arrow indicates the change of direction caused by an increase in value or intensity of the variable at the tail of the arrow. A plus sign indicates an increase in value or intensity, a negative sign indicates a decrease in value or intensity. If there is no sign, the direction of effect depends on the values of the other causal factors.

1/ MacLeod, N., "Dust in the Sahel: Cause of Drought?," The Politics of Natural Disaster, ed. Michael Glantz, Praeger Publishers, New York, 1976, p 214-231.

Figure D1

CAUSAL DIAGRAM OF DUST GENERATION IN THE SAHEL 1/



1. Source: MacLeod, N., "Dust in the Sahel: Cause of Drought?", The Politics of Natural Disaster, ed. Michael Glantz, Praeger Publishers, New York, 1976, p 214-231.