AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch #31

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture — AE30-0000-G214

B. SECONDARY
Agricultural development--Nigeria

2. TITLE AND SUBTITLE
System simulation of agricultural development: some Nigerian policy comparisons

3. AUTHOR(S)
(101) Mich.State Univ. Simulation Team

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1973	49p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Mich.State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Am.j.of agr.economics,v.55,no.3)

9. ABSTRACT

10. CONTROL NUMBER
PN-AAB-762

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Comparison
Nigeria
Simulation

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2975 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

PN-AAB-762
CSD-2975 Rev.

SYSTEM SIMULATION OF AGRICULTURAL DEVELOPMENT:

SOME NIGERIAN POLICY COMPARISONS

The Michigan State University Agricultural
Sector Simulation Team

Abstract of article published in the American Journal of Agricultural Economics, Vol. 55, No. 3, August 1973.

The generalized system simulation approach can improve the information input to the decision-making process in general. This paper illustrates its particular application to problems of planning and policy making for agricultural sector development. An overview of a simulation model of the Nigerian economy is given, and the results of a series of 15 Nigerian agricultural development policy simulation experiments are analyzed in detail. The main conclusion drawn from the policy simulations is that, at least for these 15 experiments, a technological transformation of agricultural export crop production is necessary for sustained economic growth. The paper concludes with a discussion of the approach's general applicability.

The simulation team consists of M. H. Abkin, M. L. Hayenga, T. J. Manetsch, T. W. Carroll, D. R. Byerlee, and G. L. Johnson (project director), all of Michigan State University; A. N. Halter of Oregon State University; and K. Y. Chong of the East-West Center, University of Hawaii.

SYSTEM SIMULATION OF AGRICULTURAL DEVELOPMENT:

SOME NIGERIAN POLICY COMPARISONS

The Michigan State University Agricultural
Sector Simulation Team*

Recently, a team of agricultural economists and systems scientists at Michigan State University developed a computer simulation model of the Nigerian economy [6]. Although Nigeria was chosen as the specific focus for the work, the contractual objective of this effort was more generally to further develop and assess the capability of simulation models to be used in agricultural sector planning as an aid in evaluating the likely impacts of adjustments in agricultural structures and policies. In previous papers [3, 4], the basic methodology used by the simulation team has been described and some of the features of the dynamic computer simulation model of Nigeria has been considered. In this paper, while the general structure of the model will be briefly summarized, the main objective will be to illustrate its potential usefulness by simulating the likely consequences of 15 agricultural policy alternatives for Nigeria. These policies are evaluated by comparing their effects on several performance variables--gross domestic product, export levels, value added, nutrition levels, etc.--which development administrators may consider important. While the simulated results reported here must be considered tentative and subject to change as improved estimates of available resources and behavioral relationships are developed, they do illustrate how a model like this can be employed when adapted to similar situations in other countries. For Nigeria in particular, to the extent that the simulation model faithfully represents the actual

*The simulation team consists of M. H. Abkin, M. L. Hayenga, T. J. Manetsch, A. N. Halter, T. W. Carroll, D. R. Byerlee, K. Y. Chong, and G. L. Johnson, project director. The research reported here was done under U. S. Agency for International Development contracts AID/csd-1557 and AID/csd-2975.

behavior of the Nigerian economy, the results may also provide some insight into the comparative adjustments likely to occur under these postulated conditions. The paper concludes with a discussion of the current stage of model development and the model's applicability to agricultural planning and/or policy formulation.

Description of the Model

In specifying the model, the problems of potentially relevant policy-making clientele and their problems determined which sectors and interrelationships needed particular attention within the model and the level of aggregation required. The resulting major sectors and flows incorporated within the simulation model of the Nigerian economy are shown in Figure 1. As can be seen from the diagram, the emphasis is on the agricultural sector. Since agriculture is dominant in the Nigerian economy (contributing 65 percent of the gross domestic product and 66 percent of Nigerian exports in 1962/63) and in most less-developed countries, its role in future growth will be very important.

Many planners in the less-developed countries are interested in evaluating alternative policies (often involving economic incentives or government assistance of various kinds) affecting regional specialization of production and trade. To permit considerations of simple questions related to regional specialization and interregional trade, a two-region (North and South) commodity-oriented model was conceived. However, several ecological zones within each region were also differentiated to permit more detailed consideration of problems encountered within the two regions. Although the

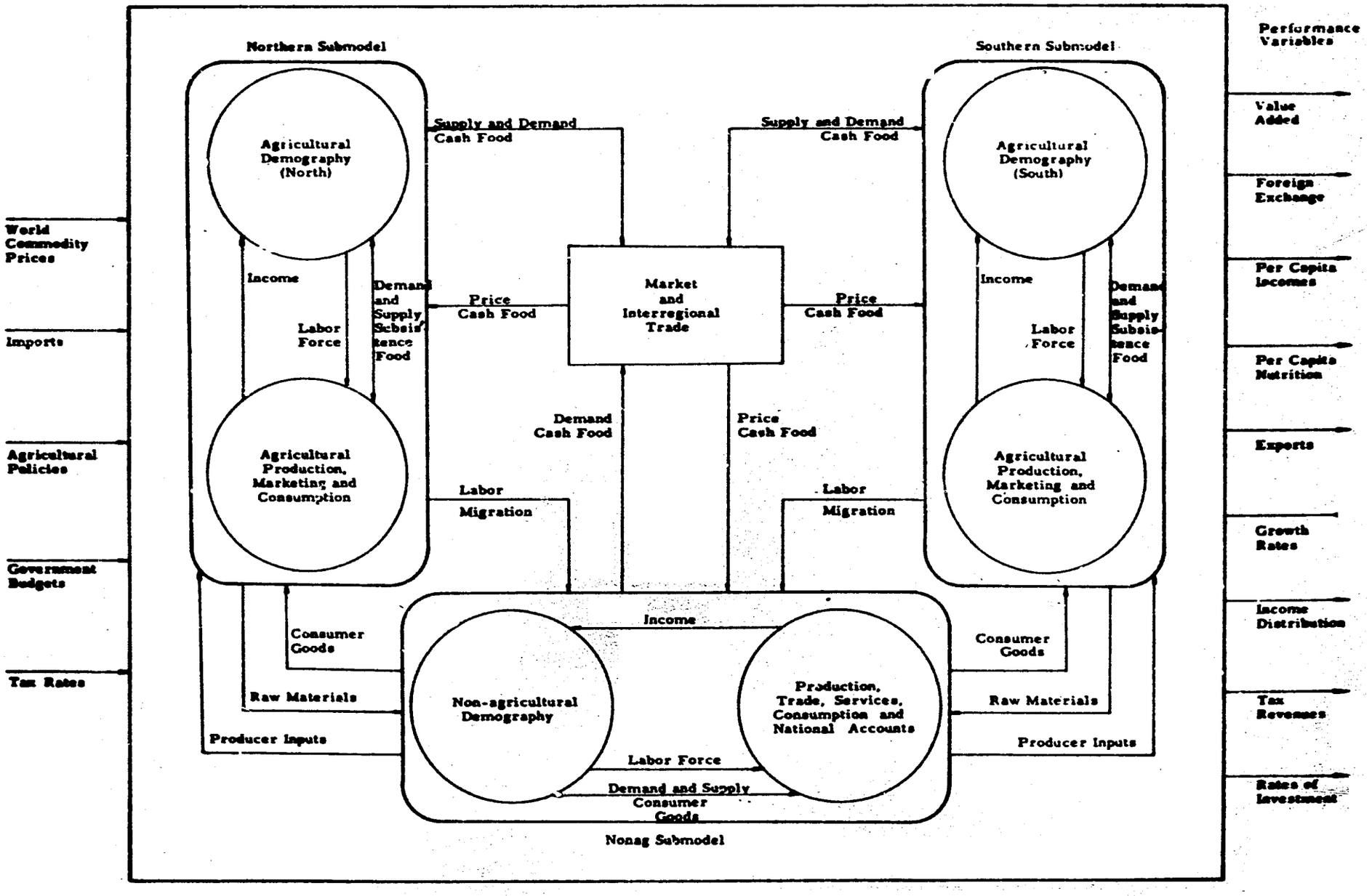


Figure 1. National model of interacting submodels, Nigeria.

model is based on Nigeria, its orientation toward both annual and perennial commodities, as well as the definition of distinct ecological zones and regions, makes its components adaptable to a broad range of countries in accordance with the objectives of the AID contract under which the work was done.

The simulation model of the Nigerian economy is composed of three major submodels: the northern regional agricultural submodel, the southern regional agricultural submodel, and the nonagricultural/national accounts submodel. In addition, there are components which model the national food market and population dynamics.

Agricultural Sector Submodels

The basic component structures of the two agricultural submodels are quite similar, as is evident in Figures 2 and 3. The nature of perennial commodities, however--trees exhibiting demographic characteristics of gestation, growth, maturity and decline--considerably complicates the southern submodel, particularly in the land allocation and modernization component [1, Chapters 2 and 3].

Briefly, the agricultural submodels allocate land to the available commodities (indicated in Figures 2 and 3) based on profitabilities perceived by farmers and subject to input constraints. Commodity yields are determined by the traditional-modern technology mix and by producer prices. From the land allocations and commodity yields, and given technological coefficients (e.g., factor input rates, marketing losses, etc.), the total production of each commodity is determined, as are the subsequent marketing and processing

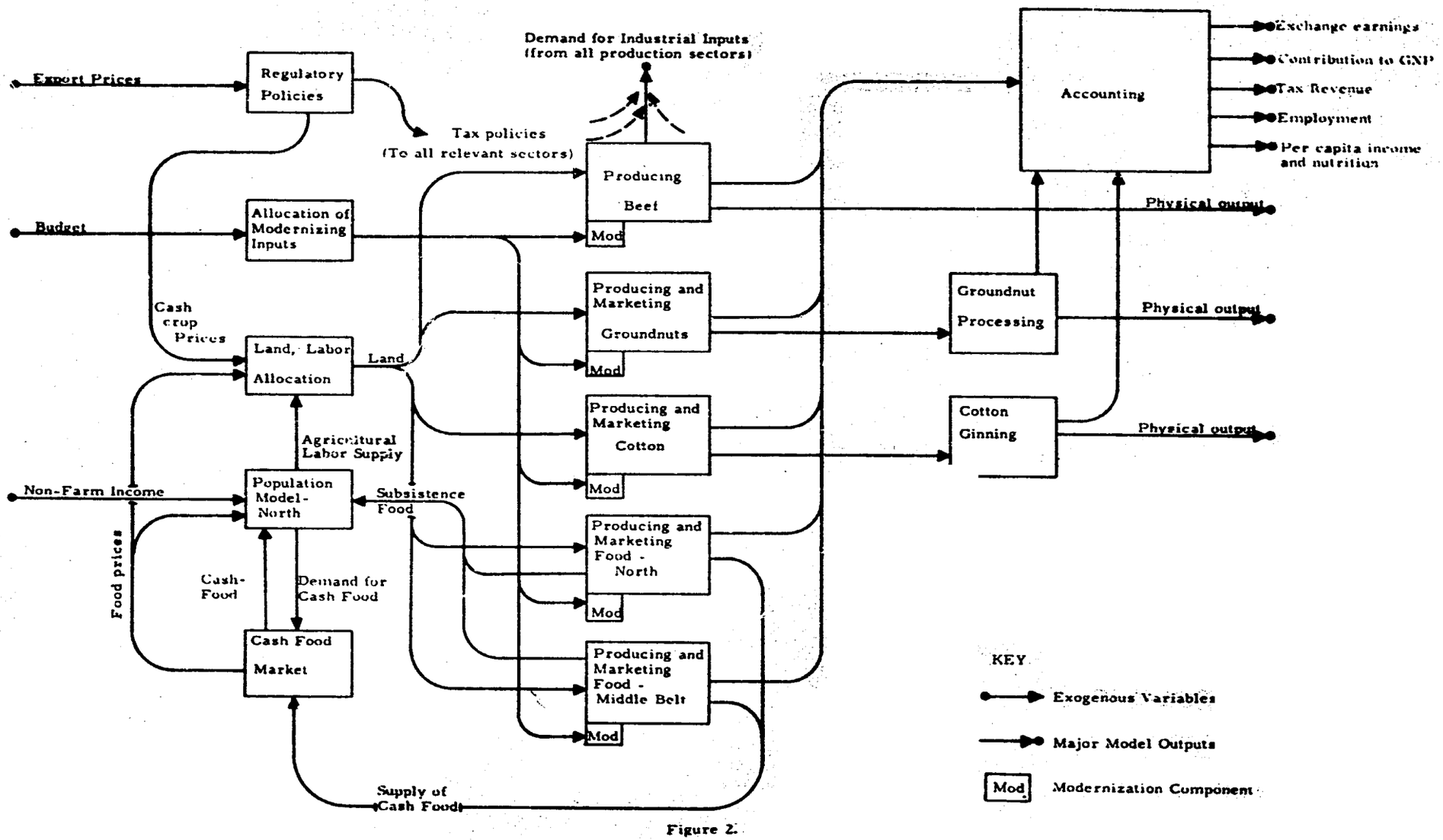


Figure 2.

Major Sectors and Interactions of the Northern Nigerian Agricultural Model

functions. Agricultural processing in the North is modeled with input-output ratios. Because of the significance of palm and rubber processing activities to the agricultural producers in the South, processing in the southern submodel is modeled in considerably greater detail. Finally, economic performance criteria are generated and the agricultural sector budgets are accounted in each region.

An additional component of the northern submodel, cattle production, simulates the meat and milk production process in traditional and modern herd management situations, using inputs of total digestible nutrients (TDN) from the production of forage and grain crops. The main interaction between the cattle and annual crops components in the northern submodel occurs in the land allocation component, where the acreages in the various crops partially determine--through competition with grazing land and the provision of crop residues--the quantities of TDN available in the cattle component.

Policy inputs to the agricultural submodels include stimulating the modernization of production, reducing or increasing marketing board surpluses (i.e., raising or lowering producer prices), and various forms of taxation. The simulation model then projects the likely consequences of alternative policy options.

Nonagricultural Sector Submodel

The nonagricultural submodel (Figure 4) is an aggregated, ten-sector input-output model of the Nigerian economy. Since the primary focus of the national model is on agriculture, the broad, aggregated nonagricultural submodel enables the key interactions between agriculture and nonagriculture--e.g., agriculture's demands for consumer goods and capital inputs, nonagriculture's demands for raw materials and food, rural-urban migration--

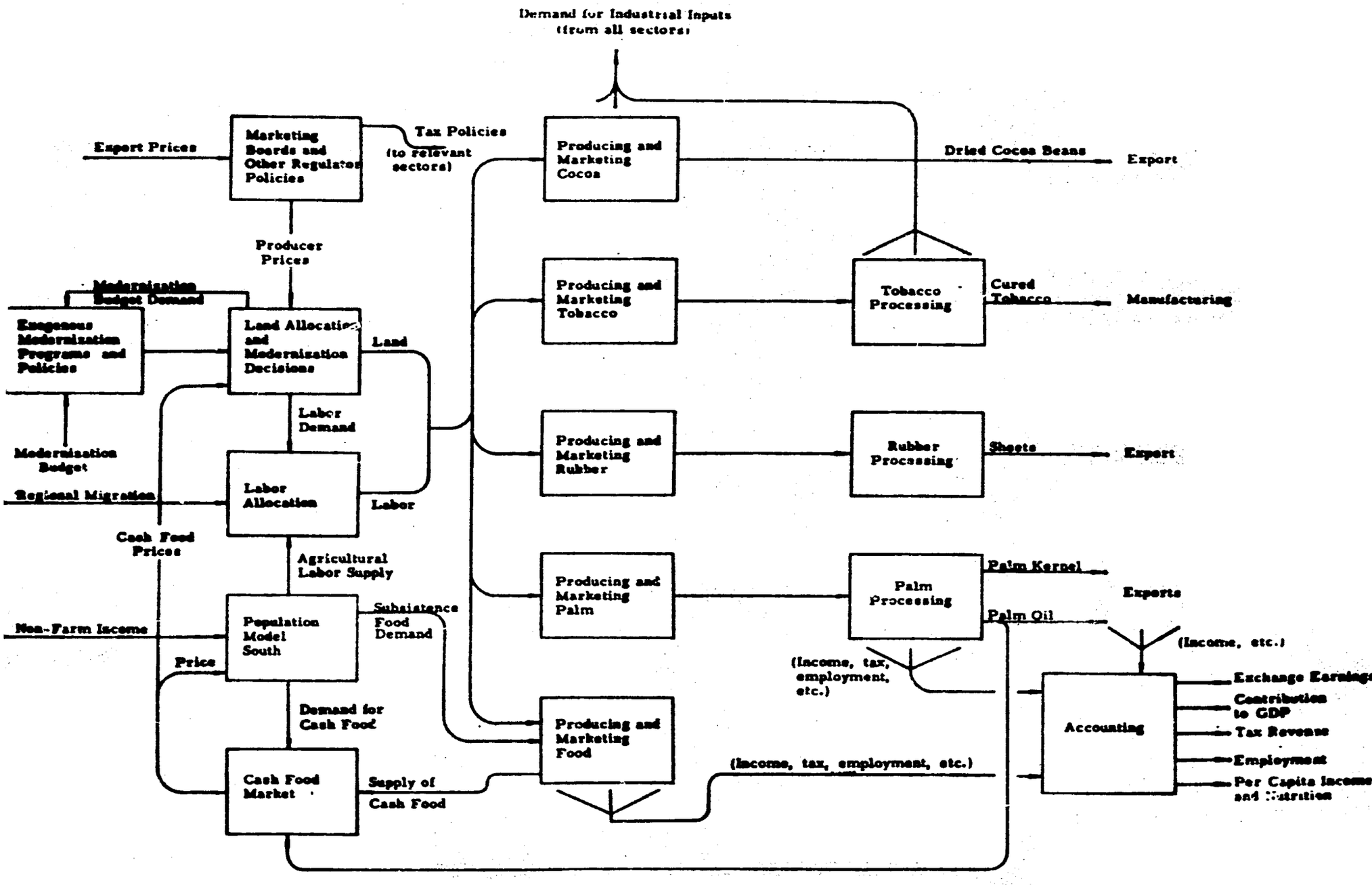
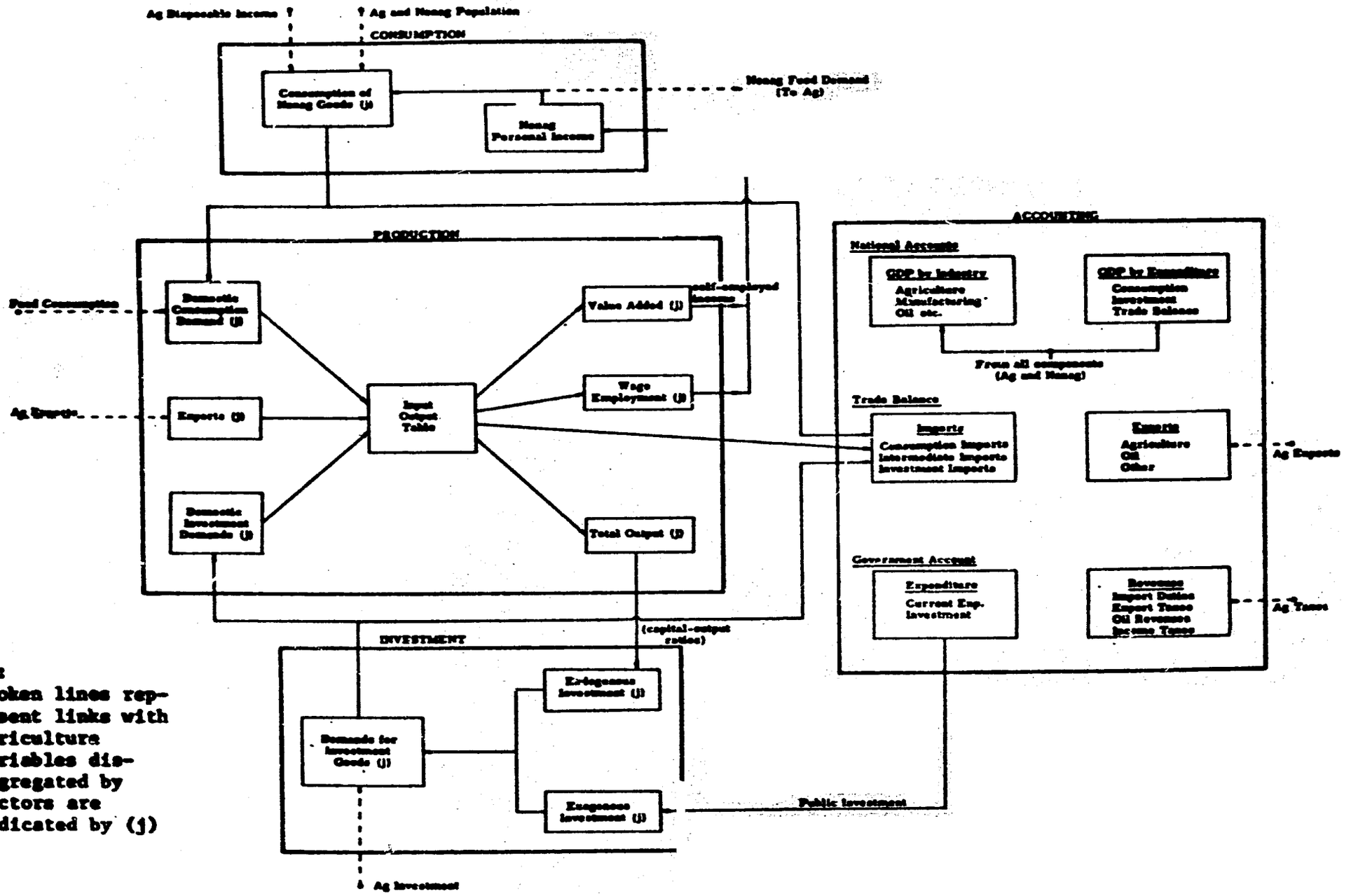


Figure 3

Major Sectors and Interactions of the Southern Nigerian Agricultural Model



Notes:
1. broken lines represent links with agriculture
2. variables disaggregated by sectors are indicated by (j)

Figure 4. Model of the nonagricultural economy and the national accounts, Nigeria.

to be investigated [2]. This submodel also constructs the national accounts, including measures of gross national (domestic) product by industry, consumption, investment, government revenues, and import-export balances.

Population Component

The population component (Figure 1) simulates the dynamic growth of a population broken into 27 three-year age cohorts. In addition to computing births, deaths, and aging of the population, the total labor force is determined and split between agricultural and nonagricultural occupations in each region and each ecological zone. Rural and urban food demands are computed as well as rural-urban migration.

Interregional Trade Component

The submodels are linked in the market and interregional trade component (Figure 1) where the national food market is modeled. It takes cash food supplies from the agricultural submodels and food demands from the population component, computes the price of transportation (based on investments in transport capacity) and interregional shipments of food, and determines the market price of food in both regions. In addition, the per capita consumption of food by the agricultural and nonagricultural populations in each region is calculated.

Model Summary

The computer simulation model is a complex of interacting submodels of major elements of the Nigerian economy. It is capable of investigating the consequences of various agricultural policy options, including inter-

actions with the nonagricultural economy. The total model[1/] contains between 2,000 and 3,000 equations and requires about 40 seconds of central processor time on MSU's CDC 6500 computer for a base run (i.e., continuation of present trends and policies) of 42 years of simulated time.

Model Validation

With an extremely large, complex model of a less-developed country, one naturally would expect that estimates of initial conditions and technical and behavioral relationships would necessarily have to be derived via a variety of techniques with data acquired from many different sources. This was the case in the Nigerian model--statistical estimation procedures were used where time series data were available (e.g., income elasticities of demand), previous experimental and survey results (e.g., crop yields, farm product mix, crop acreages) were employed, and data gaps were filled with knowledgeable estimates from researchers, extension men, and other informed personnel. These initial estimates were then incorporated into small sub-components and computer runs were made for the purpose of detecting errors. Sub-component output was then evaluated using appropriate theory, dynamic systems concepts, and the relationship of the simulated values to historical data and to otherwise expected future values. Where inconsistencies or abnormalities were noted, the problems were diagnosed, changes were made, and testing was continued. Many sensitivity runs were done to test the impact of possible errors in specific model parameters. These often indicated where additional secondary or primary data might be required for more accurate estimation of the sensitive parameters and where

structural equations (as data points themselves) needed modification or elaboration. Each sub-component was initially tested individually and then gradually aggregated (in combination with other sub-components) into larger model components whereupon the testing continued (and continues even now). While much of the testing has been rather subjective in nature, some "goodness-of-fit" tests have also been incorporated into the validation process (for more detail, see [3, pp. 279-281] and [6, pp. 34-35, 61-66, 169-172, 256-258]). While the testing procedure cannot conclusively prove that the model which has been developed is a valid representation of how the Nigerian economy will behave in the future, it is felt that the model in its current stage of development is a reasonable approximation which can provide some useful policy comparisons as the validation continues and implementation of the model in Nigerian planning agencies proceeds.

Policy Experimentation

Policy Definitions and Experimental Procedure

Following initial interactions with Nigerian policy makers and researchers, a series of 15 policy experiments was defined and run with the simulation model described above. Initial conditions in the model are for 1953. The model has been "tuned" to approximate observed conditions (e.g., exports) from 1953 to 1970 using observed export and producer prices for that period. The year 1970 was then considered the starting point with (in effect) simulated "initial conditions," and simulation results reported here are

analysed over the period 1970-1995, with policy implementation beginning in 1971. Projections are carried out to 1995 in order to give the long run diffusion responses to the production campaigns time to exert their major impacts.

With simulation it is easy to build up the complexity of the combinations of policies tested. Starting with runs to evaluate single policies or programs (e.g., reducing marketing board and export taxes), other policies and programs may be successively added, such as alternative production campaigns and infrastructure projects to investigate interactive effects. In addition a flexible output format allows the researcher to look either at the behavior of aggregated macro-economic variables or to focus upon the investigation of more detailed responses. The policy runs considered here are designed to take advantage of and illustrate these capabilities.

The 15 simulation runs are grouped into four sets which examine increasingly complex interactions at progressively higher levels of industry and geopolitical aggregation. The runs are summarized in Table 1 and described in more detail below. All four sets include Run 1, the base run, as a standard point of reference. The base run projects likely performance under current policies, with no programs to modernize production and with export and marketing board taxes maintained at current levels. Essentially, the base run makes projections assuming no changes in the system as it was in the 1960s. (For the purposes of these illustrative runs, the civil war in Nigeria was ignored.)

Table 1

NIGERIAN POLICY SIMULATION RUNS

Run No.	Run Definition
1	Base run: Status quo policy--no modernization of production; normal export taxes and marketing board surpluses.
	Policy Run Related to the Cattle Industry
4	Tsetse-fly eradication program, 1971-81.
	Policy Runs Related to Agriculture in the Northern Region
2	Export taxes and marketing board surpluses cut off in 1970.
3	Export taxes and marketing board surpluses phased out from 1970 to 1980.
5	Production campaigns in cotton and groundnuts, 1971-81.
6	Production campaigns in food grains, 1971-81.
7	Production campaigns in cotton, groundnuts and food grains, 1971-81. (Combines Run 5 and Run 6.)
	Policy Runs Related to Agriculture in the Southern Region
2	Export taxes and marketing board surpluses cut off in 1970.
3	Export taxes and marketing board surpluses phased out from 1970 to 1980.
8	Production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting, 1971-81.
9	Production campaigns in cocoa new planting, cocoa replanting and palm replanting, 1971-81.
10	Production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting, 1971-81; modernization of palm and rubber processing. (Run 8 plus modernization of palm and rubber processing.)
	Policy Runs Related to Agriculture in Both the Northern and Southern Regions
11	Production campaigns in cotton, groundnuts and food grains in the North, 1971-81; production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting in the South, 1971-81. (Combines Run 7 and Run 8.)
12	Run 11 plus production campaign in food roots in the Middle Belt, 1971-81.
13	Run 11 with a further improvement in food grain technology after 1980.
14	Run 11 with export taxes and marketing board surpluses cut off in 1970.
15	Run 11 with export taxes and marketing board surpluses phased out from 1971 to 1980.

Policies for the Cattle Industry

The first set of runs looks at one partial solution to some of the problems currently facing the cattle industry in northern Nigeria. The tsetse fly has a dramatic impact on the area where cattle can graze in good health and on the corresponding size and productivity of the Nigerian cattle industry (and the income accruing to northern Nigerians). In the first set of runs, Run 4 investigates the results of a tsetse fly eradication program budgeted for £3 million over ten years. (An eradication cost of £100/square mile is assumed.)

Policies for the North

The focus of the second set of runs (Runs 1, 2, 3, 5, 6 and 7) is on interactions among cash crops (cotton and groundnuts) and food crops in the North. Commodity marketing boards in Nigeria have the power to set producer prices as a matter of policy, whereby the boards may generate surpluses for themselves or run at a loss, in effect either taxing or subsidizing the producers. Surpluses may be used for price stabilization purposes or to finance developmental or other projects. These producer prices can have significant impacts on producer incentives and, hence, commodity outputs and private and public returns. Controversy surrounding the marketing boards in Nigeria center on the issue of whether or not the public sector is a better allocator of resources than the private sector. Runs 2 and 3, then, compare the effects of cutting off export and marketing board taxes in 1970 or phasing them out over a ten-year period. (These runs reduce taxes in both the North and South.)

In the remaining runs of this set, these taxes are maintained at recent levels (25 percent for cotton and groundnuts) while various combinations of production campaigns are tested. Promotion efforts at modernizing agricultural production can generate substantial returns to both the public and private sectors. Such modernization may entail the introduction of higher-yielding biological varieties and/or the encouragement of improved cultural practices such as weeding, spacing, time of planting and the application of fertilizers and insecticides. The increase in output can then result in higher incomes for the farmers and increased tax revenues and foreign exchange earnings for the public sector. The nonagricultural sector can also experience growth as a result of increased demands from the agricultural sector.

The total budget for the production campaigns is assumed to be £40 million spread over a ten-year period. This budget pays for extension salaries, subsidies and overhead expenses. Run 5 simulates programs to increase cotton and groundnut production via extension efforts to introduce new seed varieties and improved cultural practices, improving groundnut and cotton yields by 68 percent and 171 percent, respectively. In this run, groundnuts get 2/3 of the budget, while cotton gets 1/3. The same end (improved cash crop production) is sought in Run 6 via a food grains modernization program (to hopefully release land for cash crop expansion). If food production is being modernized, the model provides for cotton yields to increase as the labor pressure is eased. This reflects cotton being planted earlier in the season. New technologies in food grain production are assumed to increase yield 2 1/2 times. Here, all £40 million go to food grain programs. All three programs--cotton, groundnut and food grains--

are then combined in Run 7, where the budget is split 40 percent, 20 percent and 40 percent to groundnuts, cotton and food, respectively.

Policies for the South

Agricultural policies and programs aimed at the southern ecological region are examined in simulation Runs 2, 3, 8, 9 and 10. Runs 2 and 3 again compare the consequences of cutting off export and marketing board taxes or, alternatively, phasing them out (in both regions). Normal levels of marketing board taxes are assumed to be 20 percent for the three commodities handled by marketing boards (cocoa, palm oil and palm kernels), while export taxes for those three and rubber are 20 percent, 15 percent, 15 percent and 15 percent, respectively.

Runs 8, 9 and 10 investigate production campaigns in the perennial crops and efforts to improve the processing methods for oil palm and rubber products. The production campaigns assume a budget of £40 million over ten years to pay for extension salaries, subsidies and overhead expenses. Run 8 involves a modest cocoa new planting program and replanting programs for cocoa, palm and rubber. The budget is split among these programs 10 percent, 30 percent, 40 percent and 20 percent, respectively. Of the 40 percent in the palm replanting program, 25 percent is used in the areas where palm competes with rubber, and 75 percent is applied to areas where palm has no perennial competitors. Run 9 attempts to highlight the interactive effects of the oil palm-rubber competition (in comparison with Run 8) by not conducting the rubber replanting program and devoting that portion of the budget to palm replanting. The assumed yields at maturity for new planted cocoa and replanted cocoa, palm and rubber represent improvements of 86 percent, 47

percent; 49 percent and 150 percent, respectively. The model provides for these yields to gradually increase another 20 percent as farmers gain experience with the new methods of cultivation involved in modern production.

Finally, Run 10 adds investment in modern processing facilities for oil palm and rubber products to the programs in Run 8. For palm this means Stork hydraulic presses, while for rubber it means crumb factories. The investment rate is established at £100 thousand and £200 thousand per year for palm and rubber, respectively, until a prespecified level of transformation has been reached (50 percent for palm and 100 percent for rubber). While rubber processing is being transformed from sheets to crumb, the model also simulates a gradual increase in the domestic industrial demand for crumb rubber up to 50 percent of production.

Policies for Both Regions

Whereas the first three sets of runs focus on industry- or region-specific policies, the fourth set of runs, Runs 11, 12, 13, 14 and 15, examines aggregate and interactive effects of agricultural development policies and programs in both the North and the South. Run 11 combines Runs 7 and 8 so that the following production campaigns are carried out simultaneously at the same budget levels (£40 million in each of the North and the South) and in the same commodity proportions as specified above: modernization of cotton, groundnuts and food grains in the North, and new planting of cocoa and replanting of cocoa, palm and rubber in the South.

Run 12 investigates the impact of modernizing food production (roots and tubers) in the Middle Belt area of the North in addition to the

modernization programs discussed above. In this way the implications for regional specialization, i.e., the South's specialization in perennials and the North's in food, can be specifically investigated. This run is conditional in that the modernization of root and tuber food production is dependent upon future development of the requisite technologies.

Another conditional run is represented by Run 13. With the programs specified in Run 11, a further doubling of food grains yields is assumed to diffuse over a period of four or five years after 1980 as a result of new technologies which may be developed in the next ten years by national and international research stations. Thus, modern food yields after 1980 are assumed to be potentially five times the current traditional yields experienced in northern Nigeria. This experiment investigates the potential effects on exports (due to cash crop interactions), food prices, and consumption.

Finally, Runs 14 and 15 combine the production campaigns of Run 11 with the export and marketing board tax policies of Runs 2 and 3, respectively, i.e., the alternatives of cutting off and phasing out these taxes.

The following sections analyze and graphically portray the results of these 15 runs.

Analysis of Simulated Results

Policies Related to the Cattle Industry

Run 4 simulates a ten-year tsetse fly eradication program budget at £3 million. This analysis does not consider other livestock programs or

their potential interactions with other agricultural policies and programs due to limitations of the current model.[2/]

Animal populations,[3/] sales and resultant incomes all rise as might be expected. Acreage of fly-free grazing land increases dramatically, and the general range condition[4/] improves substantially over the base run as the grazing pressure is reduced.

In every case, however, the gains attributed to the fly eradication program in Run 4 are temporary in the sense that these performance variables, after an initial increase, return to the same trends as experienced in the base run, although at a higher level. By 1995, the slopes of the results of Run 4 are all either the same as the slopes of Run 1 results or are approaching these slopes. The animal population (Figure 5) increases rapidly as new grazing areas are opened. Once even these new areas have reached their animal capacity, however, male and female populations grow at the same rate as in the base run. This also causes sales and incomes to undergo the same growth rates as in Run 1 after the initial spurt.

The amount of fly-free grazing land experiences a dramatic increase from 1975 to 1985 as a direct result of the eradication program (Figure 6). After 1985, however, grazing land declines at the same rate as in Run 1 due to the growth in the human population and the corresponding expansion of crop lands. Similarly, the decline in range condition due to overgrazing is slowed substantially as new areas are opened and the grazing pressure eases. But, the cattle population is grazing even these new areas to capacity by 1995, and the range condition continues to decline at the same rate as in the base run.

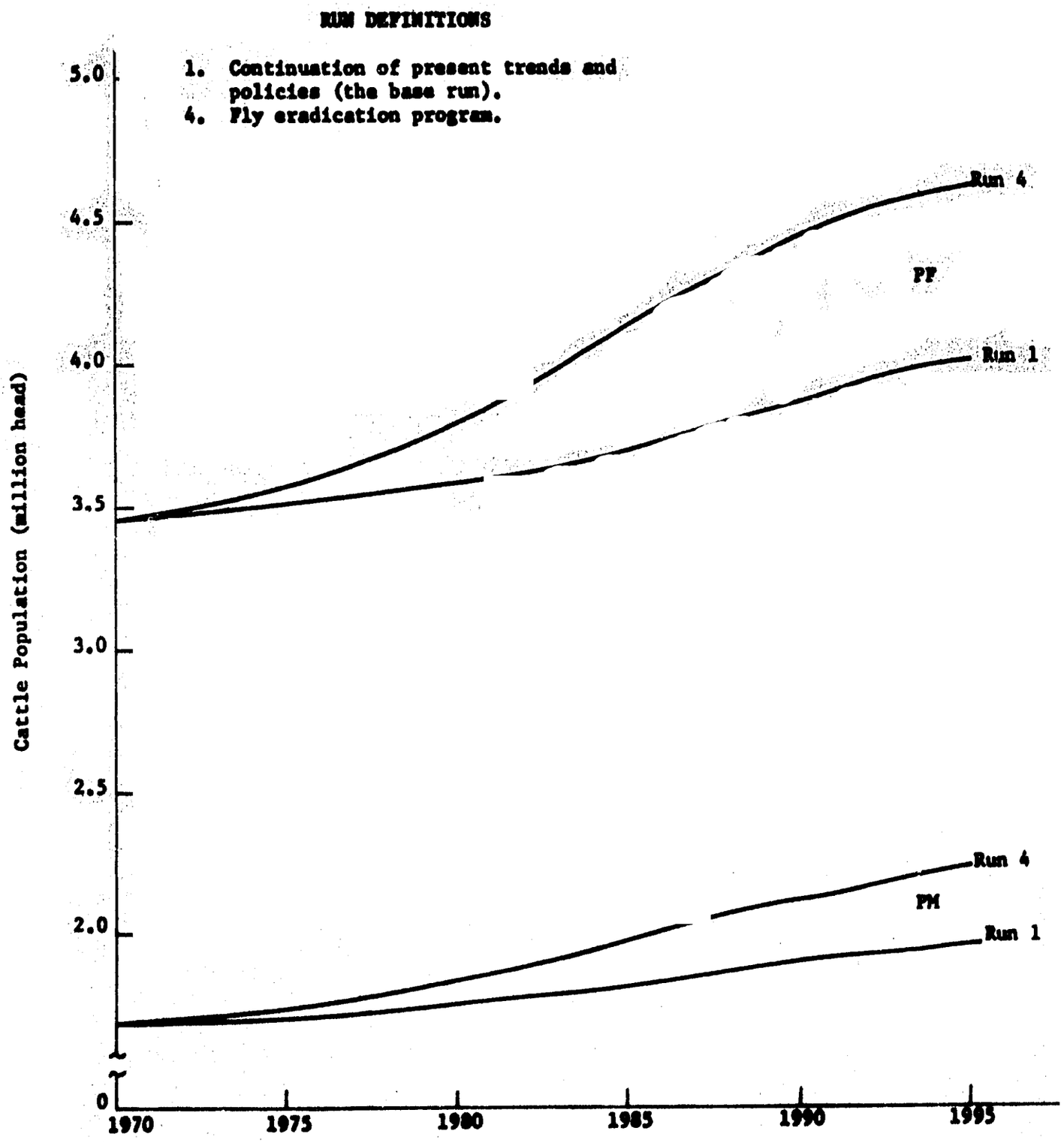


Fig. 5. Cattle population of males (PM) and females (PF), 1970-1995, with and without a fly eradication program.

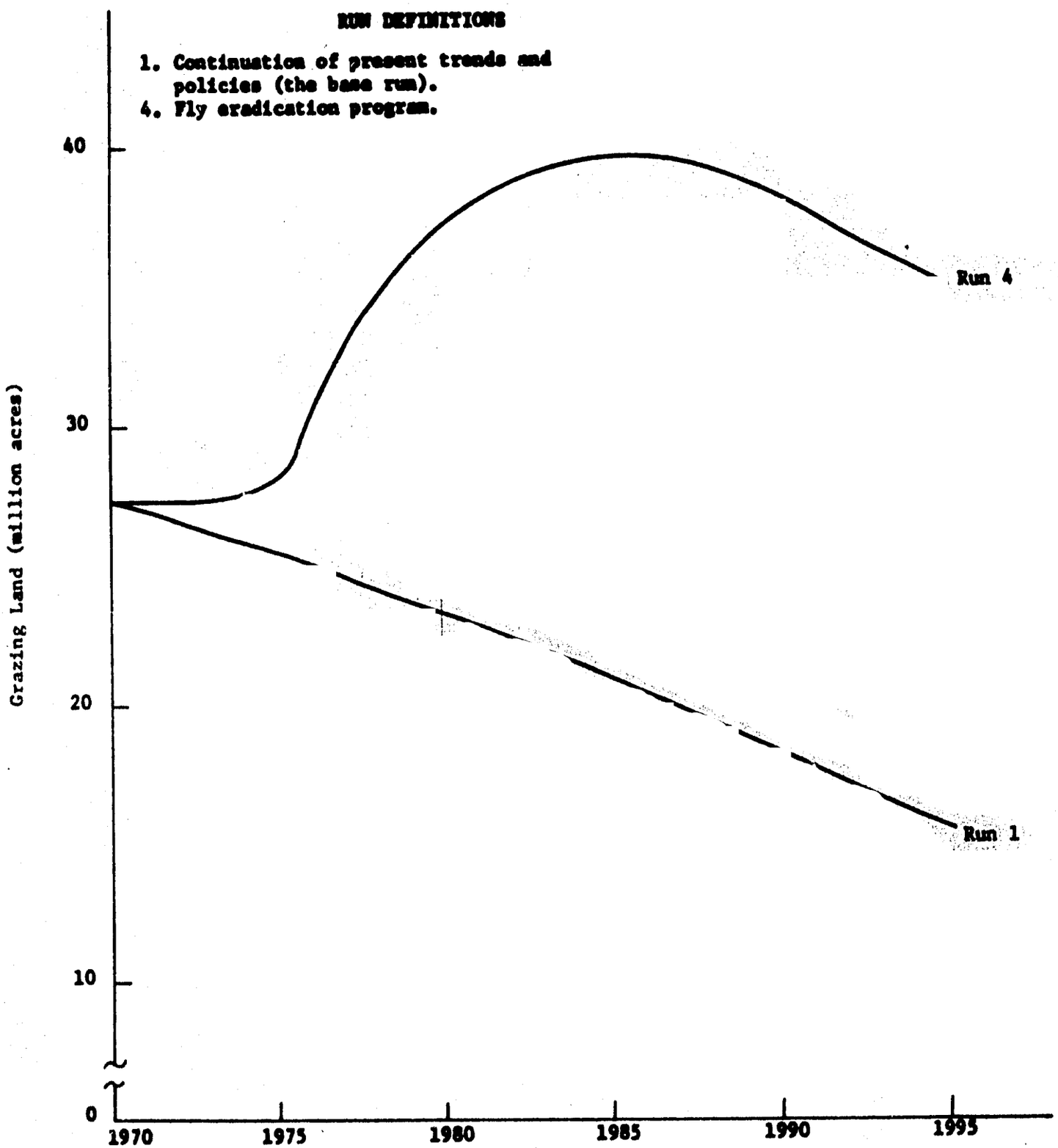


Fig. 6. Fly-free grazing land, 1970-1995, with and without a fly eradication program.

The conclusion to be drawn from this is that the fly eradication program has merely "bought time." The deterioration of overgrazed ranges has been delayed but not halted (much less reversed). The loss of grazing land to crops continues in Run 4 at the same rate as in Run 1. The animal population growth rate (and, hence, the growth in beef and milk supplies) is the same after the eradication program as before.

This is not to say there shouldn't be a fly eradication program. This program does have substantial short run results, and the time gained by it could be used to carry out programs which will have more long-lasting results Indeed, other programs, such as grazing reserves, might not even be feasible without the prior elimination of the tsetse fly and the consequent reduction in grazing pressure in the potential grazing reserve areas.

Northern Regional Policies

The set of runs which investigates the consequences of policies and programs relevant to northern Nigeria includes Runs 1, 2, 3, 5, 6 and 7 as defined above and in Table 1.

As expected, the elimination of marketing board and export taxes stimulates agricultural production and incomes. Value added in agriculture increases slightly over the base run (Figure 7), as do exports (Figure 8).[5/] The immediate elimination of taxes (Run 2) initially causes higher exports and value added than Run 3 (phasing out taxes), but also a slightly higher food price (not shown) for the nonagricultural population. Disposable agricultural worker incomes (Figure 9)[6/] markedly increased over the base

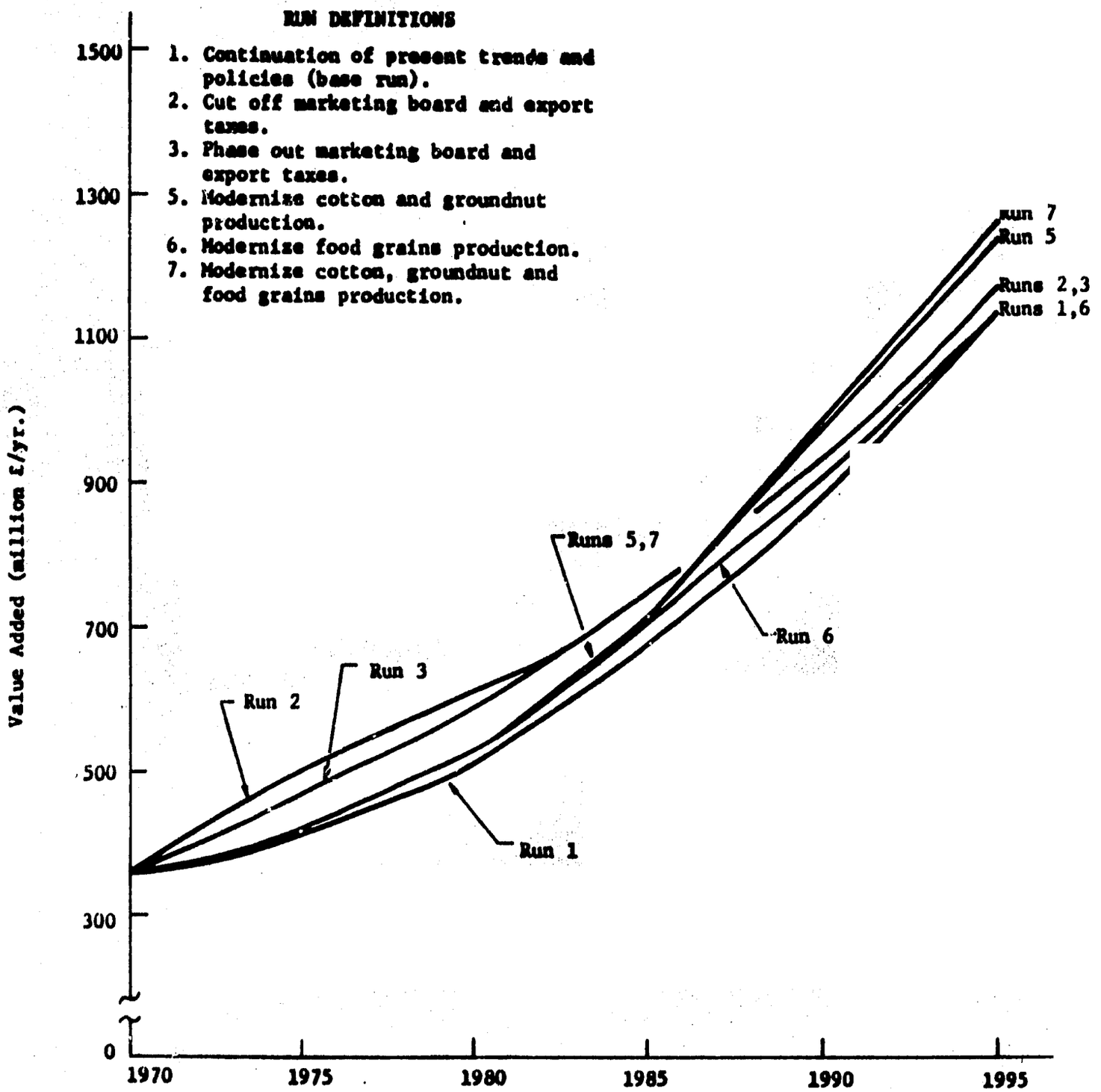


Fig. 7. Total value added in agriculture in the North, 1970-1995, under various policy conditions.

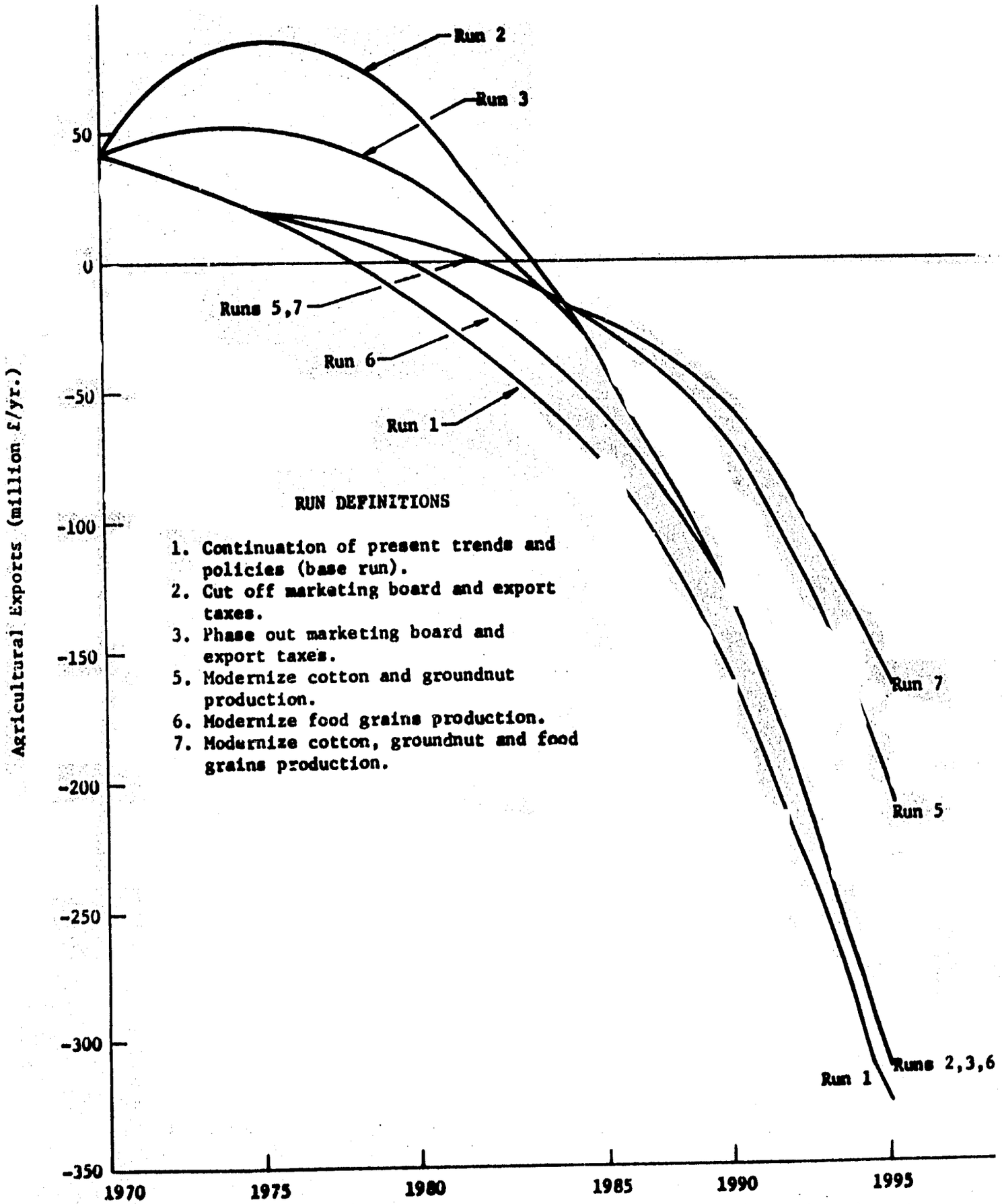


Fig. 8. Foreign exchange from northern agricultural exports (including imports of cotton and beef), 1970-1995, under various policy conditions.

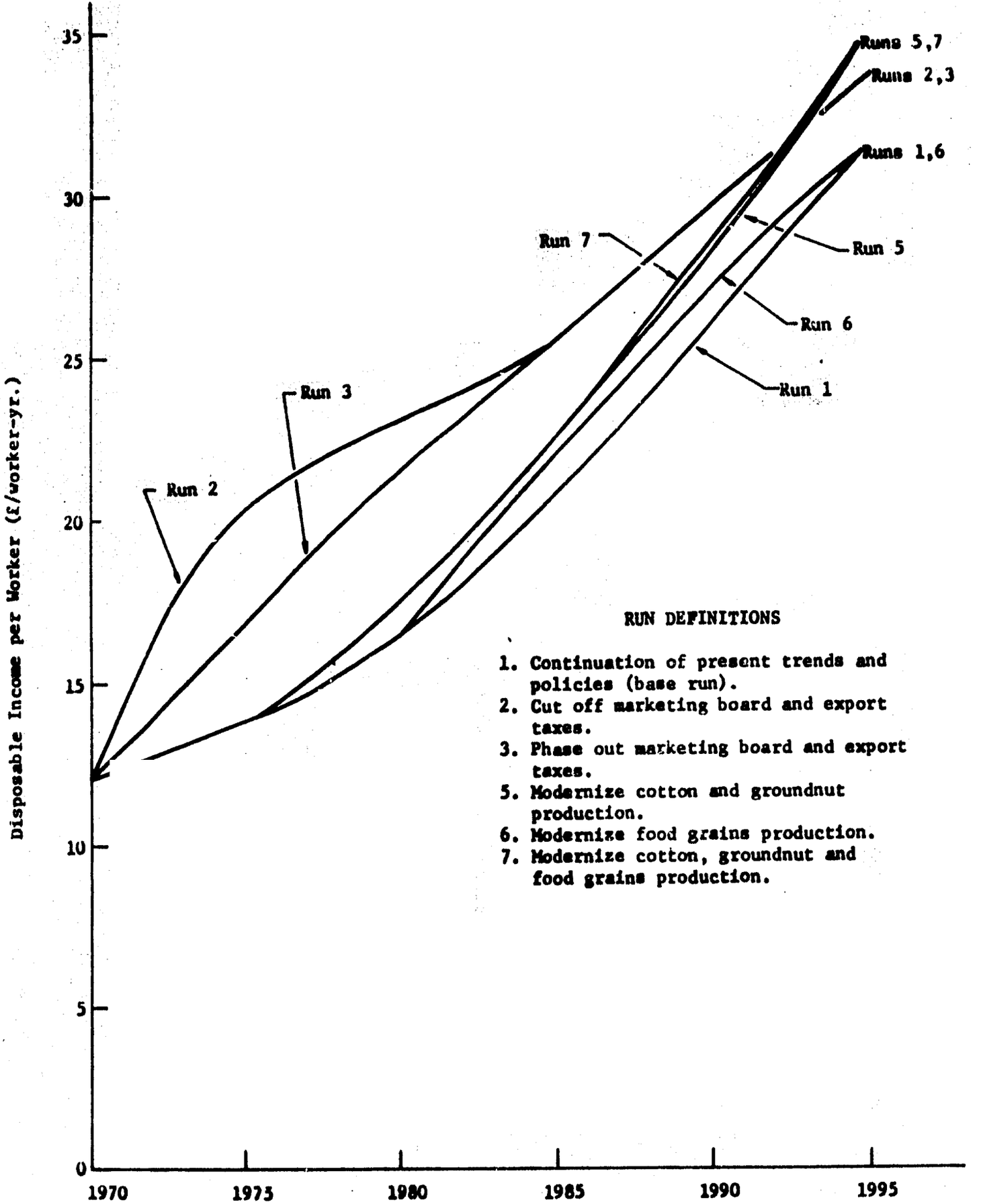


Fig. 9. Disposable income per agricultural worker in the North, 1970-1995, under various policy conditions.

run due, in part, to the higher producer prices for cash crops and to slightly higher food prices.[7/]

The major contributor to increased incomes, however, is the greatly increased (relative to the base run) cash food sales to the South (not shown) to meet the higher agricultural and nonagricultural demands for food. Southern agricultural cash food demands increase as the agricultural sector reduces its desired level of subsistence in response to higher cash incomes resulting from the export crop tax reductions.[8/] In addition, southern nonagricultural food demands rise due to the rise in nonagricultural income resulting from the greater demands for nonagricultural goods and services generated by the increased agricultural income (i.e., multiplier effects).

The long run results of Run 2 are similar to those of Run 3. After 1980, when marketing board and export taxes are zero in either policy situation, food consumption by the nonagricultural population (Figure 10) shows a substantial rise as the increased agricultural incomes from Runs 2 and 3 begin to have their multiplier effects on nonagricultural incomes. Later, higher food prices cause nonagricultural food consumption to approach the same level as in the base run.

Figure 10 indicates steadily falling nonagricultural food consumption in all runs (as does Figure 14). These results must be interpreted with caution. They represent only staple grain and root crop consumption, and do not incorporate other sources of nutrition such as fish, meat, fruits and vegetables.

The modernization of cotton and groundnut production (Run 5) substantially improves the performance of all the variables observed compared to both the base run and the runs eliminating taxes. Foreign exchange increases the

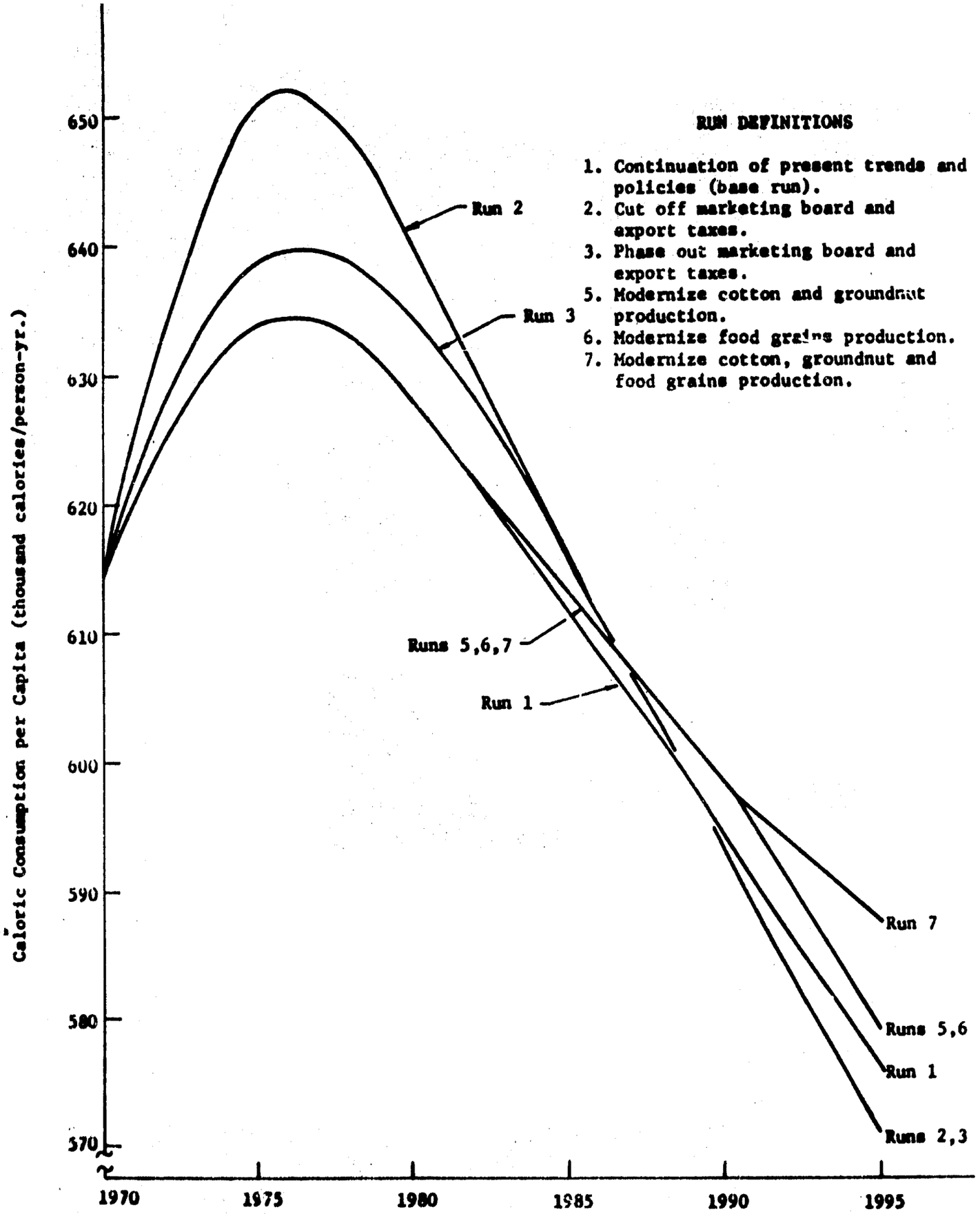


Fig. 10. Caloric consumption (of staples) per capita of the northern nonagricultural population, 1970-1995, under various policy conditions.

most (Figure 8), about 30 percent over Run 1. Since food crops rather than export crops dominate northern agricultural production, other variables, such as value added (Figure 7), income (Figure 9) and, hence, food consumption (Figure 10) show a less dramatic increase. Marketing board revenues show a 150 percent increase by 1995.

Run 6 examines a program to modernize food grains production. Indeed, foreign exchange and marketing board revenues do pick up (over the base run) as land and labor are released for cash crop production. The difference is less pronounced at the end of the run (1995) than earlier in the simulated time period as the initial reduction in total food land is gradually reversed to meet the subsistence demands of the expanding agricultural population. Throughout the time period 1970-1995, exports and marketing board revenues in Run 6 are below those of Run 5 where policies are targeted directly to the transformation of cash crop production. This can be explained by the slower diffusion of food modernization (compared to cash crop modernization diffusion) which is built into the model. A larger promotional effort (budget) would stimulate a quicker response to food modernization and, hence, a larger effect on cash crop production.

In Run 7 promotional efforts are conducted in cotton, groundnuts and food grains simultaneously. The results in Run 7 are more than the mere addition of the output variable increases experienced in Runs 5 and 6. Marketing board revenues provide a striking example of this. Run 7 revenues in 1995 are 200 percent greater than Run 1 while revenues in Runs 5 and 6 are 150 percent and 15 percent greater, respectively. This is due to the fact that cash crop production, which has expanded onto former food land

as a consequence of food modernization, is itself modernized in Run 7, further augmenting the positive results of Run 6. In addition, and more significantly in the long run, the modernization of food in conjunction with that of cotton and groundnuts allows more timely planting of the cash crops, resulting in even higher yields for the modern varieties than would otherwise be obtained.

Food prices are lower in Run 7 than in any other run. This effect is more than offset, however, by the increased productivity of food, so that value added and income are slightly higher in Run 7 than in Run 5. The lower food prices coupled with increased nonagricultural income result in higher nonagricultural food consumption (Figure 10).

Southern Regional Policies

The set of runs which investigates the consequences of policies and programs relevant to southern Nigeria includes Runs 1, 2, 3, 8, 9 and 10 as defined earlier and in Table 1.

The most striking observation about Runs 2 and 3 (cutting off and phasing out taxes) is not that the long run results are virtually identical, for taxes are eventually zero in both cases. Nor is it that incomes, value added, exports, etc. are initially higher than the other runs and consistently higher than the base run, for the reduction in taxes represents an immediate increase in producer prices, whereas there is a delay involved for the perennial modernization programs to show results.[9/] The most striking observation concerning the behavior shown in Runs 2 and 3 is that value added, exports and income (Figures 11, 12 and 13) are relatively higher initially in Run 2 than in Run 3; while later in the simulated time period (after about 1978), they are relatively higher in Run 3 than in Run 2,

finally approaching the same steady state levels in both runs. Run 2 should indeed have higher results initially, since producer price increases are immediate. The short term supply (harvest) response is initially sharp, and then tapers off, returning ultimately to normal levels as farmers gradually come to regard the higher prices as "normal." Exports begin to increase again after 1980 (Figure 12) as the long term supply (planting) response to the higher prices becomes increasingly dominant, finally tapering off again as acreage expands to its limit (as in the base run) and production declines from aging traditional trees.

In Run 3, prices rise steadily over a ten-year period while taxes are being phased out. Thus, the harvest response is lower than in Run 2. However, it lasts longer, since the new price (achieved when taxes have finally been eliminated) is not seen as "normal" by the farmers until later. Therefore, while exports in Run 2 taper off, the harvest and planting responses reinforce each other in Run 3. Eventually, however, the acreage limits are reached, the natural aging process decreases yields, and the long run results of Runs 2 and 3 are virtually the same (Figures 11, 12 and 13).

Although long run exports, when taxes are removed, are virtually the same as in the base run (due to capacity limits and aging traditional trees), the higher prices keep value added and income per worker (Figures 11 and 13) higher than the base run. Per worker income falls during the latter part of the runs because the labor force is growing faster than income.

The increased agricultural incomes, via multiplier effects on nonagricultural incomes, cause a higher consumption (in Runs 2 and 3 than in Run 1)

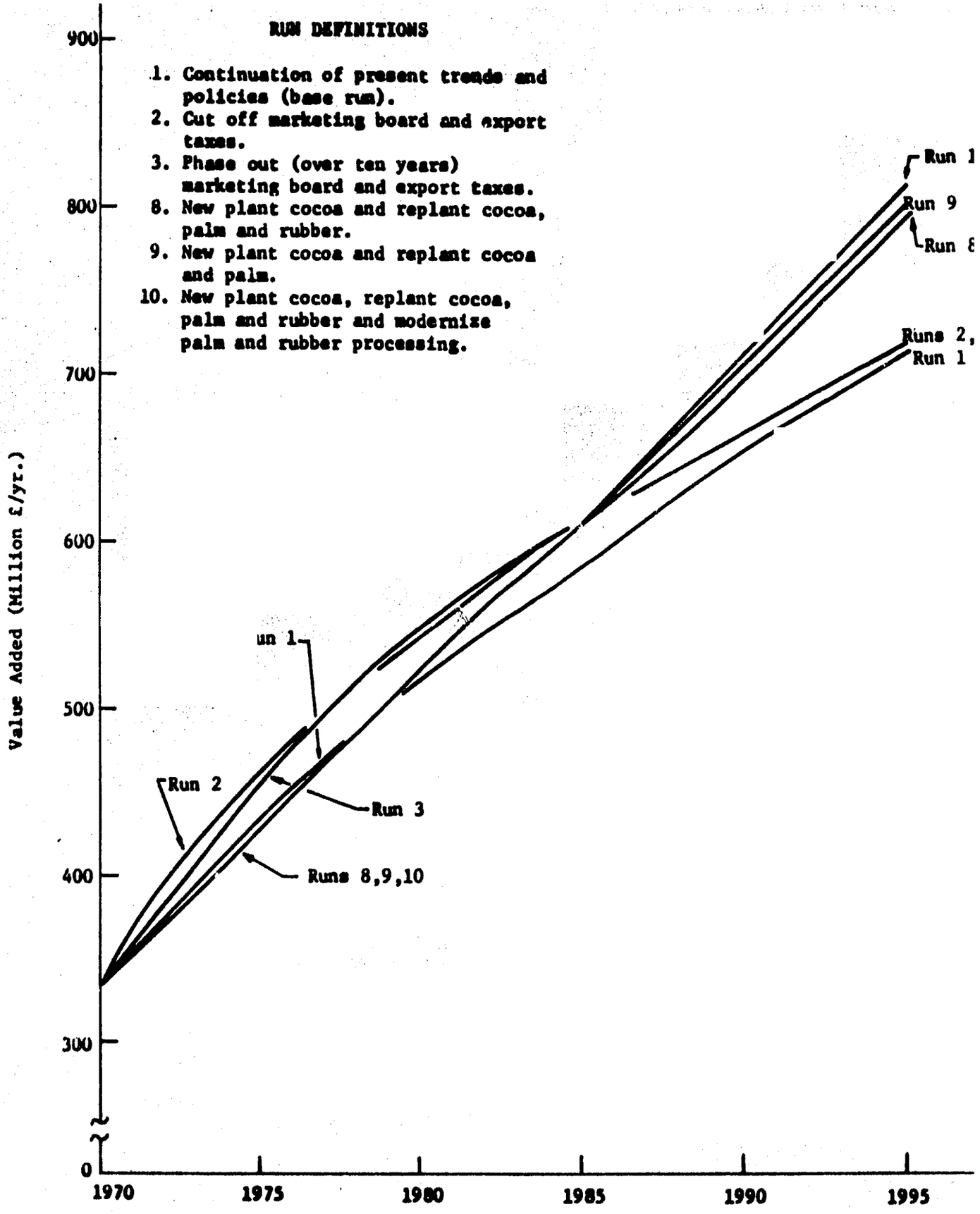


Fig. 11. Total value added in agriculture in the South, 1970-1995, under various policy conditions.

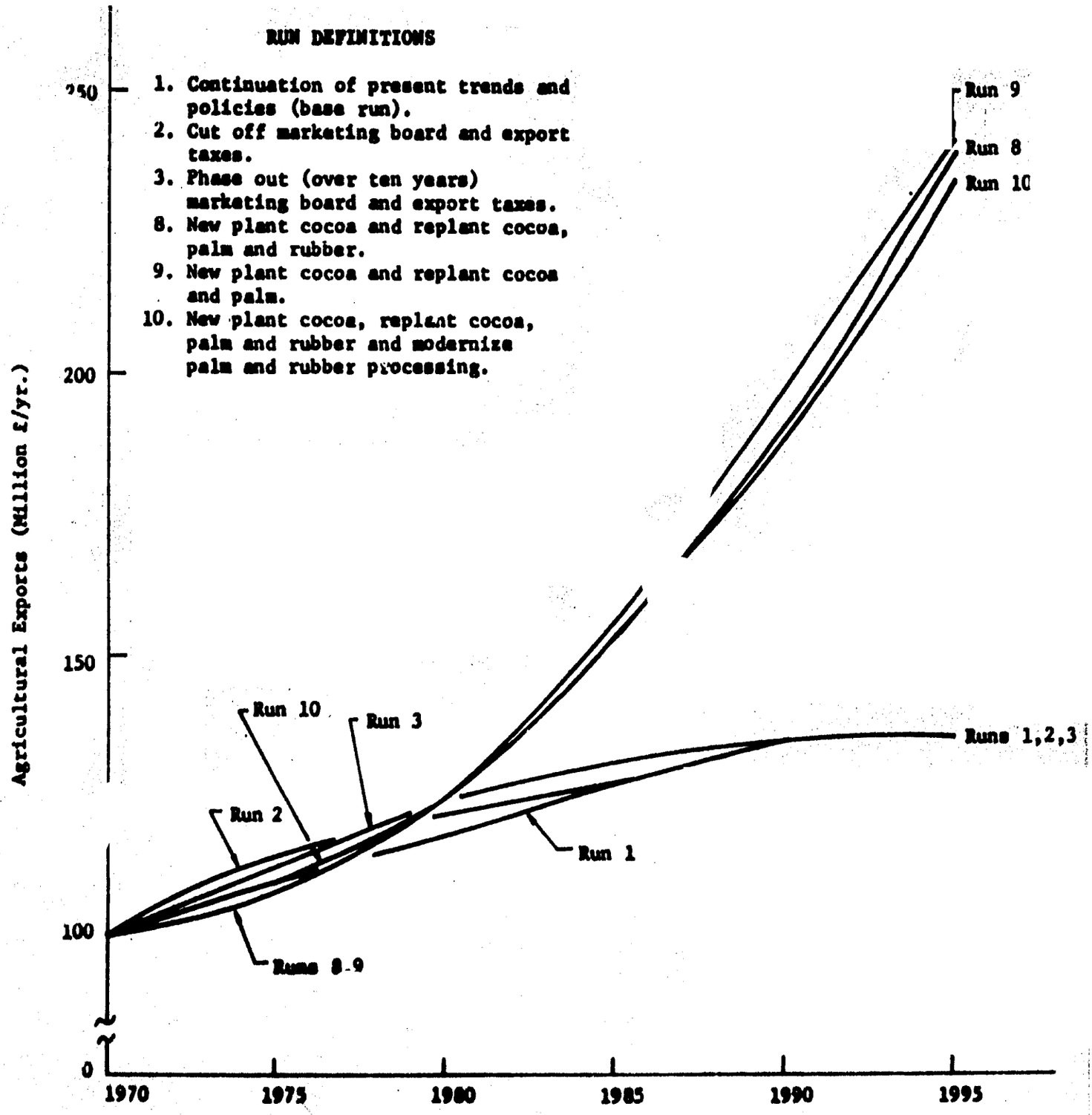


Fig. 12. Foreign exchange from southern agricultural exports, 1970-1995, under various policy conditions.

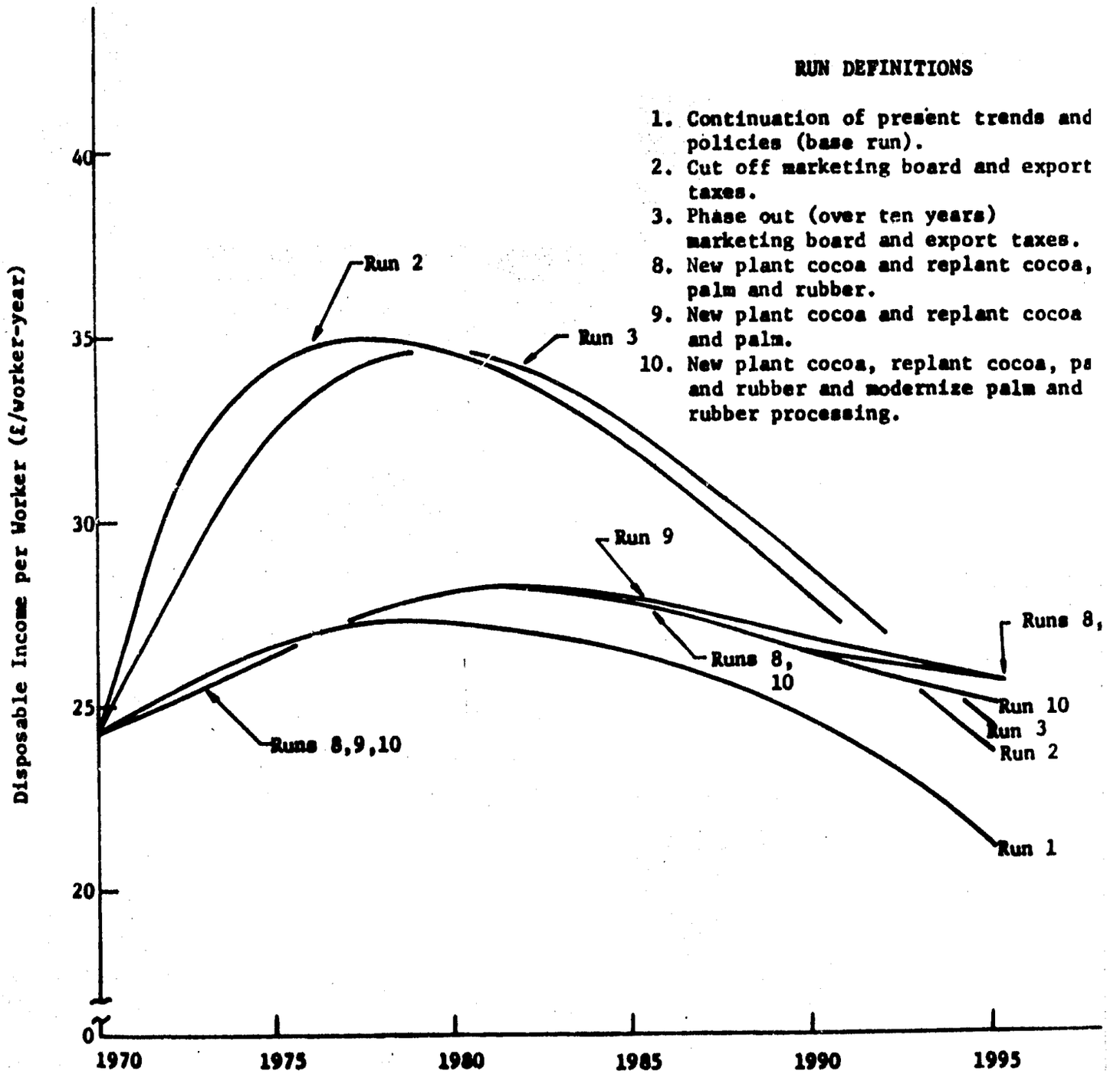


Fig. 13. Real disposable income per agricultural worker in the South, 1970-1995, under various policy conditions.

of staple calories by the nonagricultural population through most of the simulated time period (Figure 14). As incomes stabilize in the long run, however, the higher food prices associated with Runs 2 and 3 result in lower nonagricultural staple food consumption.

In comparing Runs 8 and 10 (production campaigns in the three major perennial commodities without and with modernization of palm and rubber processing), some interesting observations can be made. Value added (Figure 11) and marketing board revenues (not shown) are higher in Run 10 than in Run 8 due to the increased technical efficiency of oil palm and rubber processing facilities. While palm oil exports are also substantially improved, total exports (Figure 12) are lower due to the assumption in Run 10 that the domestic demand for rubber increases to 50 percent of production over a 15-year period, reducing rubber exports (which don't pass through a marketing board, thus not diminishing marketing board revenues). Indeed, exports are initially higher in Run 10 while domestic rubber demand is still low.

In spite of this increased production, incomes in Run 10 are lower by 1990 than in Run 8 (Figure 13). The reason is that palm oil processing with the Stork hydraulic presses, while technically more efficient (i.e., more oil is extracted per pound of fruit), is economically inefficient. That is, the increased processing costs outweigh the revenue from increased production, making palm processing unprofitable.[10/] The centralized crumb rubber factories, on the other hand, prove to be substantially more efficient (economically as well as technically) than the traditional sheet-making facilities operated at the village level.

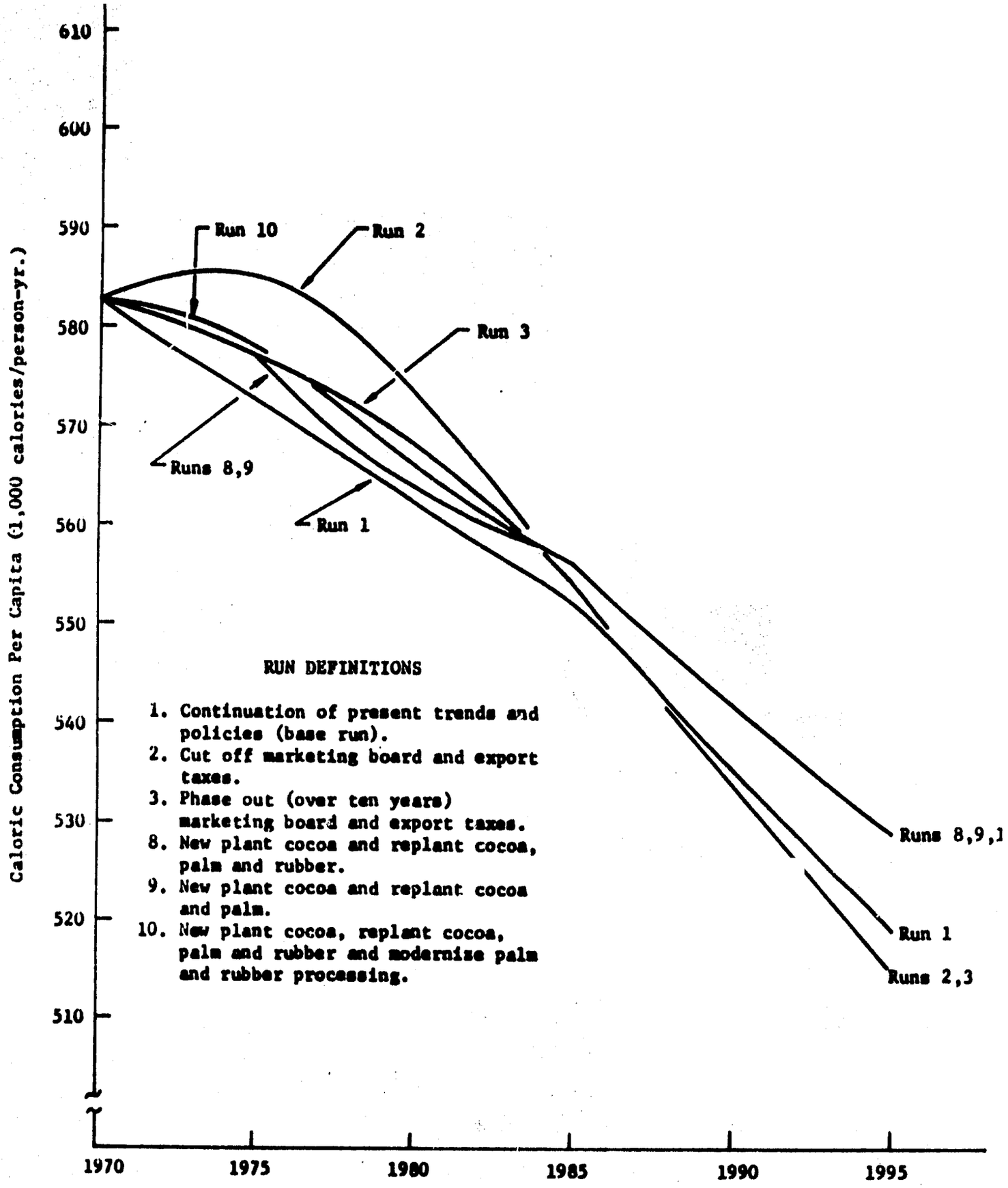


Fig. 14. Caloric consumption (of staples) per capita of the southern nonagricultural population, 1970-1995, under various policy conditions.

Run 9 was an experiment to investigate the consequences of increasing the palm replanting effort at the expense of rubber in the crop sector where the two perennials compete. Indeed, palm oil exports (not shown) do improve substantially over Run 8. Value added and total exports are also higher in spite of the still traditional rubber production.

It is interesting to note that value added, exports, marketing board revenues and income per worker are all lower in Runs 8 and 9 than in the base run for about the first six to eight years of the simulated time period (1976-1978) before rising to substantially improved levels. This is due to the fact that replanting programs mean removing trees from production and that there is a gestation lag which occurs before the new trees come into production.

Nonagricultural food consumption is higher in Runs 8, 9 and 10 than in the other runs (Figure 14) due to the multiplier effects of increased agricultural incomes (Figure 13) on nonagricultural incomes and to slightly lower food prices.

National Policies

The fourth set of runs, Runs 1, 11, 12, 13, 14 and 15, examines the results of some national agricultural development policies and programs.

Coupled with the modernization programs, the elimination of marketing board and export taxes (Runs 14 and 15) substantially enhances the results obtained when the modernization programs are implemented in the presence of these taxes. Figure 16 indicates that, while both total exports and total imports (not shown) increase in Runs 14 and 15 compared to Run 11, exports experience a relatively greater rise, leaving Nigeria with a more

favorable balance of payments. Similar increases are seen in other variables, such as GDP (gross domestic product, assuming marketing board and export tax revenues are not put to productive use) (Figure 15), value added in agriculture, and agricultural exports.

Nonagricultural food consumption is higher in Runs 11, 14 and 15 (with modernization) than in the base run (Figure 18). This is due to the multiplier effect of increased agricultural income on nonagricultural income, i.e., increasing agricultural demand for consumer goods from the nonagricultural sector.

Run 12 was an attempt to project the consequences of increased production of food root crops in the Middle Belt (assuming the requisite improved technology to be available). The indications are that the South would tend to specialize in exports while importing food from the North. By 1995, food shipments (not shown) increase by about 56 percent over Run 11. However, this results in much lower food prices (Figure 17) rather than the substitution of perennial production for food production; southern agricultural exports remain virtually the same as in Run 11. This can be attributed to the current limitations of the southern submodel, specifically the constraint on the transfer of food land to perennial production [1, Chapter 3]. Without this restriction, a move to export specialization in the South would be expected in the presence of a secure food supply from the North. The lower food prices do lead to a dramatically higher level of food consumption by the nonagricultural population (Figure 18).

An interesting observation can be made concerning agricultural value added (not shown) and gross domestic product (GDP) (Figure 15). Such a large

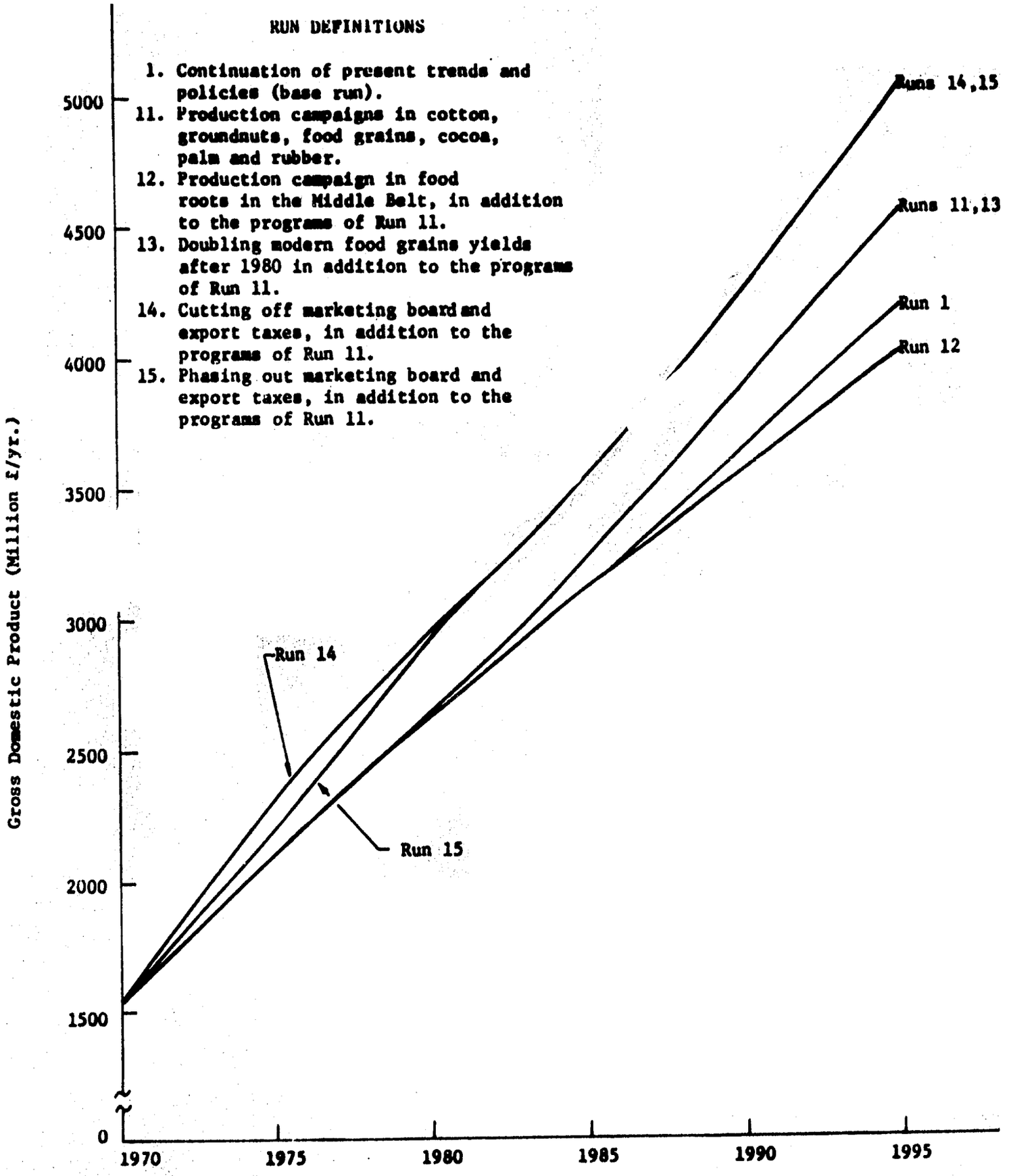


Fig. 15. Gross domestic product (assuming marketing board and export taxes are not put to productive use), 1970-1995, under various policy conditions.

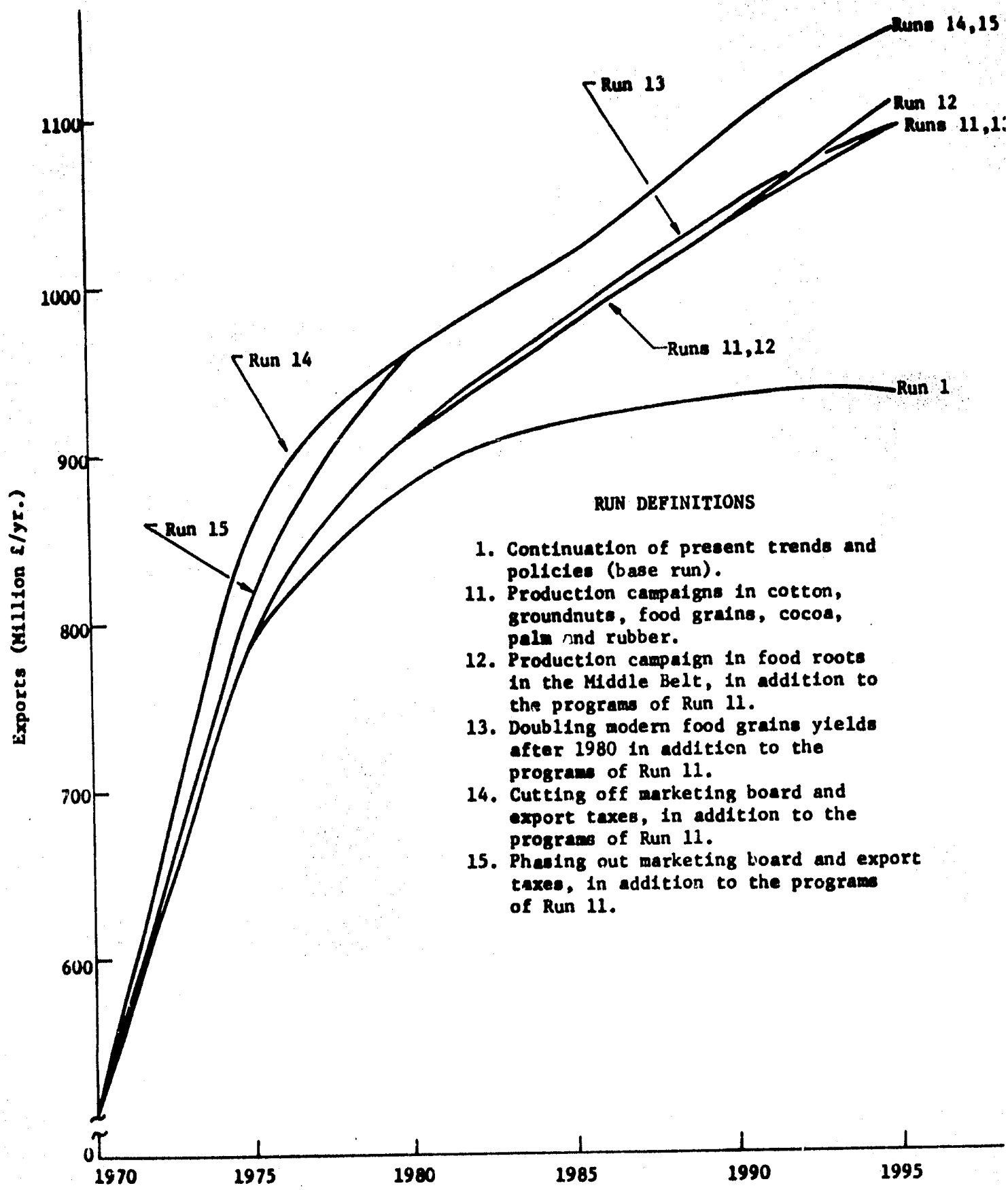


Fig. 16. Total exports (agricultural and nonagricultural), 1970-1995, under various policy conditions.

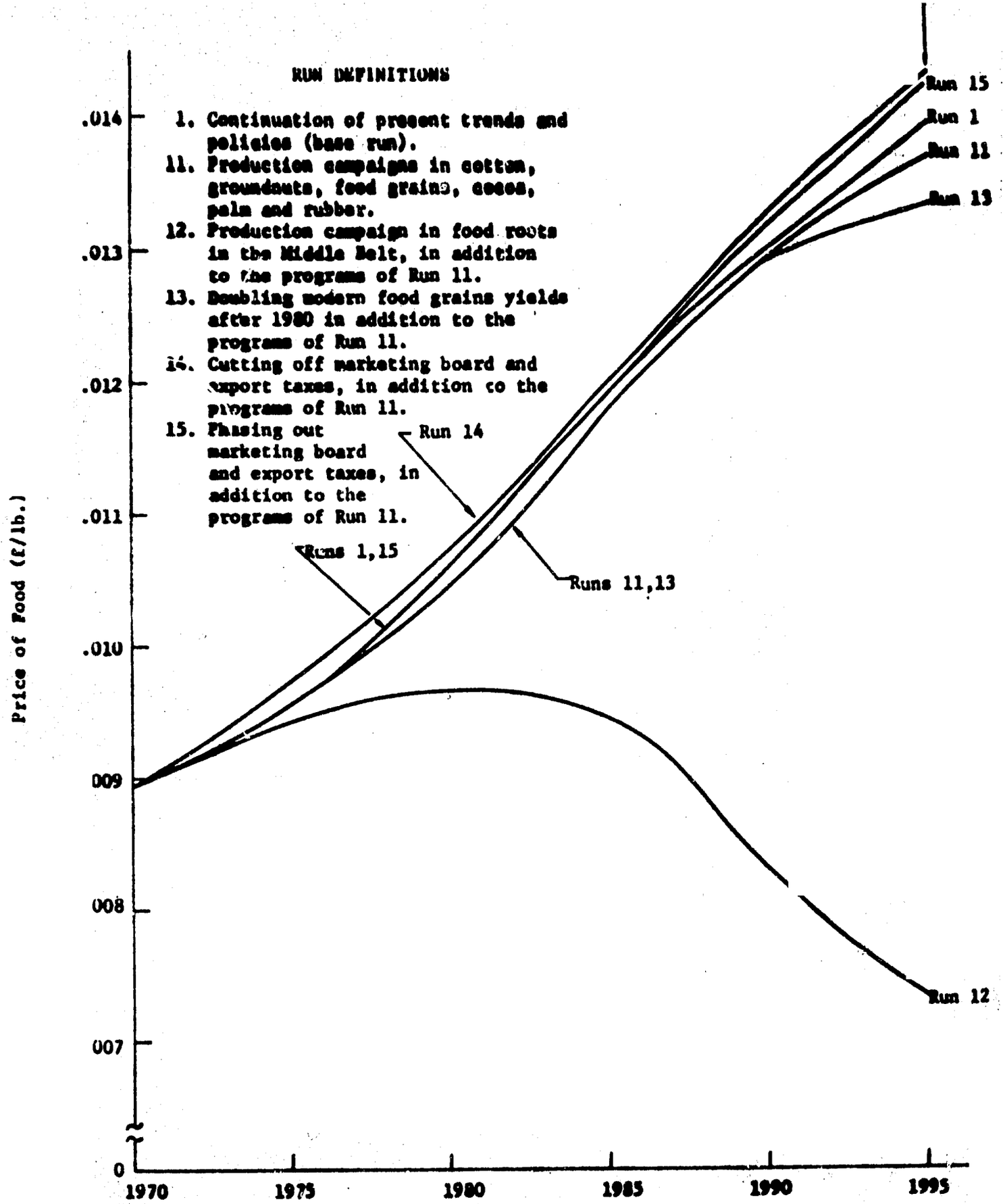


Fig. 17. Market price of food in the North, 1970-1995, under various policy conditions.

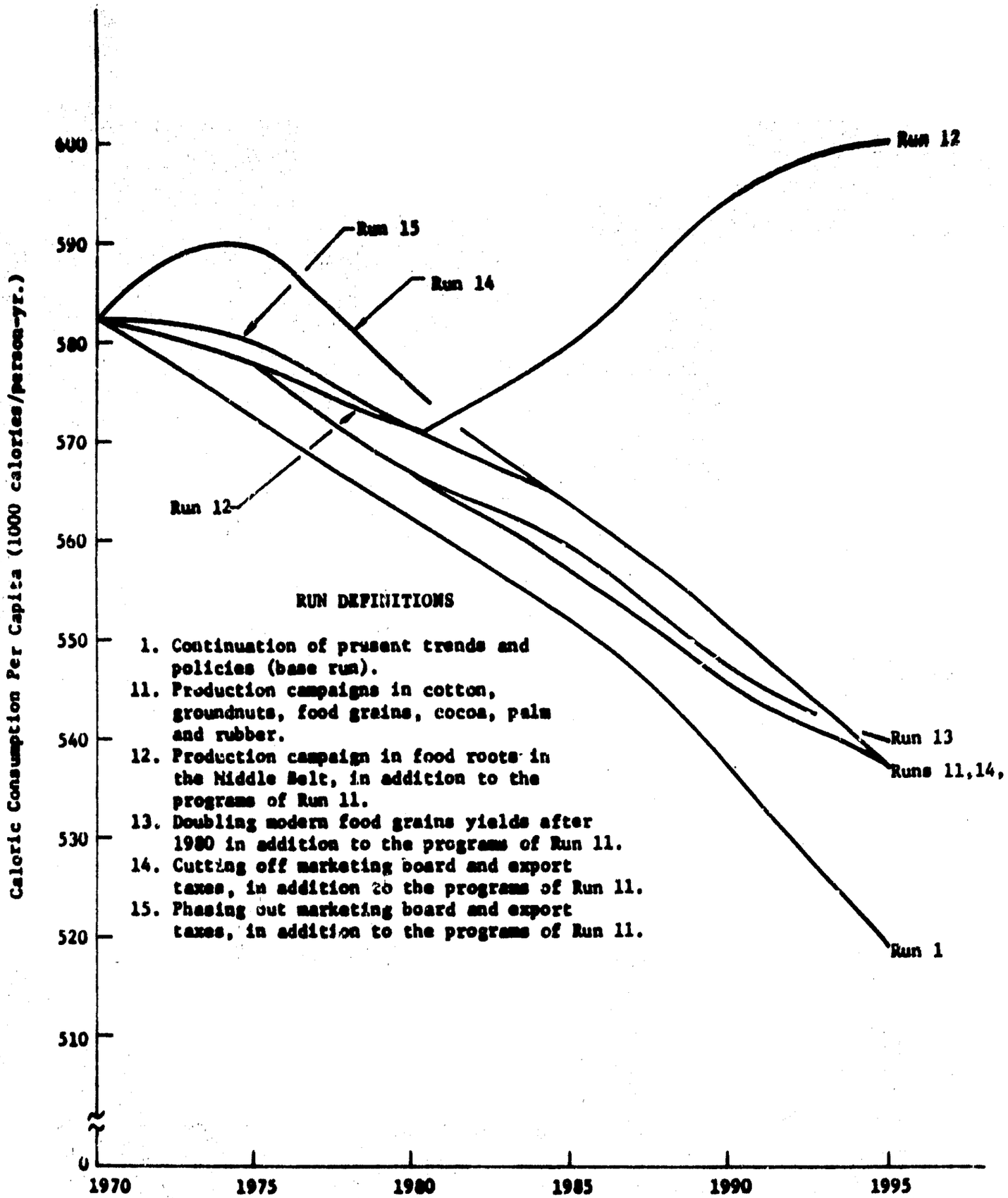


Fig. 18. Caloric consumption (of staples) of the southern nonagricultural population, 1970-1995, under various policy conditions.

proportion of value added and GDP is derived from food production (about 80 percent for agricultural value added and 30 percent for GDP) that these variables at current prices are depressed in Runs 11 and (particularly) 12 due to lower food prices (Figure 17). In "real" terms (i.e., relative to food prices in the base run), Runs 11 and 12 would show even greater improvements over Run 1, with Run 12 probably taking the lead.

Modern food grain yields in the North were gradually doubled in Run 13 over a four to five-year period after 1980 (to five times the current traditional yields) to investigate the consequences of the introduction and diffusion of new technologies expected to be developed during the 1970s. The results show that exports in the North do improve substantially over Run 11 after 1980. Value added also increases slightly. However, by the end of the simulated time period, the results of Run 13 and Run 11 become similar. The initial increase in cash crop acreage, resulting from labor and land freed from subsistence food production, is later reduced as the population continues to expand and more food land is required. Value added in Run 13 eventually falls below that in Run 11 because of the somewhat lower food prices. The effect on southern exports is nil, while the lower food prices cause southern value added to fall slightly and nonagricultural food consumption to rise.

Value added in the North rises more than twice as fast as in the South due to the much more dominant role food plays in northern agriculture. Since food accounts for over 90 percent of value added in the North and only about 75 percent in the South (in the base run), rising food prices and steady or falling export prices result in a more rapid rise in value added in the North compared to the South.

Policy Conclusions

The major conclusion to be drawn from the policy simulation results is that a technological transformation of agricultural export crop production is necessary for sustained economic growth.[11/] Other development policies show short-run benefits which are eventually eaten up by continued population growth, by activated land constraints, and by declining yields of aging perennials. This was true of the tsetse fly eradication program in which initial gains were later lost to a growing cattle population and expanding crop acreages. It was also true of the elimination of marketing board and export taxes, where land constraints and declining yields in the South and an expanding population nationally eventually nullified positive results of the higher producer prices. And it was also true of the food grains modernization programs in the North, where the growing population eventually reversed the gains made in the increased availability of land and labor for export crop production. Only production campaigns to modernize the production of export crops (via the introduction of high-yielding seed varieties and improved cultural practices) had beneficial consequences which were maintained in the long run. In addition, the combination of the export crop modernization programs with the reduction of marketing board and export taxes showed even more pronounced long run benefits due to the complementarity of these policies.

Other conclusions can be made concerning interregional and intersectoral interactions. North-South shipments of food do play a substantial role in feeding the southern population, and indications are that there is

a potential for regional specialization: in the northern Middle Belt area, where roots and tubers (the primary components of southern staple consumption) can be grown, food would be provided for a South which would specialize in export perennial crop production.

Interactions between the nonagricultural and agricultural sectors are strong and indicate that agricultural development can also lead to growth in the nonagricultural sector. For example, rising agricultural incomes mean an increasing demand for nonagricultural consumer and investment goods, creating more employment and higher incomes in the nonagricultural sector. This in turn means greater nonagricultural demands for agricultural products (food and raw materials), a further spur to agricultural income.[12/]

Conclusions

It seems appropriate to try to draw conclusions concerning the stage of development the team has reached in constructing generalized system simulation models. It is felt that the model and many of its components are ready for application. This is not to state that they are complete. However, they are ready for application in the sense that application should always be expected to involve extensive field work and interaction with decision makers which will reveal needed modification and further developments of the models. This will be true whether the models summarized above are applied in Nigeria or in some other country.

It is also the team's conviction that the building blocks or components of these models are potentially useful in a wide variety of countries and situations. The Nigerian components of the model can be taken apart and

reused to simulate and analyze other entire agricultural sectors. The nonagricultural component itself will be generally useful in relating the agricultural economies of various countries to their nonagricultural economies. In addition to being useful in constructing models of the entire agricultural economy of different countries, components developed for the total model are potentially useful in designing, analyzing and evaluating programs and more detailed projects at the subsector level. For example, the perennial crop components designed to model the Nigerian cocoa, rubber and palm subsectors have widespread applicability in modeling corresponding subsectors of other countries. These perennial crop components also have potential applications in the developed world--possibly in modeling the vineyards of California, France and Chile, and the cherry orchards of Michigan. The demographic components used for modeling the Nigerian beef herd may also have many applications in other countries; they could be used to model the cow and buffalo herds of India as well as the cattle population of the United States.

In short, although the components developed are generally applicable in various subsectors of the agricultural sector of many countries, such applications will inevitably involve much field work and a great deal of interaction with decision makers to make the generalized components relevant to specific applications and to find the appropriate data. In this way, components from the Nigerian model have been adapted and successfully applied in Venezuela, Colombia, and Korea [7].

It also appears that the processes which have been modeled are so important to the countries and their decision makers that expatriot advisors themselves

are inherently incapable of fully developing and applying the models. While there are areas in which applications can be made by expatriot advisors and staff members, it must be recognized that full use of these models by a particular LDC requires their mastery by indigenous personnel. In order for the Nigerian model to be fully used in Nigeria, for example, it will have to be mastered by Nigerians and applied, further developed, modified, and extended by Nigerian investigators in closer interaction with Nigerian decision makers than can or should be carried out by foreign advisors.

Finally, the policy decision maker, in evaluating simulated results, must be aware of the assumptions and simplifications built into the model, and he must appreciate limitations that exist vis-à-vis the questions the model is capable of addressing. In particular, the model is principally an economic model which will indicate the likely economic consequences of alternative policies; it was not designed to directly answer social or political questions. The policy-making process must still be responsive to the political pressures and social interests which are indispensable components of that same process. In short, a simulation model, while potentially an integral and important part of the decision-making process, will not replace the decision maker. It will, however, give him more information, help to identify new and economically feasible policy options, and sharpen his intuition, thus making for better decisions.

Footnotes

1/ While it cannot be completely described here, see [1], [3] and [6] for more detail.

2/ The study by Kellogg [5] examines some additional considerations on mortality loss, marketing costs, etc. which could be incorporated into the model for a more comprehensive analysis of this program and others related to the cattle industry.

3/ The initial (1970) cattle population assumed in the model is about five million head (Figure 5). Although this figure is below current estimates of Nigeria's cattle herds, the relative results of Runs 1 and 4 are still valid.

4/ "Range condition" is defined as an index of range land grass yields and reflects the carrying capacity of the range. That is, its value at any time during the simulation period (1970-1995) is the ratio of grass yields at that time to grass yields at the initial time (1970).

5/ The large negative foreign exchange shown in Figure 8 is due primarily to projected import demands of the textile industry being charged to cotton exports. In addition, about 10-20 percent of the indicated imports is beef for consumption.

6/ Disposable income in Figure 9 (and Figure 13) includes wages earned but is net of agricultural sector debt service and interest.

7/ Food accounts for about 90 percent of agricultural value added in the North.

8/ Runs 2 and 3 reduce taxes in both regions.

9/ This delay is due to the natural gestation and maturation lags of the perennials and the longer lags before the innovations are diffused beyond the direct promotion results.

10/ The transformation of processing takes place in the model irregardless of its profitability. It is carried out solely by an exogenous (policy) investment. The model's rudimentary processing component would have to be expanded to more realistically simulate investment decisions.

11/ This conclusion is, of course, dependent on the current model's validity and is limited to the policies and programs tested. It is not inconceivable that there may be some other route to sustained growth than the one indicated here.

12/ See [2] for a fuller discussion of this multiplier effect and other agriculture-nonagriculture interactions.

References

[1] Abkin, Michael H., Policy Making for Economic Development: A System Simulation Model of the Agricultural Economy of Southern Nigeria, unpublished Ph.D. dissertation, Michigan State University, 1972.

[2] Byerlee, Derek R., Agricultural Development and Urban Unemployment: A Simulation Analysis of the Nigerian Economy, unpublished Ph.D. dissertation, Oregon State University, 1971.

[3] Halter, A. N., M. L. Hayenga and T. J. Manetsch, "Simulating a Developing Agricultural Economy: Methodology and Planning Capability, American Journal of Agricultural Economics, 52:272-284, May 1970.

[4] Hayenga, M. L., T. J. Manetsch and A. N. Halter, "Computer Simulation as a Planning Tool in Developing Economies," American Journal of Agricultural Economics, 50:1755-1759, December 1968.

[5] Kellogg, Earl D., A Temporal and Spatial Model to Assist in Evaluating Investments in the Nigerian Beef Distribution System, unpublished Ph.D. dissertation, Michigan State University, 1971.

[6] Manetsch, T. J., et al., A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria, final report to USAID, Michigan State University, November 1971.

[7] Rossmiller, G. E., et al., Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985, report to USAID, Michigan State University, 1972.