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ABSTRACT

THE MOST EFFICIENT PRODUCTION TECHNIQUES FOR PROVIDING NUTRITION AND INCOME FROM THE AGRICULTURAL SECTOR OF NIGERIA

By

Hossein Yaghoobi-Rahmatabadi

The agricultural sector plays the most important role in the course of economic development in the developing countries. It is a source of food for the population and earns foreign exchange. The extent to which a country should expand its export crops at the expense of food crops is an important question. Moreover, in the process of economic development technical changes will be introduced and new varieties of crops developed. Therefore, policymakers are faced with the problem of giving priorities to different projects and different crops.

This research considers the twin objectives of earning income from the cash crops and obtaining nutrients from the food crops and applies a mathematical programming model to the agricultural sector of Nigeria. The model provides Nigeria with adequate nutrition, while maximizing the income obtained from the remaining resources

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which would be used in the cash crop sector. To determine the most efficient production techniques, various ways of producing a given crop are introduced into the model. The optimal solution of the model gives us a production pattern, a consumption pattern, and a trade pattern which are the most efficient in maximizing the revenue obtainable from the agricultural resources left over after feeding the population.

The model examines the various production techniques of crops in different stages. It first introduces improved practices of crop production. These cultural practices--now available to the Nigerian farmers--must compete with the traditional sole and mixed cropping.

Secondly, the model examines prospective varieties --not available to the Nigerian farmers at the present time--in order to explore the gains from further plant breeding programs for major crops.

Thirdly, the model imposes maximum limits on the supply of fertilizer and extension services. The supply of these resources is assumed to be equal to the amounts that could be provided in the short run.

The model seeks answers for several questions important to Nigerian policy-makers. Among these are:

1. What nutritional and income consequences may be expected from the kinds of technical improvements now available?

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2. Of various possible lines of research in plant breeding, which ones promise the greatest return?

3. Which alternative techniques or varieties of crops are most advantageous in a specific situation or area?

4. Can intercropping compete with the new cultural practices?

5. If there is a limit on importation of fertilizer, how should fertilizer be allocated among crops and between areas?

6. If there are limited extension services for the application of the new techniques, which crops or areas should be given priority?

The optimal solutions of the model provide answers for the above mentioned questions. They also determine the most efficient production techniques for providing nutrition and income from the agricultural sector of Nigeria under different assumptions.

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THE MOST EFFICIENT PRODUCTION TECHNIQUES FOR PROVIDING NUTRITION AND INCOME FROM THE AGRICULTURAL SECTOR OF NIGERIA

By

Hossein Yaghoobi-Rahmatabadi

A THESIS

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This research was made possible by a faculty research grant made by the Rockefeller Foundation to Dr. Victor E. Smith and by the continuous support of the Central Bank of Iran. In addition, the International Institute of Tropical Agriculture, in Ibadan, provided invaluable assistance in making arrangements for a data-collecting trip which Dr. Smith and I made to Nigeria in May, 1969, and in facilitating our work while we were there. I express my gratitude to the Central Bank of Iran, to the Rockefeller Foundation, to the International Institute of Tropical Agriculture, and to the many persons, both in this country and in Nigeria, who provided us with data and information. Neither the Central Bank of Iran, the Rockefeller Foundation, nor the International Institute of Tropical Agriculture has any responsibility for the analysis or the findings of this study.

In the preparation of this thesis I am indebted to more persons than I can name, but I would like to express my gratitude to a few salient contributors without whose assistance this research would not have been completed.

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I am indebted to my thesis chairman, Professor Victor E. Smith, who originally became interested in this study, got me involved in it, and worked hard with me through its various stages.

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I express my sincere gratitude to my family--my beloved mother, my dear father, my sisters, and my brother for their understanding, patience, and love.

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Most of all I owe a deep debt of gratitude to Miss Kathie L. Martin and Miss Anna R. Tepker whose moral support and inspiration made it possible for me to continue my studies. To many others that helped me, I express my gratitude.

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CHAPTER I

STATEMENT OF THE PROBLEM

The importance of expansion of the agricultural sector during the process of economic development has been discussed by many. It has been argued that in the course of economic development the agricultural sector is a source of labor for the industrial sector, a source of food for the population, earns foreign exchange, and is a source of raw material for industry.[1]

The expansion of a crop for the purpose of feeding the population does not improve the foreign exchange position unless it is a substitute for food imports. On the other hand, the production of export crops does not improve the nutritional problem of a country unless more economical foods are imported with the earnings. The extent to which a country should expand its cash crops at the expense of food crops is a question to be studied empirically.

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[1] Bruce F. Johnston and John W. Mellor, "The Role of Agriculture in Economic Development," American Economic Review, LI, No. 4 (September, 1961), 571-81.

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In Nigeria, policy makers traditionally have supported the expansion of cash crops while the expansion of food crops was "left to develop on its own within the framework of the unaided market mechanism."[2] Some economists approve of Nigeria's past agricultural policy. Carl Eicher believes that Nigerian agricultural policy has "rightly focused on expanding export rather than food crop production."[3] On the other hand some have mentioned the possibility of a food shortage when a country expands her cash crops too rapidly. Tolley and Gwyer believe that:

> In [some] countries, factor endowments have been such that any production for cash export entailed a reduction in imports for domestic food production, so that the expansion of cash export production was limited by changes in agricultural productivity unless food was imported. Large scale importation of food appears to have been an accompaniment of expanding cash export production in some countries such as Malaya, Indonesia and Peru.[4]

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[2]Godwin Okurume, "The Food Crop Economy in Nigerian Agricultural Policy," CSNRD-31 (East Lansing, Mich.: Michigan State University, February, 1969), p. 2. (Mimeographed.)

[3]Carl K. Eicher, "The Dynamics of Long Term Agricultural Development in Nigeria," Journal of Farm Economics, XLIX (December, 1967), 1150-70.

[4]George S. Tolley and George D. Gwyer, "International Trade in Agricultural products in Relation to Economic Development," Agricultural Development and Economic Growth, ed. by Southworth and Johnston (Ithaca, N.Y.: Cornell University Press, 1967), p. 414.

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There was no empirical research on this subject until Victor Smith[5] built a mathematical programming model for the agricultural sector of Nigeria. He tried to find a pattern of production to provide Nigeria with adequate nutrition, while maximizing the income obtained from the remaining resources, to be used in the cash crop sector. His findings are that:

> Nigerian agricultural revenue can be increased more rapidly by expanding the production of many a food crop (given the maximum limits on other crops and the technical relationships embodied in this model) than by expanding the production of crops that yield revenue directly.[6]

Is the past policy of expansion of export crops in Nigeria--defended by Eicher, analyzed by Tolley and Gwyer and empirically tested by Smith--applicable to the future? This question needs careful consideration.

It is implicit in Smith's work that everything depends on the technical coefficients of the production functions. In the course of economic development technical changes (in the agricultural sector) will be introduced, new varieties of crops will be developed, and new cultural techniques will be practiced; therefore, the production coefficients will change. Policy makers are faced

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[5]Victor E. Smith, "Optimal Resource Allocation for Income and Nutrition," a working paper for the Consortium for the Study of Nigerian Rural Development, Working Paper No. 11, June 1969, East Lansing, Michigan. (Mimeographed.)

[6]*Ibid.*, p. 69.

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It is obvious that the twin objectives of earning income from the cash crops and obtaining nutrients from the food crops are interrelated. This research considers this interrelationship and seeks answers to several questions important to Nigerian policy-makers, if they intend to feed the Nigerian people in the most economical way. Among these are:

1. What are the principal nutritional deficiencies?
2. Which of these may be economic in origin, in the sense that these nutrients are expensive to produce?[7]
3. What nutritional and income consequences may be expected from the kinds of technical improvements now available?
4. Of various possible lines of research in plant breeding, which ones promise the greatest return?
5. Which potential crop varieties or techniques of cultivation can improve the nutritional situation most effectively in terms of the resources used? Which can contribute the most to expanding agricultural income?

In approaching question 5 I shall ask what changes in crop production patterns would contribute the most to:

(a) meeting nutritional needs;

(b) providing revenue for Nigeria.

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[7]By expensive to produce we mean use resources that have high alternative values in income production.

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I shall further ask:

> In which areas shall specific crops be encouraged or discouraged?

In a similar way the following questions are studied:

> Which alternative techniques or varieties of crops are most advantageous in a specific situation or area?
>
> Can intercropping compete with the new cultural practices?
>
> What crops should be fertilized and how?
>
> If there is a limit on importation of fertilizer, how should fertilizer be allocated among crops and between areas?
>
> If there are limited extension services for the application of the new techniques, which crops or areas should be given priority?

To answer these questions I will apply and make use of Smith's model. In Chapter III I shall explain that model in detail.

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CHAPTER II

REVIEW OF PREVIOUS STUDIES

This study utilizes information from different disciplines in order to answer some of the questions a developing country faces in the course of expanding her agricultural sector. Apart from V. Smith's work,[1] there is no study of this kind. But there are related studies in each one of the disciplines from which I have drawn information. I shall refer to some of the related works very briefly.

Nutritionists

Nutritionists have recommended daily per capita nutrient allowances to meet the normal physiological needs of an individual with a given size, sex, age, and weight. In 1862, Edward Smith was first to recommend 4300 grams of carbon and 200 grams of nitrogen as the daily minimum

[1] Smith, "Optimal Resource Allocation for Income and Nutrition."

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allowance.[2] Since then, G. Lusk,[3] H. Lewis,[4] and many others, including scientific groups such as The British Medical Association, The Canadian Council on Nutrition, and The National Research Council of the United States, have proposed daily nutrient allowances.[5]

At the same time other nutritionists have been working on a low cost diet. Wilson, Fisher, and Fugua[6] compared the percentage of a single nutrient from a certain group of foods with the cost percentage of this group of foods. They concluded that the group of foods with the highest ratio of nutrient to cost is the most economical in providing the given nutrient. This method could be applied to a single food instead of a group. But it is not applicable to considering more than one nutrient.

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[2] I. Leitch, "The Evolution of Dietary Standards: Historical Outline," Nutrition Abstracts and Reviews, XI (1942), 509.

[3] G. Lusk, "The Fundamental Requirements of Energy for Proper Nutrition," Journal of the American Medical Association, LXX (1918), 821.

[4] H. Lewis, "Fifty Years of Study of the Role of Protein in Nutrition," Journal of the American Dietetic Association, XXVIII (1952), 701.

[5] Cecilia A. Florencio, "The Efficiency of Food Expenditure Among Working-Class Families in Colombia" (unpublished Ph.D. dissertation, Michigan State University, 1967), p. 11.

[6] E. D. Wilson, K. H. Fisher, and M. E. Fuqua, Principles of Nutrition (New York: John Wiley & Sons, Inc., 1959), Chapter 18.

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Nutritionists such as J. G. Davis[7] and J. G. Armstrong[8] tried to find economical foods for poor families by using measures which consider more than one nutrient. Their measures take into account the nutrients contained in a food, the recommended allowance for each nutrient, and the price of the food. They give equal importance to calories, protein, and other nutrients. However, they fail to give appropriate weights to the scarce nutrients and nutritional deficiencies.

Economists

George Stigler[9] was the first to calculate a low cost diet that can meet physiological needs of an active man. He disregards palatability, taste, and some cultural considerations. He uses a list of 77 commodities for which retail prices are reported by Bureau of Labor Statistics. In his search for a minimum cost diet Stigler suggests that: "One may exclude any commodity all of whose nutritive values (per dollar expenditure) are less than those of some other commodity."[10] Stigler extended this

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[7]J. G. Davis, "The Nutritional Index and Economic Nutritional Index of Food," Dairy Industries, XXX, No. 4 (1965), 193-97.

[8]J. G. Armstrong, "An Economic-Nutritional Index of Foods," Canadian Nutritional Notes, XXII, No. 3 (1966), 25-39.

[9]George Stigler, "The Cost of Subsistence," Journal of Farm Economics, XXVII (1945), 303-14.

[10]Ibid., p. 310.

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procedure by excluding a commodity if it was inferior in its "important nutrients and only slightly superior in others." He fully realizes that his method does not find the exact minimum cost subject to linear conditions. But (in the absence of the computer) Stigler's procedure is practical, since solving the problem by means of linear programming using a desk calculator would take many man-days.

In 1964, V. Smith[11] used a linear programming model to determine a least-cost diet. He was interested in solving the problem for those "whose nutritional problems stem from poverty."

The Smith and Stigler studies are concerned with the minimum cost of a diet when foods are already produced and available on the market. They do not look at the resources employed in producing these foods and the alternative uses of resources. These approaches could be useful only in attempting to improve the nutritional intake of certain individuals. For an entire country suffering from malnutrition and hunger, these approaches are not appropriate. In a poor country in which malnutrition is a result of inadequate food rather than maldistribution, these approaches fail to be helpful. If, for example,

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[11]V. E. Smith, Electronic Computation of Human Diets, Michigan State University Business Studies, Bureau of Business and Economic Research, Graduate School of Business Administration (East Lansing, Mich: Michigan State University, 1964), p. 2.

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there were an increase in the consumption of the foods in the low-cost diet, either some would get a low-cost diet at the expense of others or the production pattern must change in such a way as to provide a low-cost diet for all. In the former case, although the low-cost diet might be helpful to individuals, it does not necessarily help the society as a whole. When there is a shortage of food and some individuals are given foods with high nutritive value, others must get foods with lower nutritive values. In the latter case, if we change the pattern of production to provide a low-cost diet for everyone, the foods which are low in cost will not remain the same, because as production patterns change so do relative prices. With a change in relative prices the selected foods will no longer constitute a low cost diet.

When the problem of poverty and malnutrition stems from inadequate resources, resources should be employed to produce the highest amount of nutrition.

Geographers and Agricultural Economists

The relationship between the allocation of resources and providing nutrients for the population has been studied by some geographers, agricultural economists, and other scientists utilizing interdisciplinary approaches.

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Cooper and Spillman,[12] (in response to the shortages of World War I) were the first to study this area. They calculated the average yield per acre for different crops and computed the edible portion of the average yield. Finally they calculated the amount of protein and calories in this edible portion.

According to the Cooper-Spillman method, if one of these two nutrients were to be increased, the crop produced must have the highest amount of that nutrient per acre of land. This method fails to be helpful, however, if we want to increase two nutrients simultaneously.

In 1943, Christensen,[13] like Cooper and Spillman, was concerned about the growing need for foodstuffs during World War II. Due to the war situation there was a limit to the use of resources, so he tried to develop a method of allocating agricultural resources most efficiently. He suggested that resources should be shifted toward the production of food which would provide the nutrients in short supply. He realized the limit to this transfer because of consumption habits. To take habitual consumption into account he allowed the production of a minimum quantity of some foods which provide nutrients at a very high cost.

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[12] M. C. Cooper and W. J. Spillman, Human Food from an Acre of Staple Farm Products, Farmers' Bulletin 877, U.S. Department of Agriculture (Washington, D.C.: Government Printing Office, 1917).

[13] R. P. Christensen, Using Resources to Meet Food Needs, U.S. Department of Agriculture, Bureau of Agricultural Economics (Washington, D.C.: Government Printing Office, 1943).

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He tried to determine the efficiency of resources used to produce different foodstuffs and concluded that certain field crops, vegetables, and fruits make "most efficient use of land" while others make most efficient use of labor. However, Christensen's measure cannot be applied in assessing the efficiency of labor and land simultaneously.

In 1958, Stamp[14] suggested a method more sophisticated than the Cooper-Spillman method. He raised two questions: (1) How much food is needed to feed an average person? and (2) How much land is required to provide that amount of food?

To answer these questions he assumed that given a variety of foods, if the calorie requirement is met, then all other nutrients will also be provided. He tried to find the efficiency of land when used for several staple foods.

Stamp concluded that 250 kg of the edible portion of wheat is needed to provide enough calories for one man for a year. He assumed that the non-edible portion is 10 per cent and the seed requirement is also 10 per cent, concluding that 300 kg of wheat should be harvested to feed one person one year. He further concluded that, for countries with low productivity, this amount could be obtained from one acre of land.

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[14] L. D. Stamp, "The Measurement of Land Resources," Geographical Review, XLVIII (1958), 1-15.

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Using the same computation for other crops, Stamp concluded that the cultivation of rice can feed slightly more than one person per acre, while the same amount of land devoted to potatoes could feed three persons a year.

He also computed the amount of calories obtained from land if it were devoted to the production of milk and meat. For milk, two and one-half acres of land is required to obtain enough calories for one person per year. For meat, almost seven acres is needed.

Considering the world land shortage, Stamp suggested that a world land use survey be carried out, and that land use patterns be interpreted from the climatological, ecological, and social anthropological points of view. He emphasized the need for planned "land use" with international cooperation.

In 1961, Zobler[15] used a model similar to Christensen's in measuring the efficiency of land. Using his model he compared land efficiency in Japan and the United States. According to his calculations, land in Japan is 7.7 times more efficient than in the United States. But the existence of abundant land in the United States makes it possible there to provide all nutritional requirements except riboflavin, while in Japan only the ascorbic acid requirement could be met.

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[15] L. Zobler, "A New Measure of Food Production Efficiency," Geographical Review, LI (1961), 459-569.

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All the above mentioned studies were concerned with finding the most efficient way of meeting the nutritional requirements for individuals or specific countries. None considered a developing country which must allocate part of its agricultural resources to cash crops. Developing countries are faced with the problem of allocating agricultural resources to obtain the highest earnings from cash crops, as well as meeting their nutritional requirements most efficiently. Some economists have touched on this problem and have tried to solve it.

African Scholars

In 1956, Galletti, Baldwin, and Dina[16] did a sample study of Nigerian cocoa farmers. In their study Galletti and his associates tried to measure the money value efficiency and calorie efficiency of several crops. They measured these efficiencies both in terms of per acre of land and per hour of labor worked on the land.

Galletti, Baldwin, and Dina realized that a farmer is not only faced with the question of maximizing the food value of his production, but with the problem of maximizing the money value of his crop as well. As far as food crops are concerned, it is reasonable to assume that

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[16] R. Galletti, K. D. S. Baldwin, and I. O. Dina, Nigerian Cocoa Farmers: An Economic Survey of Yoruba Cocoa Farming Families (London: Oxford University Press, 1956).

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farmers are "aiming at the highest return per acre and per hour of work in food value."[17] But in case of producing a cash crop like cocoa "the objective of the farmer could be assumed to be to maximize his cash income from the cocoa produced."[18]

Galletti and his colleagues tried to rationalize the geographical specialization in the production of the crops between different villages in their sample survey. Finally they say:

> Since the principal crops have very different values in calories per pound and pence per pound and very different yield per acre and per hour of work, the farmer's view of what it is best to grow will be different according to whether he is developing at the highest return per acre and per hour of work in food value or the highest return in money value.[19]

Bruce Johnston[20] agreed with Galletti, Baldwin, and Dina that farmers aim at the highest food value in producing food crops and at obtaining the highest return in money value when producing cash crops. He realized that food value efficiency should not be measured only by one food element, the calorie. He stated: "obviously, the food value of different staples also depends upon

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[17] Ibid., p. 332.

[18] Ibid., p. 318.

[19] Ibid., p. 332.

[20] Bruce F. Johnston, The Staple Food Economies of Western Tropical Africa (Stanford, Calif.: Stanford University Press, 1958).

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their content of protein and other essential nutrients."[21]

Johnston used the data from Galletti, Baldwin, and Dina's study and reproduced a table of calorie and money value efficiency for different crops. He pointed out that money value efficiency ranks differently from calorie efficiency.

Although it seems that Johnston had most of the ingredients to build a rigorous model, he failed to do so. It is reasonable to say that he did not see the usefulness of linear programming models although he said:

> While strictly speaking it is not possible, of course, to maximize simultaneously yield per acre and return per hour of work, in practice it seems reasonable to suppose that many cultivators pay heed to both objectives.[22]

Smith made use of all the above mentioned disciplines and built a mathematical programming model for the agricultural sector of Nigeria to find an optimal solution for the consumption of food, the production of agricultural produce, and the pattern of trade. Since this study makes use of Smith's model, I will discuss it in the next chapter in more detail.

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[21] Ibid., p. 133.

[22] Ibid., p. 133n.

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CHAPTER III

THE MODELS

Smith Model[1]

The Restraints

The Smith model assumes that the agricultural sector is responsible for feeding the Nigerian people. The objective of the model is to maximize the revenue obtainable from agricultural resources not used to provide food for Nigeria--after providing nutrients for the total population of Nigeria. In providing food for the people of Nigeria, market prices of food play no role in the model. Foods are valued for their nutritional contributions. The model allows the agricultural sector to produce cash crops for export, providing foreign exchange to be spent for imported foods. In this case the revenue is subtracted from payments.

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[1]Victor E. Smith, "Optional Resource Allocation for Income and Nutrition," A working paper for the Consortium for the Study of Nigerian Rural Development, Working Paper No. 11, June 1969. (Mimeographed.)

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Maximize: $\sum_j r$

where (1)

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[2] Ibid

In order to explain the model more clearly I quote V. Smith's mathematical statement of the model.[2]

Maximize:	$\sum_j r_j x_j$		Revenue
where (1)	$x_j \geq o$	and	Restraints
(2) a)	$\sum_j a_{ij} x_j \geq o$	$i = 1$	Foreign Exchange
b)	$\sum_j a_{ij} x_j \gtrless b_i$	$i = 2 \ldots, n$	Nutrition
c)	$\sum_j a_{ij} x_j \gtrless b_i$	$i = n + 1 \ldots, n + h$	Habit
d)	$\sum_j a_{ij} x_j \geq o$	$i = (n + h) + 1 \ldots, (n + h) + c$	Commodity
e)	$\sum_j a_{ij} x_j \geq b_i$	$i = (n + h + c) + 1 \ldots, (n + h + c) + f$	Resource Use
f)	$\sum_j a_{ij} x_j \geq b_i$	$i = (n + h + c + f) + 1 \ldots, (n + h + c + f) + m$	Maximum Limit

Here r_j is the revenue provided by one unit of activity x_j, a_{ij} is the quantity of attribute i possessed by one unit of activity j, and b_i is the quantitative level of the i^{th} constraint.

In the objective function, the revenue, r_j, is positive only if the j^{th} activity represents a sale of produce not used for food within Nigeria. If the j^{th} activity requires a net purchase from outside the Nigerian agricultural sector, r_j is negative. In all other cases it is zero.

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[2] *Ibid.*, p. 26.

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The Smith model allows the production of crops to be expanded 20 per cent beyond the estimate of their 1963 levels. The acreage of arable land, with the exception of Area V, is 9 1/2 per cent beyond the estimate of 1963 level. Arable land in Area V can expand by 332 thousand acres beyond the estimate of 1963, but at the expense of reducing yields on all land in the area. The population of Nigeria is assumed to be 9 1/2 per cent beyond the 1963 estimate. The traditional animal industries are allowed to increase in Area I by 20 per cent, and in Areas II through VI by 9 1/2 per cent beyond the 1963 estimate.

Apart from the kola nut and alcoholic beverages, the consumption of individual foods is allowed to expand up to a level four times the estimate of per capita consumption in a particular area in 1963. The consumption of kola nuts must be at least as much as the estimate of 1963 and the consumption of alcoholic beverages is set equal to estimate of 1963 levels.

The quantity of bush pasture in Area I is assumed to be equal to the estimate of 1963 less the amount of change in arable land from the 1963 estimate. In other areas the quantities of bush pasture are not limiting factors.

The Activities

The Smith model divides activities into the following categories:

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> Consumption activities (which provide nutrients and use agricultural output), production activities (which provide output and use resources), processing activities (which convert agricultural output into other forms for export or use), buying activities (which transfer agricultural produce from one area to another) and exporting activities (which dispose of agricultural output in exchange for revenue and foreign exchange).[3]

In the Smith model, importing activities are consolidated with consumption activities. This is why he does not mention them as a separate category. A sketch of the model is shown in Table 1.

The Areas

Because of differences in production possibilities and consumption habits, Smith divided Nigeria into six ecological areas. Each area has its own restraints and can provide the required nutrients either by production of foods within the area, by buying from other areas, or by importing from outside the country.

Smith's division of Nigeria into six areas is as follows: the Dry Savanna in the North (Area I); the intermediate Savanna (Area II); the Western Moist Forest (Area III); the Central Moist Forest (Area IV); the Eastern Moist Forest (Area V); and the Forest-Savanna Mosaic (Area VI).

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[3] *Ibid.*, p. 33.

TABLE I A Sketch of the Model

Area		I						II						III						IV						V						VI					
	Activities*	C	C	G	P	B	E	C	C	G	P	B	E	C	C	G	P	B	E	C	C	G	P	B	E	C	C	G	P	B	E	C	C	G	P	B	E
	Revenue	-x			x	-x	x	-x			x	-x	x	-x			x	-x	x	-x			x	-x	x	-x			x	-x	x	-x			x	-x	x
Restraints	Foreign Exchange	-x			x		x	-x			x		x	-x			x		x	-x			x		x	-x			x		x	-x			x		x
I	Nutrient	x	x																																		
	Commodity		-x	x	-x	x	-x					-x						-x						-x						-x						-x	
	Resource			x																																	
	Max. Limit			x																																	
II	Nutrient							x	x																												
	Commodity					-x			-x	x	-x	x	-x					-x						-x						-x						-x	
	Resource									x																											
	Max. Limit									x																											
III	Nutrient													x	x																						
	Commodity					-x						-x			-x	x	-x	x	-x					-x													
	Resource																x																				
	Max. Limit																x																				
IV	Nutrient																			x	x																
	Commodity																	-x			-x	x	-x	x	-x					-x							
	Resource																					x															
	Max. Limit																					x															
V	Nutrient																									x	x										
	Commodity																							-x			-x	x	-x	x	-x					-x	
	Resource																											x									
	Max. Limit																											x									
VI	Nutrient																															x	x				
	Commodity					-x						-x						-x						-x						-x			-x	x	-x	x	-x
	Resource																																	x			
	Max. Limit																																	x			

*Key: C = Consume, G = Grow or Produce, P = Process, B = Buy, E = Export

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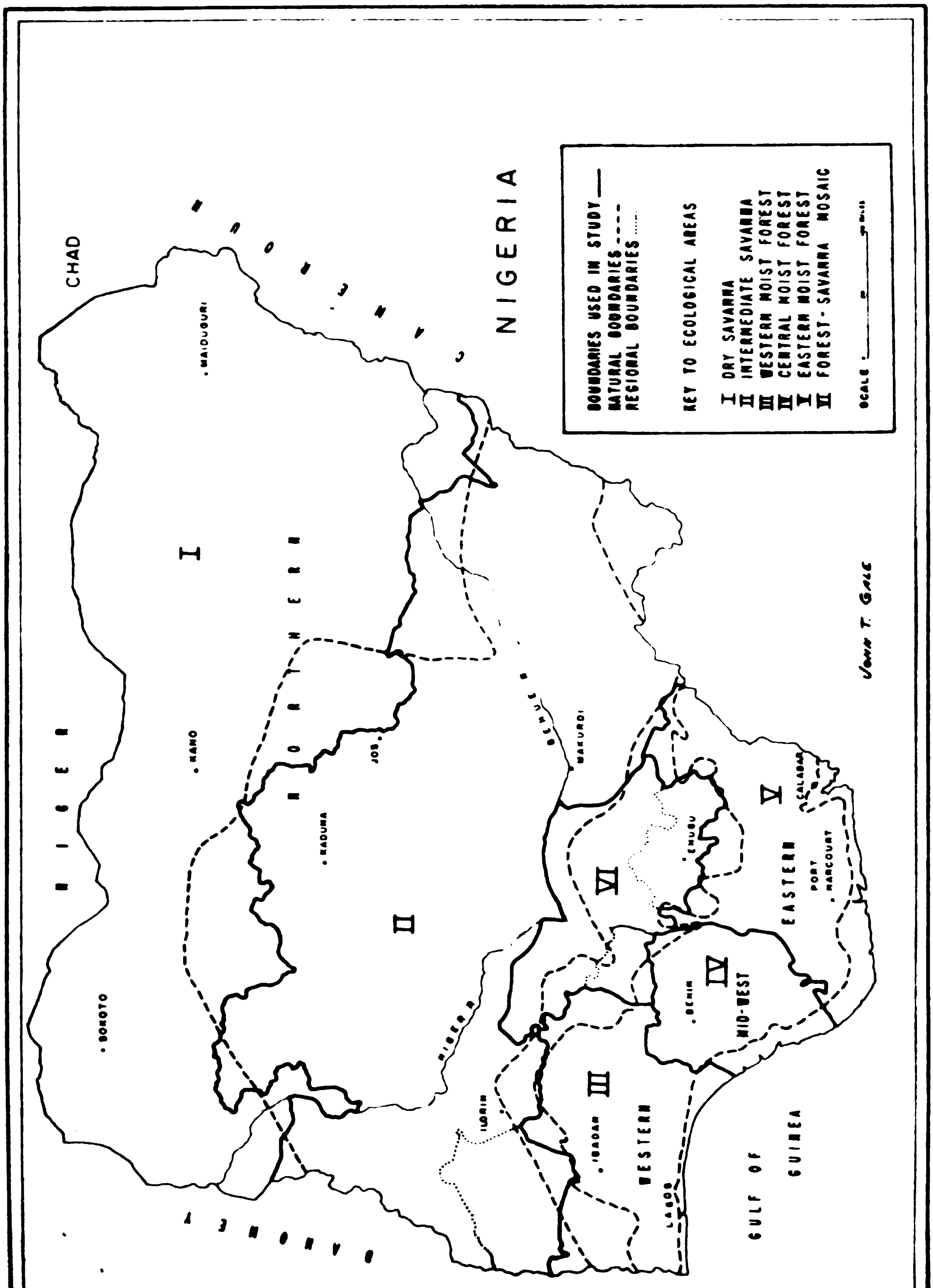
The map on the following page shows the ecological areas Smith used.

Interpreting the Results

The optimal solution will have three groups of production activities: the production activities at zero level; the production activities at positive level (but not maximum); and the production activities at the maximum level allowed by the model. The production activity at zero level will not earn enough to pay for the resources that could be used for other activities. The production activity at a positive level earns enough to pay for the resources it uses. The activity at the maximum level usually earns more than the resources it employs. In this case, if we relax the maximum limit by one unit, the unused resources (in case there are unused resources) or the resources from marginal cases (in the event there are no unused resources) will transfer to this activity (which earns more than the cost of resources it employs) and the revenue could be increased by this amount. If we continue to relax the maximum limit gradually, all the resources used in activities with zero marginal contributions will eventually be transferred. In this case resources will become available only by contracting other activities. Since the expanded activity should pay at least as much for the resources as they earn in the contracted activity,


NIGERIA
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I
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BOUNDARIES USED IN STUDY
NATURAL BOUNDARIES
REGIONAL BOUNDARIES
KEY TO ECOLOGICAL AREAS
I DRY SAVANNA
II INTERMEDIATE SAVANNA
III WESTERN MOIST FOREST
IV CENTRAL MOIST FOREST
V EASTERN MOIST FOREST
VI FOREST-SAVANNA MOSAIC
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FIGURE I

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Changes in the Smith Model

The Smith model utilizes information about the technology and the crops cultivated during the middle or early 1960s in Nigeria. The data used in the model reflect an agricultural sector with only the traditional means of production; namely, labor and land.[4] Most of the cultural practices considered in the Smith model are primitive, reflecting the agricultural sector of Nigeria during the early 1960s. In other words, the production function applied in the model, with minor exceptions,[5] uses only two common agricultural inputs. Capital as a factor of production has been left out of the model.

The optimal solution of any linear programming model may call for expanding some activities. If these activities or their coefficients existed in the past but do not now exist, recommendations would apply to the past rather than the future. We can talk about what should have been done in the past, but will not find guidelines for the future.

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[4]There are two kinds of labor in the model; labor in May and June (the months of heaviest labor employment) and labor during the rest of the year.

[5]There are some minor exceptions; Smith provided for the use of fertilizer in the production of commercial maize to be grown on a very limited acreage of land in Areas III, V, and VI.

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This study will consider future problems in the Nigerian agricultural sector and will seek answers for some of these problems. We will concentrate mainly on the scope for application of new cultural practices (now available to the Nigerian farmers), the introduction of new varieties of crops, and the benefits of plant breeding programs. The production coefficients used in this study, in addition to the production coefficients used in the Smith model, can be generally classified into two categories: (1) the production coefficients for the new cultural practices and new varieties of crops now available to the farmers, and (2) the production coefficients for the cultural practices and varieties of crops that will be available in the future. The data used in this study do not concern us with past problems. The old cultural practices are kept in the model and must compete with the new activities for resources and the capacities (maximum limits) to produce a crop. Therefore, this study realistically takes into account the fact that in order to apply the new techniques they must be superior to the old ones in terms of the objective function of the model.

Application of the new techniques requires capital. Charges relating to the use of capital are included in the models.

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In most cases there are several sets of production coefficients for each particular crop and several models in which these activities must compete with each other. Therefore, each separate model has sets of production coefficients which could correspond to the existing situation at the present time or in the near future.

The classification of activities used in the models for this study is the same as that used in the Smith model, but there are some additional activities, depending on the model.

Since this research is a continuation of Smith's study, the sequence numbers of the models are preserved. A brief description of these models follows: Model 1, in which there are no maximum limits on consumption activities; Model 2, in which there are maximum limits on consumption activities; and Model 3, in which the output levels for animal industries were lowered and the estimates of the milk output of the nomadic herds were raised. Changes in Model 4 were in a wide range of activities and coefficients. For example the coefficients of cropping activities, particularly in Areas I and II, were changed. Further, the percentage of the essential amino acids containing sulfur required to form the fully utilizable protein was raised. Particularly, among other changes, new production and consumption activities were introduced into the model.

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Since Model 4 is my benchmark model I shall describe the changes that occurred from 5 to 7 inclusive.

Model 5: Improved Techniques of Crop Production Included

The differences between Model 4 and Model 5 are the following: (1) There are 69 additional production activities (of which one is mixed cropping and 68 are sole cropping) in Model 5. The additional production activities are the new cultural practices and the new varieties of crops generally available to the Nigerian farmer. These activities and their input-output coefficients are shown in Table 2. (2) The introduction of the tomato in Areas I and III, high lysine maize in Areas III through VI, and yellow maize in Area IV provides new agricultural products which did not exist in Model 4. To dispose of these products two consumption activities for tomatoes in Areas I and III, four consumption activities for high lysine maize in Areas III through VI, and one consumption activity for yellow maize in Area VI were also added to Model 4. (3) To try to keep new production techniques out of Model 4, the production of commercial maize--the only new technique in Model 4--was allowed to expand only to a very limited acreage.[6] But in Model 5 the restriction on the maximum production of this crop was

[6] In Model 4 the production of commercial maize was allowed to expand in Area III up 11,000 acres, in Area V up to 7,000 acres, and in Area VI up to 13,000 acres.

Table 2. Technical Coefficients for Improved Practices Currently Available (Production Activities Introduced as Part of Model 5)

Production Activity	Yield (pounds per acre)	Labor Required: May & June (man-days)	Labor Required: Other (man-days)	Fertilizer Required: Single Super-phosphate (pounds)	Fertilizer Required: Sulphate of Ammonia (pounds)	Fertilizer Required: Muriate of Potash (pounds)	Expenses: Seed: Extra Cost of Improved Seed (shillings)	Expenses: Seed: Dressing (shillings)	Expenses: Storage (shillings)	Expenses: Sprayer and Chemicals (shillings)	Expenses: Other (shillings)	Total Expenses (shillings)
Area I												
Maize, recommended practices	1,500	17	23	196	280		2.5	3.5				6
Millet, recommended practices	800	11	21	56	56			1				1
Rice												
Upland, recommended practices	1,280	20	35		112		2	2				4
Swamp, recommended practices	1,800	22	51	168	336		3	3				6
Sorghum												
Recommended practices	1,150	18	21	112	112		1	1				2
Dwarf variety	2,000	19	17	168	280		1	1				2
Wheat, irrigated	2,240		42.5	168	224		40				130[a]	170
Cassava, sweet, recommended practices[b]	2,375	14.5	15		56							
Potato, Irish, recommended practices	10,000	31	34	224	224	56						
Yam, recommended practices	3,880	22	67		112			37.5				
Cowpea												
Sole												
Recommended practices	440	6	21	84			3			79.5		82.5
New variety	1,000	5	45	80			3			79.5		82.5
Mixed, seed and hay												
Improved variety[c]	120		40									
Groundnut, recommended practices	1,170	13	38	84			2.5	3	.5			6
Onion, recommended practices	13,000		60		112							
Tomato, irrigated	94,000	20	1,000	622	533	92					1,600[d]	1,600
Cotton, recommended practices	860	11	35	112	112					79.5		79.5
Area II												
Maize, recommended practices	1,360	17	23	196	280		2.5	3.5				6
Millet, recommended practices	790	11	21	56	56			1				1
Rice												
Upland, recommended practices	1,280	20	35		112		2	2				4
Swamp, recommended practices	1,800	22	51	168	336		3	3				6
Sorghum												
Recommended practices	980	18	21	112	112		1	1				2
Dwarf variety	2,000	19	17	168	280		1	1				2
Cassava, sweet, recommended practices[b]	2,375	14.5	15		56							

a For water and cultivation.
b The figures are for an acre of cassava of which half is planted in the current year. The other half, planted in the previous year, is being harvested during the current year.
c The yield of hay is 1120 pounds per acre.
d Includes spraying, irrigation, and all expenses except for labor and fertilizer.

Table 2 (cont'd.)

Production Activity	Yield (pounds per acre)	Labor Required: May & June (man-days)	Labor Required: Other (man-days)	Fertilizer Required: Single Super-phosphate (pounds)	Fertilizer Required: Sulphate of Ammonia (pounds)	Fertilizer Required: Muriate of Potash (pounds)	Expenses: Seed: Extra Cost of Improved Seed (shillings)	Expenses: Seed: Dressing (shillings)	Expenses: Seed: Storage (shillings)	Expenses: Sprayer and Chemicals (shillings)	Expenses: Other (shillings)	Total Expenses (shillings)
Potato, Irish, recommended practices	10,000	31	34	224	224	56						
Yam, recommended practices	8,150	21	68		112			37.5				37.5
Cowpea												
Sole												
Recommended practices	410	6	21	84			3			79.5		82.5
New variety	1,000	5	45	80			3			79.5		82.5
Groundnut, recommended practices	1,040	13	38	84			2.5	3	.5			6
Onion, recommended practices	13,000		60		112							
Cotton, recommended practices	630	11	35	112	112					79.5		79.5
Area III												
Maize												
Western White 1, early	2,400	10	70				7					7
Western White 1, late	1,900		80				7					7
Cassava, bitter, new variety[b]	11,000	15	25									
Yam, new variety	12,700	54	150		112							
Cowpea												
Sole												
New variety	600		50					3		69		72
Tomato												
Recommended practices, early	13,400	20	47	207	178					79.5		79.5
Recommended practices, late	31,000		67	207	178					79.5		79.5
Oil palm, new practices	8,000	3.5	16.5								20[e]	20
Cocoa, new practices	1,100	7	33								192[f]	192
Rubber, new practices	950	6.5	33							20	38[g]	58
Area IV												
Maize												
Commercial	1,700	10	70								107[e]	107
Western White 1, early	2,400	10	70				7					7
Western White 1, late	1,900		80				7					7
Cassava, bitter, new variety[b]	10,000	15	25									
Yam, new variety	13,700	54	150		112							
Cowpea												
Sole												
New variety	600		50					3		69		72

e For fertilizer, quantities unspecified.
f 70 shillings of this are for fertilizer; the remainder is for miscellaneous expenses.
g For tools, tractor and other expenses.

Table 2 (cont'd.)

Production Activity	Yield (pounds per acre)	Labor Required: May & June (man-days)	Labor Required: Other (man-days)	Fertilizer Required: Single Superphosphate (pounds)	Fertilizer Required: Sulphate of Ammonia (pounds)	Fertilizer Required: Muriate of Potash (pounds)	Expenses: Seed: Extra Cost of Improved Seed (shillings)	Expenses: Seed: Dressing (shillings)	Expenses: Seed: Storage (shillings)	Expenses: Sprayer and Chemicals (shillings)	Expenses: Other (shillings)	Total Expenses (shillings)
Oil palm, new practices	8,000	3.5	16.5								20[e]	20
Cocoa, new practices	1,000	5	31								188[f]	188
Rubber, new practices	950	6.5	33							20	38[g]	58
Area V												
Maize												
Western White 1, early	2,400	10	70	196	280		7					7
Western White 1, late	1,900		80	196	280		7					7
Rice, swamp, new variety	3,800	60	120	168	336							
Cassava, bitter, new variety[b]	11,500	15	25									
Yam, new variety	14,000	54	150		112							
Cowpea												
Sole												
New variety	600		50					3		69		72
Oil palm, new practices	8,000	3.5	16.5								20[e]	20
Rubber, new practices	950	6.5	33							20	38[g]	58
Area VI												
Maize												
Western White 1, early	2,400	10	70	196	280		7					7
Western White 1, late	1,900		80	196	280		7					7
Millet, recommended practices	650	11	21	56	56			1				1
Rice, swamp, new variety	3,800	60	120	168	336							
Sorghum, recommended practices	720	18	21	112	112		1	1				2
Cassava, bitter, new variety[b]	10,000	15	25									
Yam, new variety	12,700	54	150		112							
Cowpea												
Sole												
New variety	600		50					3		69		72
Groundnut, recommended practices	770	13	38	84			2.5	3	.5			6
Bean, soya, improved practices	2,100	20	30	224								
Oil palm, new practices	8,000	3.5	16.5								20[e]	20

Table 2 (cont'd.)

a For water and cultivation.
b The figures are for an acre of casssava, of which half is planted in the current year. The other half, planted in the previous year, is being harvested during the current year.
c The yield of hay is 1120 pounds per acre.
d Includes spraying, irrigation, and all expenses except for labor and fertilizer.
e For fertilizer, quantities unspecified.
f 70 shillings of this are for fertilizer; the remainder is for miscellaneous expenses.
g For tools, tractor and other expenses.

Source: While some modifications have been made as a result of comparisons with other data, the data given here are based primarily upon information and estimates received from the following:

(1) David Andrews, Institute of Agricultural Research, Samaru.

(2) Dr. Fatunla, University of Ife.

(3) J. H. Green, Department of Plant Science, Institute of Agricultural Research, Samaru.

(4) J. E. Y. Hardcastle, "A Short Description of the Federal Department of Agricultural Research and its Achievements," Departmental Information Paper No. 2, Federal Department of Agricultural Research, Ibadan. Page 4.

(5) Colin Harkness, Institute of Agricultural Research, Samaru.

(6) Kenneth Kopf, Senior Agronomist, U.S. Agency for International Development, Lagos.

(7) Olantunde A. Ojomo, Plant Breeder, Western State Ministry of Agriculture and Natural Resources, Ibadan.

(8) Peter Onosirosun, University of Ife.

(9) Gary Robertson, Acting Deputy Director, Federal Department of Agricultural Research, Ibadan.

(10) William M. Steele, Institute of Agricultural Research, Kano Station, Kano.

(11) Jerome C. Wells, Government Agricultural Investment in Nigeria: 1962-67. Final Report on Project No. 25. Center for Research on Economic Development, University of Michigan, and Nigerian Institute for Social and Economic Research, University of Ibadan. Ann Arbor, Michigan. No date. Pages 105, 132 and 151.

(12) Henry C. Wiggin, Western State Ministry of Agriculture and Natural Resources, Ibadan.

(13) Richard B. Woodroofe, Chief Agricultural Officer, Kano State Ministry of Agriculture, Kano.

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relaxed. This crop was treated like other new techniques. (4) In addition to the production of commercial maize, all the new production practices and new varieties of crops were allowed to compete with both mixed cropping and sole cropping. Each particular crop utilizing new techniques can expand to the sum of the maximum limits of the same crop (in sole and mixed cropping) in any specific area. (5) Thus, Model 5 has 686 activities, 76 activities more than Model 4. The model reflects a situation in which the new production techniques as well as the traditional production practices are available at the same time and most compete with each other.

Model 6: Propsective Varieties of Crops Included

Model 6 has 29 more production activities than Model 5. These are prospective activities using techniques not available to the Nigerian farmers at the present time. They could be available in the future as research on plant breeding continues. These activities and their technical coefficients are shown in Table 3.

This model is designed to explore the possible gains from further plant breeding programs in major crops, assuming that the new techniques introduced in Model 5 are also available. This model is rather a long-run model.

Table 3. Technical Coefficients for Prospective Varieties (Production Activities Introduced as Part of Model 6)

Production Activity	Yield (pounds per acre)	Labor Required: May & June (man-days)	Labor Required: Other (man-days)	Fertilizer Required: Single Super-phosphate (pounds)	Fertilizer Required: Sulphate of Ammonia (pounds)	Expenses: Seed: Extra Cost of Improved Seed (shillings)	Expenses: Seed: Dressing (shillings)	Expenses: Seed: Storage (shillings)	Expenses: Sprayer and Chemicals (shillings)	Expenses: Fertilizer (Minor Elements) (shillings)	Total Expenses (shillings)
Area I											
Maize	4500	18	27	580	840	7	5			3	15
Millet	3000	11	19	150	250	3	1				4
Rice											
Upland	2400	20	40	250	250	2	2				4
Swamp	4000	25	70	350	700	6	6				12
Sorghum	4000	21	19	250	500	2	2				4
Groundnut	1500	14	39	120		2.5	3	.5			6
Bean, soya	1500	20	32	224							0
Cotton	1200	11	45	180	180				79.5		79.5
Area II											
Maize	4500	18	27	580	840	7	5			3	15
Millet	3000	11	19	150	250	3	1				4
Rice											
Upland	2400	20	40	250	250	2	2				4
Swamp	4000	25	70	350	700	6	6				12
Sorghum	4500	21	19	250	500	2	2				4
Groundnut	1500	14	39	120		2.5	3	.5			6
Bean, soya	2100	20	33	224							0
Cotton	1200	11	45	180	180				79.5		79.5
Area III											
Maize											
Early	4000	10	75	580	840	7	5			3	15
Late	3000	0	85	580	840	7	5			3	15
Area IV											
Maize											
Early	4000	10	75	580	840	7	5			3	15
Late	3000	0	85	580	840	7	5			3	15
Area V											
Maize											
Early	3600	10	75	580	840	7	5			3	15
Late	2800	0	85	580	840	7	5			3	15
Rice, swamp	6000	60	130	475	1050	6	6				12
Area VI											
Maize											
Early	4000	10	70	580	840	7	5			3	15
Late	3000	0	80	580	840	7	5			3	15
Millet	3000	11	19	150	250	3	1				4
Rice, swamp	6000	60	130	475	1050	6	6				12
Sorghum	4000	19	25	250	500	2	2				4
Groundnut	1200	14	39	120		2.5	3	.5			6

Source: These data are based upon quantitative judgments made by Ray Olson (Department of Agronomy, Kansas State University), George Sprague (Beltsville Plant Industry Station, Agricultural Research Service, U.S. Department of Agriculture) and John McKelvey (Deputy Director, Agricultural Division, Rockefeller Foundation), in interviews with Glenn L. Johnson (Department of Agricultural Economics, Michigan State University). Some modifications have been made in the original estimates.

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Model 7: Restriction of Supply of Fertilizer and Extension Services

In Model 5 there are no restraints on the availability of extension services or fertilizer importation. Model 5 assumes there are enough extension services for the implementation of the new production techniques at the farm level. With regard to importing fertilizer, in Model 5 there was no limit on the amount of fertilizer that could be imported. As long as the marginal contribution of fertilizer was greater than its cost, the model allowed unlimited importation.

Model 7 puts maximum limits on importation of single superphosphate, sulphate of ammonia, and supply of extension services.[7] The maximum amount of single superphosphate that could be imported is 60 thousand tons and the limit for sulphate of ammonia is 30 thousand tons. These figures are close to the amounts presently imported. The estimate for their imports is 35 and 20 thousand tons respectively.[8]

Regarding the restriction on extension services, the problem was complicated because there were no data on availability of the services or the requirement of each

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[7]There is no limit on importation of muriate of potash but in the optimal solution of Model 7 the level of this activity is zero.

[8]I thank Mr. Colin Harkness (Institute of Agricultural Research, Samaru) for these estimates.

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particular crop. To solve this problem we assumed that the new techniques of production require extension services in the same proportion as they do land. The unit of extension services is expressed in terms of the acreage of land. Each unit of 1,000 for extension services could be used to apply the new techniques to 1,000 acres of land. There were no data on the amount of extension services available, but from Model 5 we had information about the quantity of extension services required when there is no limit on their availability. Therefore we assumed that roughly 25 per cent of the required extension services are available. This limit is equal to the supply of services that can apply the new techniques of production to 4.5 million acres of land.

Thus Model 7 has exactly the same activities as Model 5, but there are additional restraints on importing fertilizer and the availability of extension services. Model 7 looks for the answer to the question when these factors are limiting.

Model 7 is a short-run model and seeks answers to present problems in Nigeria (with limited supply of fertilizers and extension services).

These restraints (on the supply of fertilizer and extension services) would restrict the expansion of new techniques which make use of them as inputs.

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Sources of Data

Data on the nutritional composition of foods, nutrient allowances, food consumption, and nutrient intake are the same as those used in Smith's study. Data on the nutritional composition of foods were obtained from Platt's Tables,[9] Orr and Watt,[10] and the FAO compilation, Amino Acid Content of Foods.[11] Mr. Ephraim O. Idusogie was principally responsible for the data on nutrient allowances, food consumption, and nutrient intake.

Data on technical coefficients of traditional cultural practices, acreages, transportation costs, and the amount of resources available are again the same as those used in Smith's study. Mr. John Whitney obtained the data mostly from the Rural Economic Survey[12] but also made use of information from many other sources.

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[9] B. S. Platt, Tables of Representative Values of Foods Commonly Used in Tropical Countries, Privy Council, Medical Research Council Special Report Series No. 302 (London: Her Majesty's Stationary Office, 1962).

[10] M. L. Orr and B. K. Watt, Amino Acid Content of Foods, Home Economics Research Report No. 4, U.S. Department of Agriculture, Agricultural Research Service, Institute of Home Economics, Household Economics Research Division (Washington, D.C.: Government Printing Office, December, 1957).

[11] Food and Agricultural Organization of the United Nations, Amino Acid Content of Foods (Provisional), Food Consumption and Planning Branch, Nutrition Division (Rome: Food and Agricultural Organization of the United Nations, July 1963).

[12] Nigeria, Federal Office of Statistics, Rural Economic Survey of Nigeria; Lagos, Farm Survey, 1963/64,

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Data on new techniques of production can be classified into two categories: (1) the data concerning the new cultural practices now available to the Nigerian farmers, and (2) the data for the prospective varieties of crops.

The first category of data (Table 2) was collected on a trip to Nigeria in May, 1969. Although there have been some modifications in the original estimates, most of the data were obtained by interviews with the following agriculturalists:

1. David Andrews, Institute of Agricultural Research, Samaru.
2. T. Fatunla, University of Ife.
3. J. H. Green, Department of Plant Science, Institute of Agricultural Research, Samaru.
4. Colin Harkness, Institute of Agricultural Research, Samaru.
5. Kenneth Kopf, United States, Agency for International Development, Lagos.
6. Olatunde A. Ojomo, Plant Breeder, Western State Ministry of Agriculture and Natural Resources, Ibadan.
7. Peter Onosirosun, University of Ife.
8. Gary Robertson, Acting Deputy Director, Federal Department of Agricultural Research, Ibadan.

RES/1966/1, February 28, 1966; Livestock Enquiry, 1963, 64 and 1964/65, RES/1966/2, no date; Farm Survey, 1964/65, RES/1966/5, no date.

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9. William Steele, Institute of Agricultural Research, Kano Station, Kano.
10. Henry Wiggin, Western State Ministry of Agriculture and Natural Resources, Ibadan.
11. Richard Woodroofe, Chief Agricultural Officer, Kano State Ministry of Agriculture, Kano.

In addition to the above mentioned persons, some of the data were drawn from the following sources:

1. J. E. Y. Hardcastle, "A Description of the Federal Department of Agricultural Research and Its Achievements," Departmental Information Paper No. 2, Federal Department of Agricultural Research, Ibadan, p. 4.
2. Jerome C. Wells, Government Agricultural Investment in Nigeria: 1962-1967, Final Report on Project No. 25, Center for Research on Economic Development, University of Michigan and Nigerian Institute for Social and Economic Research, University of Ibadan (Ann Arbor, Mich.: n.d.), pp. 105-32, 151).

The second category of data (Table 3) was collected by Glenn L. Johnson (Department of Agricultural Economics, Michigan State University). These data are based upon quantitative judgments made by the following agriculturalists:

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1. John McKelvey, Deputy Director, Agricultural Division, Rockefeller Foundation.
2. Ray Olson, Department of Agronomy, Kansas State University.
3. George Sprague, Beltsville Plant Industry Station, Agricultural Research Service, United States Department of Agriculture.

There have also been some modifications in this set of data.

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CHAPTER IV

A COMPARISON OF THE EFFICIENCY OF DIFFERENT CROP PRODUCTION TECHNIQUES

This chapter will analyze and mark comparisons between the production techniques for the various crops in different models. The chapter has two objectives: (1) to compare the efficiency of the production techniques of a given crop, and (2) to determine the superior crops and the methods of producing these crops. The evaluation is based on the extent to which an activity can compete with the rest of the activities of the model. The extent to which a cropping technique must compete with the rest of the activities depends on which model we refer to. Each successive model has additional production techniques which must compete with the old activities. To refresh the reader's memory we will explain, very briefly, the models and underlying techniques.[1]

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[1]The models used in this study are explained in detail in Chapter III.

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Résumé of the Models

Models mentioned in this chapter are Models 4, 5, and 6. Model 4 is the benchmark model in which, with the exception of commercial maize,[2] the production activities are the traditional cultural practices. These practices consist of sole and mixed cropping, using the traditional means of production; namely, labor and land.

Model 5 has all the production and consumption activities of Model 4 plus a set of new production activities. These new production activities are either new cultural practices, or new varieties of crops (which give a higher yield per acre of land) or combinations of both (the new variety of crop and the new method of production). These cultural practices or varieties of crops (with the exception of dwarf sorghum and a new variety of cowpea, which will be available shortly) are presently available to Nigerian farmers. Some of the new production activities introduce foods that were not already in the traditional Nigerian diet.[3] To utilize these foods the appropriate consumption activities have been introduced in the models.

To get Model 6 we added other production activities to Model 5. These production activities use prospective

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[2]In Model 4 a limited acreage of land, in Areas III, V, and VI, is allowed to be used for the production of commercial maize. These limits are 11,000 acres in Area III, 7,000 acres in Area V, and 13,000 acres in Area VI.

[3]For example high lysine corn is not now in the diet of Nigerians.

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varieties, not presently available to Nigerian farmers, but which may result from further research on developing new varieties of high yielding crops. This model is designed to examine the benefits of these activities.

Cropping Activities

The models used in this study allow the levels of traditional cropping activities--sole and mixed cropping activities--to expand up to 120 per cent of the estimate of their production levels in 1963. Should the solution of any particular model call for the expansion of these activities to their limits, the expansion would be to the levels allowed in this study--not necessarily the actual levels of cropping activities at the present time.

The new production practices introduced into the models are allowed to expand only up to the sum of the maximum limits for sole plus mixed cultivation of the same crop in each particular area. These new practices must compete with traditional practices for the capacity (maximum limit) allowed for the production of a specific crop in a particular area. In other words, all production activities of all crops must compete for the available "resources" in a particular area. But at the same time the new production practices of a particular crop must also compete with the old practices of the same crop for the given "capacity" for that crop in each area.

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The levels of cropping activities in the optimal solutions of Models 5 and 6 are shown in Tables 4, 5, and 6. The optimal solutions of Models 5 and 6 are such that the levels of many food crops either are less than the benchmark model or go to zero, while the levels of cash crops in most cases are above the benchmark model. The reason for the expansion of cash crop activities at the expense of food crop activities is obvious. The model requires a certain amount of nutrients for the total population of Nigeria. This requirement can be met with less resources when the productivity of these resources increases. The increase in productivity releases some of these factors for the production of cash crops. In other words, when the people are fed adequately the resources shift to the production of cash crops which directly provide revenue.

The crops considered in this study can be divided into three categories: (1) crops grown exclusively for food (nutrient producing crops), (2) crops grown exclusively for export or sale to the non-agricultural sector (income producing crops), and (3) crops grown for food as well as for sale. In these models any increase in the productivity of either food crops, or the crops used for both food and sale will release resources for the expansion of cash crops. That is why, in general, the levels

Table 4. Levels of Food Crop Activities

Activity	Area																							
	I				II				III				IV				V				VI			
	Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model		
		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6
	1,000 acres																							
Maize																								
Traditional practices																								
Sole	9.3	9.3	9.3	0	190	190	0	188	691	691	0	0	1.8	1.8	1.8	1.8	--	--	--	--	16	16	0	0
Mixed	28	28	28	28	440	440	440	440	646	646	0	0	66	66	32	32	437	437	0	0	425	425	0	0
New practices																								
Commercial	--	--	--	--	--	--	--	--	1348	11[a]	0	0	68	--	0	0	444	7.0[b]	0	0	455	13[c]	0	0
Recommended practices	37	--	0	0	630	--	82	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Western White 1, early	--	--	--	--	--	--	--	--	674	--	674	674	34	--	34	34	222	--	0	0	227	--	227	0
Western White 1, late	--	--	--	--	--	--	--	--	674	--	674	674	34	--	0	0	222	--	83	87	227	--	227	138
Prospective variety, early	37	--	--	0	630	--	--	2.4	674	--	--	0	34	--	--	0	222	--	--	0	227	--	--	227
Prospective variety, late	--	--	--	--	--	--	--	--	674	--	--	0	34	--	--	0	222	--	--	0	227	--	--	0
Millet																								
Traditional practices																								
Sole	2309	1705	0	0	20	20	0	0	--	--	--	--	--	--	--	--	--	--	--	--	5.0	0	0	0
Mixed	8274	8224	8274	8224	20	20	20	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	10,533	--	0	0	40	--	20	0	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	0	0
Prospective variety	10,533	--	--	1008	40	--	--	40	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	--	5.0

a The maximum for Model 4 is 11.
b The maximum for Model 4 is 7.0.
c The maximum for Model 4 is 13.
-- The activity is not available in this area.

Table 4 (cont'd.)

Activity	Area I Maximum	I Model 4	I Model 5	I Model 6	Area II Maximum	II Model 4	II Model 5	II Model 6	Area III Maximum	III Model 4	III Model 5	III Model 6	Area IV Maximum	IV Model 4	IV Model 5	IV Model 6	Area V Maximum	V Model 4	V Model 5	V Model 6	Area VI Maximum	VI Model 4	VI Model 5	VI Model 6
Rice, upland																								
Traditional practices																								
Sole	140	140	140	0	25	25	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	140	--	0	0	25	--	25	25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	140	--	--	0	25	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rice, swamp																								
Traditional practices																								
Sole	426	426	426	426	74	74	74	74	--	--	--	--	13	13	0	0	101	101	0	0	78	78	0	0
Mixed	--	--	--	--	--	--	--	--	--	--	--	--	26	26	26	26	7.0	7.0	0	0	4.1	4.1	0	0
New practices																								
Recommended practices	426	--	0	0	74	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New variety	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	108	--	0	0	82	--	82	0
Prospective variety	426	--	--	0	74	--	--	0	--	--	--	--	--	--	--	--	108	--	--	34	82	--	--	82
Sorghum																								
Traditional practices																								
Sole	2002	2002	329	41	889	889	0	0	--	--	--	--	--	--	--	--	--	--	--	--	5.0	5.0	0	0
Mixed	6260	6260	6260	6260	2629	2629	2118	2629	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	8262	--	0	0	3518	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	0	0
Dwarf variety	3300	--	1672	0	1400	--	1400	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	8262	--	--	0	3518	--	--	759	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	--	0
Wheat																								
Traditional practices																								
Sole	73	73	73	73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Irrigated	8.0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 4 (cont'd.)

Activity	Area																							
	I				II				III				IV				V				VI			
	Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model		
		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6
Cassava, bitter, root[d]																								
Traditional practices																								
Sole	--	--	--	--	--	--	--	--	512	512	0	0	164	164	0	0	188	188	0	0	293	293	0	0
Mixed	--	--	--	--	--	--	--	--	640	640	0	0	133	133	133	133	525	525	0	0	647	647	0	0
New practices																								
New variety	--	--	--	--	--	--	--	--	1153	--	0	0	297	--	1.4	33	713	--	0	0	940	--	0	583
Cassava, sweet, fresh[d]																								
Traditional practices																								
Sole	317	317	0	317	940	940	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	317	317	317	317	840	840	840	840	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	634	--	317	0	1780	--	313	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potato, Irish																								
Traditional practices																								
Sole	9.7	5.2	5.2	5.2	84	84	55	84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	4.2	0	0	0	8.4	8.4	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	14	--	0	0	93	--	37	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potato, sweet																								
Traditional practices																								
Sole	6.0	6.0	6.0	6.0	12	12	12	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	18	18	18	18	36	36	36	36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cocoyam																								
Traditional practices																								
Sole	--	--	--	--	--	--	--	--	25	25	0	25	5.0	5.0	5.0	5.0	62	62	0	0	--	--	--	--
Mixed	--	--	--	--	--	--	--	--	136	136	0	0	75	75	75	75	248	248	0	0	--	--	--	--

d It is assumed that half the cassava acreage is in its first year and the other half has a crop that is in its second year.

Table 4 (cont'd.)

Activity	Area I Maximum	I Model 4	I Model 5	I Model 6	Area II Maximum	II Model 4	II Model 5	II Model 6	Area III Maximum	III Model 4	III Model 5	III Model 6	Area IV Maximum	IV Model 4	IV Model 5	IV Model 6	Area V Maximum	V Model 4	V Model 5	V Model 6	Area VI Maximum	VI Model 4	VI Model 5	VI Model 6
Yam																								
Traditional practices																								
Sole	455	455	154	0	449	449	0	449	470	470	0	0	39	39	0	0	277	277	0	0	240	240	0	0
Mixed	241	241	241	241	269	269	0	269	235	235	1.1	45	394	394	0	0	917	917	0	0	504	504	0	0
New practices																								
Recommended practices	695	--	0	0	718	--	718	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New variety	--	--	--	--	--	--	--	--	705	--	537	518	432	--	346	314	1194	--	713	675	744	--	577	411
Cowpea																								
Traditional practices																								
Sole, seed	15	0	0	0	20	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	1.4	0	0	0
Mixed																								
Seed	3020	0	0	0	4325	3628	465	4065	--	--	--	--	--	--	--	--	24	4.0	0	0	884	729	0	0
Seed and hay	3020	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Sole, seed																								
Recommended practices	3034	--	0	0	4346	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New variety	3034	--	0	0	4346	--	720	0	32	--	.45	0	8.0	--	0	0	24	--	0	0	885	--	333	0
Mixed, seed and hay																								
Improved variety	3034	--	0	3034	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Melon seed																								
Traditional practices																								
Sole	19	19	19	19	53	53	53	53	75	75	75	75	3.2	3.2	0	0	1.8	1.8	0	0	7.7	7.7	0	0
Mixed	39	39	39	39	78	78	78	78	85	85	85	85	133	133	0	0	316	316	0	0	96	96	96	96
Okra																								
Traditional practices																								
Sole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9.6	9.6	0	0
Mixed	--	--	--	--	--	--	--	--	264	0	0	0	89	89	0	0	60	60	0	0	30	30	0	0
Onion																								
Traditional practices																								
Sole	350	300	0	0	175	150	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																								
Recommended practices	350	--	159	159	175	--	77	77	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tomato																								
New practices																								
Recommended practices, early	--	--	--	--	--	--	--	--	3.0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Recommended practices, late	--	--	--	--	--	--	--	--	3.0	--	3.0	3.0	--	--	--	--	--	--	--	--	--	--	--	--
Irrigated	1.0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

a The maximum for Model 4 is 11.
b The maximum for Model 4 is 7.0.
c The maximum for Model 4 is 13.
d It is assumed that half the cassava acreage is in its first year and the other half has a crop that is in its second year.
-- The activity is not available in this area.

Table 5. Levels of Cash Crop Activities

Activity	Area																							
	I				II				III				IV				V				VI			
	Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model		
		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6
	1,000 acres																							
Groundnut[a]																								
Traditional practices																								
Sole	1543	1543	0	0	220	220	0	0	--	--	--	--	--	--	--	--	--	--	--	--	67	0	0	0
Mixed	3416	3416	0	0	370	370	0	0	--	--	--	--	--	--	--	--	--	--	--	--	101	0	0	0
New practices																								
Recommended practices	4959	--	4959	0	590	--	590	0	--	--	--	--	--	--	--	--	--	--	--	--	168	--	168	0
Prospective variety	4959	--	--	4959	590	--	--	590	--	--	--	--	--	--	--	--	--	--	--	--	168	--	--	168
Bean, soya[a]																								
Traditional practices																								
Sole	10	10	10	0	10	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	185	110	0	0
New practices																								
Improved practices	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	185	--	185	185
Prospective variety	10	--	--	10	10	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cotton																								
Traditional practices																								
Sole	248	248	0	0	339	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	248	248	0	0	359	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	52	0	52	52
New practices																								
Recommended practices	495	--	495	0	698	--	698	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	495	--	--	495	698	--	--	698	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tobacco																								
Traditional practices																								
Sole	4.0	4.0	4.0	4.0	11	0	11	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

a Groundnut and soya bean are food crops as well as cash crops.
-- The activity is not available in this area.

Table 6. Levels of Tree Crop Activities

Activity	Area																							
	I				II				III				IV				V				VI			
	Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model		
		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6
	1,000 acres																							
Oil Palm																								
Traditional practices	--	--	--	--	--	--	--	--	1265	1265	0	0	223	223	0	0	2409	1792	0	0	964	964	0	0
New practices	--	--	--	--	--	--	--	--	1265	--	1265	1265	223	--	223	223	2409	--	2409	2409	964	--	964	964
Cocoa																								
Traditional practices	--	--	--	--	--	--	--	--	1325	545	0	0	52	52	0	0	--	--	--	--	--	--	--	--
New practices	--	--	--	--	--	--	--	--	1325	--	1325	1325	52	--	52	52	--	--	--	--	--	--	--	--
Kola Nut																								
Traditional practices	--	--	--	--	--	--	--	--	603	603	548	548	--	--	--	--	--	--	--	--	--	--	--	--
Rubber																								
Traditional practices	--	--	--	--	--	--	--	--	24	0	0	0	482	356	0	0	48	0	0	0	--	--	--	--
New practices	--	--	--	--	--	--	--	--	24	--	24	24	482	--	482	482	48	--	48	48	--	--	--	--

-- The activity is not available in this area.

of many cash crop activities expand at the expense of food crops (see Tables 4 and 5).

Food Crops

Table 4 shows that the levels of some particular food crops or specific cultural practices for a given crop would go to zero in the solutions of Models 5 and 6. These are the activities for which the yield or their nutrient value (or both) is so low that they can not earn enough to employ resources. The activities at positive but not at maximum levels earn enough to pay for the resources they employ. On the other hand, there are some activities that remain at their maximum level in the solutions of Models 5 and 6. These activities, generally, earn more than the alternative cost of the resources they use. Expansion of this set of activities would increase the revenue obtainable from the agricultural sector.

To analyze the effects of new techniques of production, we will examine each crop individually in different models.

Model 5

Maize.--The new maize production practices introduced in Model 5 are commercial maize in Area IV,[4]

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[4]In Areas III, V, and VI limited acreages of commercial maize were allowed to be produced in Model 4 (the benchmark model). In Model 5 these limits were raised to the sum of sole plus mixed cropping maize in these areas.

recommended practices in Areas I and II and Western White 1 (early and late crops) in Areas III through VI.

In the solution of this model, the levels of traditional practices of mixed crop activities in Areas I and II are at their maxima (Table 4). Therefore, these activities can compete with the new practices of maize production in producing maize in these areas.

The solution level for recommended practices is zero in Area I and 82 thousand acres in Area II.

The new variety of maize called Western White 1 (early and late crops) uses all the existing maximum limits maize in Areas III and VI. In Area IV only the early crop can expand to its maximum limit. In Area V the level of the late crop is positive but not at its maximum.

As compared to the other activities of maize production, commercial maize is not profitable and the levels of commercial maize are zero in all areas where these activities exist (III through VI).

Millet.--The new cultural practices of millet production introduced in this model are recommended practices in Areas I, II, and VI.

In the solution of this model, the traditional mixed cropping activities are able to compete with the recommended practices to produce millet in Areas I and II. These activities expand to their maximum limits in these areas (Table 4). Since the remaining capacity left over from mixed cropping in Area II is used by the recommended practices, and the sole cropping cannot use any of this capacity, the recommended practices are superior to the traditional sole cropping practices.

Rice.--The new practices of rice production introduced in this model are recommended practices of upland and swamp rice in Areas I and II and the new variety of swamp rice in Areas V and VI.

In the solution of this model, recommended practices of upland rice can compete with the traditional sole cropping only in Area II, but not in Area I, the principal growing area for upland rice (Table 4). But the recommended practices for swamp rice cannot compete with the traditional sole cropping (neither in Area I nor in Area II). The new variety of swamp rice is able to compete with both sole and mixed cropping practices in Area VI and uses all the capacity of swamp rice allowed in this area. In Area V no type of rice culture is in the solution of the model.

Sorghum.--The new practices introduced in Model 5 are the recommended practices in Areas I, II, and VI and dwarf variety in Areas I and II.

Table 4 shows that the solution level for recommended practices is zero in all three areas. The production of dwarf variety of sorghum is profitable to its maximum limit in Area II, but in Area I the solution level for this variety of sorghum is 1,700 thousand acres and its expansion beyond this limit is not profitable. The traditional mixed cropping practice is superior to the sole cropping in Area II because it uses the remaining capacity left over from dwarf variety in Area II. In Area I, the mixed cropping practice is profitable to be expanded to its maximum limit, while the sole cropping practice can be expanded to 330 thousand acres.

Wheat.--Irrigated wheat in Area I is the only new wheat production activity introduced in Model 5.

The solution level for irrigated wheat is zero. Given the technical coefficients of the model, this method of wheat production is not profitable because of the high cost of irrigation and other expenses, while the traditional sole cropping wheat--with a lower yield and no irrigation cost--can compete with all old and new activities of the model for resources. This activity is expanded to its maximum limit.

Cassava.--The new practices introduced in this model are the new variety of bitter cassava in Areas III through VI and the recommended practices of sweet cassava in Areas I and II.

Neither the traditional practices of producing bitter cassava (sole and mixed cropping) nor the new variety of the crop is profitable in Areas III, V, and VI. The solution level for these activities is zero (see

Table 4). But in Area IV the traditional sole cropping practice is at its maximum level while only 1,400 acres of the total capacity available for this crop is allocated to the new variety.

The mixed cropping practice of sweet cassava are worth carrying on to their maximum levels in Areas I and II, while the level of the traditional sole cropping is zero in both areas. In the solution of Model 5, the remaining capacity left over from mixed cropping of sweet cassava in Area I is used by recommended practices. In Area II part of remaining capacity left over from mixed cropping is used by recommended practices and the rest of the capacity is left unusued.

Irish Potato.--The new practices introduced in this model are recommended practices in Areas I and II.

In Area I neither the mixed cropping practice nor the recommended practices of potato production can compete with the other production activities of the model for employing the resources. The level of these activities is zero in the optimal solution of the model (see Table 4). The level of sole cropping practice is positive but not maximum in Area I. However, in area II the levels of recommended practices and traditional sole cropping practices are positive but not at their maximum while the level of mixed cropping practices is zero in this area.

Sweet Potato.--No new practices of sweet potato production were introduced in Model 5. The traditional practices of sole and mixed cropping can compete with all other new and old activities for resources. The solution level for the traditional practices of this crop is at the maximum for both sole and mixed cropping in Areas I and II, where this crop is produced (Table 4).

Cocoyam.--There are no new practices of cocoyam production in this model. The traditional practices of sole and mixed cropping must compete with the new and old production activities of the other crops for resources.

The traditional practices of sole and mixed cropping are able to compete with the old and new practices of other crops only in Area IV, but not in Areas III and V. The solution level for traditional practices of sole and mixed cropping is at the maximum in Area IV and zero in Areas III and V (see Table 4).

Yam.--The new practices introduced in this model are recommended practices in Areas I and II and the new variety of yam in Areas III through VI.

In the solution of this model the recommended practices can compete with the traditional practices of sole and mixed cropping in Area II. This activity exhausts all the allowed capacity for the production of yam in the area. But in Area I the traditional practices are superior to the recommended practices. In this area

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the level of recommended practices is zero while the level of mixed cropping is at its maximum and the level of sole cropping is positive but not maximum.

The new yam variety is superior to traditional practices in yam production. It can take over part of the capacities for the production of yam in Areas III through VI. But the traditional practices of yam production, with the exception of mixed cropping in Area III (with its solution level at 1,000 acres), cannot fill the capacities allowed in the model (see Table 4).

Cowpea.--The new practices introduced in this model could be divided into sole and mixed cropping practices. There are two kinds of new sole cropping practices: (1) recommended practices in Areas I and II, and (2) the new variety of cowpea in Areas I through VI.

Cowpea is an inferior crop compared to others because, in the solution of the model, the level of most techniques of producing this crop in different areas is either zero or negligible as compared to the capacities allowed (see Table 4). The solution level for recommended practices and traditional sole cropping is zero in Areas I and II. The level of the new variety of cowpea is also zero in Areas I, IV, and V but positive (not maximum) in Areas II, III, and VI.[5]

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[5]The solution level in Area III is only 450 acres.

Regarding mixed cropping there is an improved variety which produces both seed and hay for raising sheep. This activity is available only in Area I. The solution level for this activity is zero in Model 5.

Melon Seed.--No new cultural practices of melon seed were introduced in Model 5. The traditional sole and mixed cropping practices of the crop must compete with all other production activities of the model for resources.

Melon seed is a superior crop because the traditional mixed cropping practices in Area VI and both sole and mixed cropping practices in Areas I, II, and III can compete with all the old and new practices of other crops for resources. The solution for these activities is at their maximum levels (Table 4).

Okra.--No new cultural practices of okra were added to Model 5. There are traditional practices of sole cropping in Area VI and traditional practices of mixed cropping in Areas III through VI in the model. These activities must compete with all other production activities of the model for resources.

In the solution of the model, these activities cannot compete with old and new practices of other crops for resources. The solution level for this crop is zero in all areas (see Table 4).

Onion.--The new cultural practices of onion introduced in this model are recommended practices in Areas I and II.

The recommended practices of onion production are superior to the traditional practices in both areas. The recommended practices use up part of the allowed capacities for onion production in both areas while the level of sole cropping is zero in the solution of the model (Table 4).

Tomato.--The new cultural practices of tomato added to this model are: (1) irrigated tomato in Area I, and (2) recommended practices (early and late crops) in Area III.

In the solution of the model the level of irrigated tomato in Area I is zero because of the high cost of the implementation of this method (see Table 2). The level of early crop of recommended practices in Area III is zero while the level of late crop of recommended practices--which has a higher yield per acre--is at its maximum (see Table 4).

Model 6

Maize.--The new practices introduced in Model 6 are prospective varieties of maize. It is considered as early crop in Areas I and II and as both early and late crops in Areas III through VI.

The solution of the model shows that the prospective variety of maize is not promising in most of the areas. It cannot compete with other methods of maize production in Areas I, III, IV, and V. Only the early crop in Area VI, with its yield per acre higher than the late crop, can expand up to its maximum limit, while in Area II it can take only a small amount of the capacity--2,400 acres--from the traditional sole and mixed cropping (see Table 4).

Millet.--The new practices of millet production added to Model 6 is the prospective variety of millet.

The solution of the model shows that in Areas II and VI, where a limited acreage of land is allocated for millet production, the prospective variety can compete with other activities of millet production for the use of the capacity. But in Area I, the principal area for millet production, the prospective variety cannot compete with the traditional mixed cropping for the full use of the capacity. It uses only a part of the capacity left over from mixed cropping. Mixed cropping still is profitable and can expand up to its maximum limit in this area (Table 4).

Rice.--The new practices of rice production introduced in Model 6 are: (1) the prospective variety of upland rice in Areas I and II, and (2) the prospective variety of swamp rice in Areas I, II, V, and VI.

The solution of the model shows that the prospective variety of upland rice is not profitable in either area. Its solution level is zero in both Areas I and II (see Table 4).

With regard to swamp rice, the prospective variety can compete with other activities of Area VI for the use of resources. It can expand up to its maximum limit in this area but in Area V the level of prospective variety is positive but not maximum. The prospective variety of swamp rice cannot compete with the other production activities of the model for resources in either Area I or Area II, therefore, they are not profitable in these areas.

Sorghum.--The new practices introduced in this model are for the prospective variety of sorghum in Areas I, II, and IV.

The solution of the model shows that the prospective variety of sorghum cannot compete with the traditional sole and mixed cropping for the use of capacity in Area I, the principal growing area. The solution level of prospective variety is zero in this area. Its level is also zero in Area VI, where a small acreage of land--5,000 acres--is allowed to be used. Only in Area II part of remaining capacity, left over from traditional mixed cropping is allocated to the prospective variety (Table 4).

Wheat.--No new production activity of this crop was introduced in Model 6. The traditional sole cropping and irrigated wheat in Area I must compete with all old and new activities of other crops for resources in this area.

In the solution of Model 6 the traditional sole cropping can compete with all other old and new activities for resources. The solution level for this activity is at its maximum (Table 4). But irrigated wheat is not economical to be produced because of high cost of irrigation and other expenses.

Cassava.--No new practices for this crop were introduced in this model. The production activities for this crop are the same as for Model 5 and they must compete with all new and old activities of other crops of Model 5 for resources.

In the solution of the model, the traditional mixed cropping of bitter cassava in Area IV can still compete with the new activities of this area for resources. The new variety of bitter cassava, which was at zero level in Area VI in Model 5, becomes positive in this model and its level in Area IV rises from 1,400 acres to 33,000 acres (see Table 4).

The traditional mixed cropping practices of sweet cassava can compete with old and new activities in Areas I and II. The recommended practices of sweet cassava become uneconomical to produce in this model. It is replaced by sole cropping in Area I and it goes to zero in Area II.

Irish Potato.--No new production activities for Irish potato were introduced in this model. The production activities of this crop are the same as Model 5 and must compete with all other production activities of Model 6 for resources.

The solution of this model shows that the traditional sole cropping is superior to recommended practices. The level of traditional cropping in Area I remains positive--the same as Model 5. But in Area II it expands at the expense of recommended practices. The level of recommended practices in Area II, which was 37,000 acres in Model 5, goes to zero in Model 6 (see Table 4).

Sweet Potato.--The production activities for this crop in Model 6 are only the traditional sole and mixed cropping practices. These activities must compete with the new and old practices of other crops for resources.

The solution of all these models shows that this is a profitable crop. It can compete with all other activities of the models for resources. In all three models (Models 4, 5, and 6) the level of both sole and mixed cropping is at maximum (see Table 4).

Cocoyam.--There are no new practices for cocoyam production in this model. The production practices of this crop in Model 6 are the traditional sole and mixed cropping. These activities must compete with the other activities of Model 6 for resources.

The solution of the model shows that in Area III only sole cropping is profitable to be produced at its maximum limit while in Area IV the levels of both sole and mixed cropping are at their maximum (Table 4). In

Area V neither sole cropping nor mixed cropping is profitable to be produced in this model.

Yam.--No new activities for yam production were added to Model 6. The traditional sole and mixed cropping in Area I through VI, are recommended practices in Areas I and II and the new variety of yam in Areas III through VI must compete with all other production activities of the model for resources.

The solution of the model shows that the level of the new variety of yam contracts from Model 5 to 6 in Areas III through VI, because other crops, which have advantages over the new variety, use part of the resources. In Area II both traditional sole and mixed cropping, which do not need fertilizer, go to their maximum limit at the expense of recommended practices. In Area I only the level of sole cropping expands to its maximum (see Table 4).

Cowpea.--No new practices in cowpea production were added to Model 6. The production activities of this crop are the same as in Model 5. These activities must compete with the other production activities of this model for resources.

In the solution of this model, with the exception of mixed cropping, the level of the production activities for cowpea is zero. Mixed cropping practices are profitable in this model. New practices of mixed cropping, which apply an improved variety of cowpea for both seed and hay, exhaust the total capacity allowed for the

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production of cowpea in Area I. However, in Area II the traditional mixed cropping of cowpea cannot expand to the maximum limit (see Table 4).

Melon Seed.--The cultural practices of this crop in Model 6 are the traditional sole and mixed cropping practices. These practices must compete with the old and new practices of other crops for resources.

The crop is superior in Areas I, II, and III because the traditional sole and mixed cropping can compete with new practices of other crops for resources. The solution levels for both sole and mixed cropping are at maximum in these areas. In Area VI only mixed cropping can expand to the maximum limit. But in Areas IV and V the traditional practices cannot compete with other production activities for resources (see Table 4).

Okra.--The production activities of this crop in Model 6 are sole cropping in Area VI and mixed cropping in Areas III through VI. They must compete with the other production activities for resources.

The solution of the Models 5 and 6 shows that when the new practices of other crops were introduced in these models, the production of this crop no longer remains profitable. The solution level for all activities of this crop is zero in all areas in Models 5 and 6 (see Table 4).

Onion.--The traditional sole cropping and recommended practices of onion are the production activities of this crop in Model 6. These activities must compete with other production activities of the model for resources.

In the solution of this model the level of production activities for onion remains the same as Model 5. The solution level for traditional sole cropping is zero and for recommended practices positive in both Areas I and II (see Table 4).

Tomato.--No new additional activity in tomato production was introduced in Model 6. The production activities of this crop in Model 6 are: (1) irrigated tomato in Area I, and (2) recommended practices (early and late crops) in Area III.

Irrigated tomato production is not profitable because of its high cost. The solution level for this activity is zero. The solution for the early crop of recommended practices in Area III is zero but the level of late crop, which has a higher yield per acre, is at its maximum (see Table 4).

Cash Crops

The cash crops in this study can be divided into two categories: (1) crops that do not have food value and are used merely for sale to the non-agricultural sector or outside Nigeria, and (2) crops that could be used for food purposes as well as for sale. Cotton and tobacco constitute the first category and groundnuts and soya beans form the second category.

The production of crops that do not have food value (cotton and tobacco) will not appear in the solution of any model unless there are free resources in that area after meeting the nutritional requirement of the model. Resources will not be shifted to the production of cash crops unless the nutritional requirement is met, if those resources have any use in producing the nutrients needed.

The production level of the crops that have both nutritional and export value will exhaust the total capacities allowed for these crops in most models. When the nutritional requirement is not met in other ways, these crops will be used as food crops and when the requirement is met they can be used as cash crops. Unless the resources in a particular area are used by crops with higher earnings or with higher value in the production of nutrients, the production levels of these crops will be at their maxima.

To analyze the production level of cash crops in Models 5 and 6 each model is explained.

Model 5

Groundnuts.--The new cultural practices considered in this model are the recommended practices in Areas I, II, and VI.

The traditional sole and mixed cropping practices were at maximum level in the solution of benchmark model in Areas I and II. But these activities cannot compete with the recommended practices for the use of capacity in Model 5. The recommended practices of groundnuts will exhaust the total allowed capacity for this crop in all areas (see Table 6).

Soya Bean.--The new production activity of soya bean introduced in Model 5 is the improved practices in Area VI.

In the solution of the model the improved practices can compete with the traditional sole cropping for the capacity to produce soya bean in Area VI, the principal area for soya bean. In Area I, where a limited acreage for soya bean production is allowed, the traditional sole cropping can compete with all new and old production activities of other crops for the resources. The solution level for this activity is at its maximum. In Area II the traditional sole cropping is not profitable in this model. The solution level for this activity is zero (see Table 5).

Cotton.--New production practices are introduced in this model for cotton production in Areas I and II.

In the solution of the model the recommended practices can compete with the traditional sole and mixed cropping practices for the capacities allowed. The recommended practices exhaust the total capacities allowed for the production of this crop in both Areas I and II. The traditional mixed cropping practices in Area VI are able to compete with the other crops for the resources. The level of this activity is at its maximum (see Table 5).

Tobacco.--The cultural practice in tobacco production is sole cropping in Areas I and II. The method of production, under the general guidance of Nigerian Tobacco Company, is at a high level of technical competence. Production activities for this crop are promising. In the solution of the model this crop can compete with all other production activities for resources, and its level is at maximum in both areas (Table 5).

Model 6

Groundnuts.--The new production activities for groundnuts added to Model 6 are for the prospective varieties of groundnuts. These activities are promising and they can take over the capacities allowed for production from the recommended practices in all three areas (I, II, and VI). The solution levels for the prospective varieties are at the maxima in Areas I, II, and III (see Table 5).

Soya Bean.--The new production activities for soya bean introduced in this model are production of the prospective varieties of the crop in Areas I and II. The prospective variety of soya bean is promising and production is at the maximum in both areas. In Area VI the improved practice of the crop can compete with the production activities of other crops for resources. Its solution level is at the maximum in this model (see Table 5).

Cotton.--The new production activities for cotton introduced in Model 6 are in production of the prospective varieties in Areas I and II. These prospective varieties of cotton are promising. In the solution of this model these activities exhaust the total capacities allowed for the production of cotton in both areas. They can take over the capacities from recommended practices of cotton production. In Area VI, the mixed cropping practices of the crop can compete with all other production activities of the model for resources. The solution level for this activity is at the maximum (see Table 5).

Tobacco.--No new cultural practices were added to this model. The current sole cropping of tobacco in Areas I and II must compete with all other production activities of the model for the resources available. These activities are able to compete for resources in both areas. The solution level for these activities are at the maximum in Areas I and II (see Table 5).

Tree Crops

The tree crops considered in this study could be divided into three categories: (1) the crops that do not have nutritional value and are solely for export (cocoa and rubber); (2) the crop that has only nutritional and pleasure value (kola nut); and (3) the crop that could be used for food purposes as well as for export (oil palm).

The production of crops that do not have food value (cocoa and rubber) will not be in the solution of any of the models unless there are free resources in that area after meeting the nutritional requirements of the model.

The production of the crop that has only nutritional and pleasure value (kola nut) can be at maximum or positive level but not at zero level because of the nature of restraint on consumption of this crop. In the model there is a minimum limit on the consumption of kola nut which must be satisfied. In order to satisfy this requirement, the production level should be positive and at least as much as the requirement.

The production of the crop that has both nutritional value and export value (oil palm) will exhaust the total capacities allowed for this crop in most areas and models. When the nutritional requirement is not met in other ways it will be used as a food, and when the requirement is met by other foods, it could be used as a cash crop. Unless all resources in that area are used by crops with a higher earning or with higher value in the production of nutrients the production of this crop will generally be at its maximum.

To describe the production of tree crops in Models 5 and 6 each of the crops will be discussed separately.

<u>Model 5</u>

<u>Oil Palm</u>.--The traditional practices of oil palm production are available in Areas III through VI. In Model 5 the new production practices of the crop were introduced in these areas. These two sets of activities must compete with each other for the use of capacities in the areas.

The new practices of this crop are promising. Solution of the model shows that these activities exhaust the total capacities in all areas (see Table 6).

<u>Cocoa</u>.--Cocoa is produced only in Areas III and IV. In these areas the new practices for cocoa production must compete with the traditional practices for the capacities.

The new practices of cocoa production are profitable and can take over the allowed capacity for this crop in both areas (Table 6).

<u>Kola Nuts</u>.--No new production practices of this crop were introduced in this model. The traditional practices in kola nut production in Area III are the only activities for this crop. The solution level for kola nut production is 548 thousand acres (Table 6). It cannot go below this level even if this activity does not make an efficient use of resources because the minimum

restraint on consumption of kola nuts must be satisfied in all three areas (I, II, and III) where the crop is consumed. This amount of production is required to satisfy the consumption restraint.

Rubber.--The traditional practices of rubber production are available in Areas III, IV, and V. In Model 5 new production practices of rubber were introduced in these areas.

The solution of the model shows that rubber production becomes profitable in Areas III and VI due to the introduction of new practices (Table 6). The traditional production of rubber was not an efficient use of resources in Model 4.

Model 6

Oil Palm.--No additional production practices for oil palm were introduced in Model 6. The traditional and new practices of oil palm production must compete with the other production activities of the model.

The solution of the model shows that the new practices for oil palm production are promising. They are able to compete with all new and old production activities of Model 6 for the resources. The level of these activities are at maximum in all areas (see Table 6).

Cocoa.--There are no additional production practices for cocoa in Model 6. The same activities of cocoa production (traditional and new practices) must compete with other production activities of Model 6 for resources.

The new production practices of the crop are profitable in both areas. The solution levels for these activities are at the maximum in both Areas III and IV (see Table 6).

Kola Nuts.--The traditional cultural practices of kola nuts in Area III are the only production activities considered for this crop.

The solution level for kola nut production is again at 548 thousand acres (see Table 6). The level of this activity cannot be less than this figure even if this crop is not economical to produce. The reason, again, is that the minimum restraint on the consumption of kola nuts must be satisfied in all three areas where this crop is consumed.

Rubber.--The cultural practices for rubber considered in this model are the traditional and the new practices in Areas III, IV, and V, as in Model 5.

The new practices in rubber production are profitable in all areas. The solution levels for these activities are at their maxima in all three areas (see Table 6).

CHAPTER V

THE EFFECTS OF IMPROVED CROPPING TECHNIQUES UPON RESOURCE USE, ANIMAL INDUSTRIES, AND PATTERN OF TRADE

The introduction of new production methods with different technical coefficients will affect resource use, the levels of the animal industries, and trade patterns. This chapter will examine the allocation of resources in the different models and levels of resource use in different areas. It will explain the solution level and the desirability of expanding the animal industries. It will also describe the optimal patterns of trade for the different areas and models.

Resource Use

Table 7 shows that the available labor during May and June will be used up in Areas III and V in all three models. In Area VI, 1.5 per cent of the available labor is unused in Model 4 (the benchmark model), but this unused labor will be used in Models 5 and 6. The introduction of new practices in Models 5 and 6 will increase

Table 7. Quantities of Resources Available and Unused

Resource and Area	Quantity Available	Quantity Unused			Percentage Unused		
		Model			Model		
		4	5	6	4	5	6
Labor in May and June (1000 man-days)							
I	449,000	173,000	175,000	201,400	38.5	39.0	44.9
II	181,150	77,200	66,000	78,400	42.6	36.4	43.3
III	84,290	0	0	0	0	0	0
IV	51,580	2,400	20,100	21,300	4.7	39.0	41.3
V	92,140	0	0	0	0	0	0
VI	70,000	1,030	0	0	1.5	0	0
Labor during Rest of Year (1000 man-days)							
I	1,795,800	1,250,000	1,276,000	1,173,200	69.6	71.1	65.3
II	797,200	520,000	560,000	487,800	65.2	70.2	61.2
III	404,100	145,000	0	2,600	35.9	0	.6
IV	247,500	79,600	140,500	144,500	32.2	56.8	58.4
V	442,400	212,000	63,200	64,200	47.9	14.3	14.5
VI	336,200	164,000	51,600	84,600	48.8	15.3	25.2
Land under Cultivation (1000 acres)							
I	15,041	0	0	0	0	0	0
II	6,534	0	0	0	0	0	0
III	5,188	238	0	0	4.6	0	0
IV	1,260	0	0	0	0	0	0
V	3,390	0	0	0	0	0	0
VI	2,830	0	0	0	0	0	0

Table 7 (cont'd.)

Resource and Area	Quantity Available	Quantity Unused: Model 4	Quantity Unused: Model 5	Quantity Unused: Model 6	Percentage Unused: Model 4	Percentage Unused: Model 5	Percentage Unused: Model 6
Additions to Land under Cultivation* (1000 acres)							
V	322	321	0	0	99.7	0	0
Bush Pasture (1,000,000 acres)							
I	784	0	0	0	0	0	0
II	847	823.9	823.9	823.9	97.3	97.3	97.3
III	2.64	1.91	1.91	1.91	72.3	72.3	72.3
IV	2.64	2.19	2.19	2.19	83.0	83.0	83.0
V	10.99	8.89	8.89	8.89	80.9	80.9	80.9
VI	99.55	91.97	91.97	91.97	92.4	92.4	92.4
Manure* (1000 metric tons)							
I	3,000	0	1,411	1,411	0	47.0	47.0
II	1,500	3.1	729	729	.2	48.6	48.6

* This resource was introduced into the models only for the areas listed.

the revenue obtainable from an additional unit of labor during the months of May and June in Areas V and VI, but it decreases the revenue obtainable from an additional unit of this resource in Area III from 70 shillings to 2.4 shillings per man day (see Table 8).

Except for Model 5, and then only in Area III, there is unused labor for the rest of the year in all areas and all models. In Model 5 only Area III uses all the labor available. However, in this case an additional man day of labor can earn only .24 shillings.

Land is a scarce factor in all areas in Models 5 and 6. In the benchmark model (Model 4), only in one area (Area III) is 4.6 per cent of the land unused. The introduction of new production practices with different technical coefficients in Models 5 and 6 changes the importance of the different resources, because the new production activities generally have a higher yield per acre. The importance of land as a scarce factor declines in Models 5 and 6. Table 8 shows that the revenue obtainable from an additional acre of land, except in Area III, diminishes as new production techniques are introduced. In Area III the revenue obtainable from an additional acre of land increases from zero in Model 4 to 99 shillings in Model 5 and then declines to 70 shillings in Model 6.

There is unused bush pasture in Areas II through VI, but in Area I, 100 per cent of the available bush pasture is used. In this area the revenue obtainable

Table 8. Revenue Obtainable from an Additional Unit of Resource*

Resource	Unit	Area																	
		I			II			III			IV			V			VI		
		Model			Model			Model			Model			Model			Model		
		4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
		Shillings																	
Labor, in May and June	man-day	0	0	0	0	0	0	69.98	3.30	2.43	0	0	0	8.78	15.21	17.71	0	8.67	8.97
Labor, other	man-day	0	0	0	0	0	0	0	.24	0	0	0	0	0	0	0	0	0	0
Land, arable	acre-year	177	61	33	1380	99	40	0	99	70	386	286	286	515	344	209	593	172	156
Land, arable, additional	acre-year	--	--	--	--	--	--	--	--	--	--	--	--	0	232	351	--	--	--
Pasture, bush	acre-year	4.42	.82	.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manure	long ton	11.54	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--

* This table shows the potential gain from having one additional unit of a specific resource to use, subject to the conditions of the model. Those conditions include maximum limits upon production and consumption activities and constant quantities of all other resources.

These values are the opportunity-cost valuations of the resources.

-- The resource is not considered in this area.

from an additional acre of pasture decreases from 4.42 shillings per acre (in Model 4) to .82 shilling in Model 5 and .75 shilling (in Model 6).

In this study manure is used only for the production of onions. Onion production in the benchmark model exhausts the amount of manure allowed for in Area I. An additional ton of manure would increase the income by 11.5 shillings. But with the introduction of new cultural practices in Models 5 and 6, the production of onions will not expand enough to use all available manure and an additional ton of manure will not contribute to revenue (see Table 8).

To conclude, labor during the months of May and June is a scarce factor in Areas III, V, and VI in both Models 5 and 6. If Nigerians plan to use machinery to release labor during this season, priority should be given to these areas.

Labor during the rest of the year is scarce only in Area III and Model 5. In all other areas and models there is unused labor which could be used in sectors other than agriculture.

Land is a scarce resource in all areas in both Models 5 and 6. The possibility of increasing arable land should be studied. Table 8 shows the revenue obtainable from an additional acre of land in different areas. If land is more scarce in a particular area this revenue will be higher. Therefore, this table is a useful guide for giving priority for expanding the land available.

Animal Activities

With the exception of Area I, the models used in this study allow the levels of animal activities to expand to 109.5 per cent of the estimate of the output levels for each particular area in 1963. In Area I the animal activity levels are allowed to expand to 120 per cent of the 1963 estimate. If it appears from the solution of any particular model that further expansion of these activities would be profitable, the expansion would be beyond the levels allowed in this study--not necessarily the actual levels of animal industries at the present time.

Table 9 shows the levels of the animal industries in the optimal solutions of the models and the maximum limit allowed for the expansion of each particular activity. Except for bush cattle in Area I, the levels of the traditional animal industries are at the maximum in all areas and all models. The level of bush cattle in Area I cannot go to its maximum limit because pasture land is a limiting factor. The earnings per acre of pasture land in Area I are more if pasture is allocated to the production of goats and sheep than bush cattle. Therefore, the production levels of goats and sheep are at their maxima, the level of bush cattle cannot reach its maximum. The pasture land left over from grazing goats and sheep can produce 870

Table 9. Levels of Animal Industries

Activity	Unit	Area																							
		I				II				III				IV				V				VI			
		Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model			Maximum	Model		
			4	5	6		4	5	6		4	5	6		4	5	6		4	5	6		4	5	6
Cattle, bush	1,000 head -- output	1072	869	869	869	336	336	336	336	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	3.3	3.3	3.3	3.3	28	28	28	28
Cattle, commercial	1,000 head -- output	--	--	--	--	11.0	0	0	3.5	--	--	--	--	--	--	--	--	6.0	0	0	0	1.2	0	0	0
Goats	100,000 head -- output	28.9	28.9	28.9	28.9	11.0	11.0	11.0	11.0	2.96	2.96	2.96	2.96	2.08	2.08	2.08	2.08	8.9	8.9	8.9	8.9	1.8	1.8	1.8	1.8
Sheep, bush	100,000 head -- output	8.4	8.4	8.4	8.4	4.4	4.4	4.4	4.4	.56	.56	.56	.56	.066	.066	.066	.066	1.4	1.4	1.4	1.4	3.4	3.4	3.4	3.4
Sheep, hay-fed	100,000 head -- output	a	0	0	4.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Swine, commercial	1,000 head -- output	28.9	0	0	0	7.2	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chickens, commercial	100,000 chicks -- input	--	--	--	--	5.3	0	0	0	7.9	0	0	0	--	--	--	--	b	0	0	0	b	0	0	0

a Limited by the production of cowpea hay.
b Limited by the feed production of the Ministry of Agriculture.
-- The activity is not available in this area.

thousand head of bush cattle. The model considers the production of hay-fed sheep only in Area I. The level of this activity is zero in Models 4 and 5 and positive in Model 6. Neither the commercial pork nor the poultry production activities can earn enough to employ resources in any area. The levels of these activities are at zero in all three models.

Table 10 shows the potential gain from the expansion of each particular activity in different models. The potential gain from the expansion of the animal industries declines as we go from Model 4 to 5 and 6. As new techniques of production are introduced, nutrients become more abundant and the importance of animal meat as a source of nutrients declines.

To conclude: in Area I, where pasture land is a scarce factor, we should economize by expanding the production of sheep and goats. Their earnings per acre of pasture are higher than for bush cattle in that area. But in Areas II through VI where pasture land is abundant, we should consider the revenue and the cost of raising per head of cattle.[1]

With the exception of commercial cattle in Area II and Model 6, modern animal activities--commercial pork and commercial chicken--are not profitable. In Area II

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[1]Only the potential revenue is shown in Table 10. The cost of raising the various animals must also be considered but there are no available data in these models.

Table 10. Additions to Revenue Possible if an Animal Activity were Expanded*

Activity	Unit	Area I, Model 4	Area I, Model 5	Area I, Model 6	Area II, Model 4	Area II, Model 5	Area II, Model 6	Area III, Model 4	Area III, Model 5	Area III, Model 6	Area IV, Model 4	Area IV, Model 5	Area IV, Model 6	Area V, Model 4	Area V, Model 5	Area V, Model 6	Area VI, Model 4	Area VI, Model 5	Area VI, Model 6
									Shillings										
Per Unit of Activity																			
Cattle, bush	head -- output	0	0	0	581	164	161	692	226	223	416	103	103	386	109	107	386	109	107
Cattle, commercial[a]	head -- output	--	--	--	0	0	0	--	--	--	--	--	--	0	0	0	0	0	0
Goats	head -- output	59	35	31	90	36	32	60	28	28	45	18	16	63	25	22	72	29	26
Sheep, bush	head -- output	87	46	40	109	41	36	59	27	27	67	25	21	61	23	20	70	27	23
Sheep, hay-fed	head -- output	b	b	b	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Swine, commercial	head -- output	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Chickens, commercial	100 chicks -- input	--	--	--	0	0	0	0	0	0	--	--	--	b	b	b	b	b	b
Per Acre-Year of Pasture																			
Cattle, bush	head -- output	0	0	0	19.4	5.5	5.4	28.8	9.4	9.3	33.3	8.3	8.3	16.1	4.5	4.5	2.8	.8	.8
Cattle, commercial[a]	head -- output	--	--	--	0	0	0	--	--	--	--	--	--	0	0	0	0	0	0
Goats	head -- output	4.9	2.9	2.6	11.2	4.5	4.0	33.6	15.8	15.7	22.4	9.0	8.0	34.8	14.0	12.5	14.3	5.7	5.1
Sheep, bush	head -- output	5.8	3.0	2.6	10.9	4.1	3.6	19.6	8.9	8.8	22.3	8.2	7.1	20.4	7.7	6.8	8.8	3.3	2.9
Sheep, hay-fed	head -- output	c	c	c	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Swine, commercial	head -- output	c	c	c	c	c	c	--	--	--	--	--	--	--	--	--	--	--	--
Chickens, commercial	100 chicks -- input	--	--	--	c	c	c	c	c	c	--	--	--	c	c	c	c	c	c

* The entries show the gain possible if a single activity were to be expanded by a small amount, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a The pasture for commercial cattle makes use of arable land.

b The model imposes no direct limit on this activity.

c Not a pasture-using activity.

and Model 6 the level of commercial cattle expands to an output of 3,500 head. The expansion of commercial cattle (in Model 6) in Area II is profitable only to this limit.

Patterns of Trade

Shipping commodities from one place to another place involves three categories: exporting, importing, and buying. Exporting activities ship agricultural surpluses abroad to earn revenue and foreign exchange. These activities are either explicit or consolidated with consumption, processing, or production activities. Explicit export activities are for groundnut seed, groundnut cake, cotton, cocoa, and rubber. Export activities for hides and skins are consolidated with consumption. The export or sale activities consolidated with production or processing are for tobacco, palm kernel, and palm kernel oil.

Import activities bring commodities into Nigeria. They have a negative revenue effect, a part of which is the foreign exchange required. These activities are either explicit or consolidated with production or consumption. The explicit import activities are for three kinds of fertilizers: sulphate of ammonia, single superphosphate, and muriate of potash. Activities consolidated with production activities are the importation of fertilizers for the production of commercial maize, oil palm, and cocoa. The import activities consolidated with consumption are for sugar, European beer, wheat flour, whole wheat, and salt codfish.

Buying activities transfer commodities from one area to another. They have a negative revenue effect equal to the transportation costs. With the exception of buying activities for fertilizers--which ship fertilizers for agricultural production--these activities ship produce to areas where it will be consumed. The effect of the transportation charges to these activities is that in the solution of the model no commodity is transferred to any area unless its nutrient value is at least as much as the cost of transportation and production.

In the models discussed in this chapter there are no maximum limits on either export, import, or buying activities. The level of these activities in the optimal solution of any model is limited directly by the amounts of the commodities produced or consumed, and indirectly by the maximum limits on consumption and production activities. The solution levels of the export, import, and buying activities determine the pattern of trade between areas as well as for Nigeria as a whole.

Exports or Sales to the Non-Agricultural Sector

Area I.--In the optimal solution of Model 5 the revenue producing activities for this area are the export of groundnuts and the sale of cotton and tobacco. A large portion of the revenue (2,742 million shillings out of 3,028) comes from the export of groundnut seed (see section A of Table 11). The revenue from export or sale of cotton and tobacco are 282 and 3.6 million shillings respectively.

In the optimal solution of Model 6, the revenue producing activities are the same as in Model 5, but the revenue obtained from export of groundnut seed and sale of cotton in Model 6 is higher than in Model 5. The prospective varieties of groundnuts and cotton, which have a higher yield per acre of land, use the total capacities allowed for the production of these crops and yield larger amounts of these export products. This, in turn, provides a higher revenue for the area in Model 6.

Area II.--The revenue producing activities in Model 5 are again the exportation of groundnuts and the sale of cotton and tobacco. The principal revenue producing activity in this area is cotton (in contrast to Area I in which groundnut production is the principal revenue producing activity). The total revenue for this area is 500 million shillings of which 292 million shillings come from the sale of cotton, 198 million shillings from the export of groundnut seed, and the remaining 10 million shillings from the sale of tobacco (see section A of Table 11).

The revenue obtained from the export activities of Area II will increase from 500 million shillings in

Table 11. Summary of Revenue Transactions

Activity	Area																		Total		
	I			II			III			IV			V			VI					
	Model			Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
							Million shillings														
A. Transactions Yielding Revenue (on balance)																					
Export hides and skins[a]																					
Beef							.055	34	34	17	.028	.028	38	38	38	16			71	72	72
Goat							4.1	4.1	4.1	7.9	7.9	7.9	86	86	86	16	16	16	114	114	114
Sheep							.63	.63	5.6	5.0	5.0	5.0	31	31	31	2.5	2.5	9.5	39	39	51
Sell cotton	104	282	394		292	557											9.0	9.0	104	583	960
Export																					
Groundnut, seed	36	2742	3515		198	361													36	2,940	3,876
Groundnut cake	114																		114		
Bean, soya																	82	82		82	82
Sell tobacco	3.6	3.6	3.6		10	10													4	14	14
Export																					
Cocoa							382	2550	2550	20	91	91							402	2,641	2,641
Rubber								30	30	137	589	589		59	59				137	678	678
Palm kernel										17	59	59	137	658	658	67	243	243	221	960	960
Red palm oil								1553	1553		271	271		2901	3015		862	858		5,587	5,697
Palm kernel oil							74	255	255										74	255	255
Palm kernel cake							32	109	109										32	109	109
Total: Section A	258	3028	3913		500	928	493	4536	4541	206	1023	1023	292	3773	3887	102	1215	1218	1,348	14,074	15,509
B. Expenditures on Food from Outside Nigerian Agriculture																					
Wheat																					
Whole													124	49	64	32			156	49	64
Flour							177			39									216		
Fish, dried, freshwater	13	.54	5.3	35			746	236	213	143	73	64	395	64	48	119	49	60	1,451	423	390
Sugar, white				52			242			.36						42			336		
Beer, European				2573			1069			235			786						4,663		
Total: Section B	13	.54	5.3	2660			2234	236	213	417	73	64	1305	113	112	193	49	60	6,822	472	454

a We assume that all hides and skins are sold for export.

Table 11 (cont'd.)

Activity	Area I Model 4	I 5	I 6	II 4	II 5	II 6	III 4	III 5	III 6	IV 4	IV 5	IV 6	V 4	V 5	V 6	VI 4	VI 5	VI 6	Total Model 4	Total 5	Total 6
C. Expenditures on Fertilizer																					
Sulphate of ammonia	10	168	108	5.0	184	164		17	16		10	9.2		28	36		64	106	15	471	439
Single superphosphate		214	239		127	113		.16	.16					4.2	8.4		44	72		389	433
Muriate of potash					.71			.029	.029											1	0
Miscellaneous,[b] for																					
Maize, commercial							1.2						.75			1.4			3		
Oil palm								25	25		4.5	4.5		48	48		19	19		97	97
Cocoa								93	93		3.6	3.6								97	97
Total: Section C	10	382	347	5.0	312	277	1.2	135	134		18	17	.75	80	92	1.4	127	197	18	1,054	1,065
D. Payments for Transportation of Foods[c]																					
From Area I																					
Millet													23	23	23	28	4.6	2.4	51	28	25
Rice							174												174		
Wheat, whole				12															12		
Groundnuts										3.0						35			38		
Oil, groundnut				18			8.2			1.9			3.6			7.7			39		
Beef[d]				0	0	0		0	0	0									0	0	0
Goats				0		0					0					0	0	0	0	0	0
Mutton										0	0	0				0	0	0	0	0	0
Subtotal (Area I)				30	0	0	182	0	0	4.9	0	0	27	23	23	71	4.6	2.4	314	28	25
From Area II																					
Maize, local white									8.1				27	31	12				27	31	20
Rice												8									8
Sorghum								10	10				11	11	11	1.7	13	13	13	34	34
Potato																					
Irish													2.3						2		
Sweet													16.4						16		
Cowpea								67	67	21	21	21		.086	.086				21	88	88
Groundnuts														26	26		5.1			31	26
Melon seed								7.8	7.8											8	8
Oil, red palm	12[e]	12[e]	12[e]																12	12	12
Beef																0	0	0	0	0	0
Goats										0		0	0	0	0				0	0	0
Mutton									2.7							0	0	0	0	0	3
Subtotal (Area II)	12	12	12					85	96	21	21	29	57	68	49	1.7	18	13	91	204	199

b Our data give the amounts spent on fertilizer, but do not specify which kinds are purchased.
c Zero transportation costs for meat animals indicate that the animals are brought in on foot.
d The nomadic herds identified as Area I animals in the model actually spend about two-thirds of their time within the geographical boundaries of Area II.
e The oil originated in either Area III or Area VI.

Table 11 (cont'd.)

Activity	Area: I, Model 4	I, 5	I, 6	II, Model 4	II, 5	II, 6	III, Model 4	III, 5	III, 6	IV, Model 4	IV, 5	IV, 6	V, Model 4	V, 5	V, 6	VI, Model 4	VI, 5	VI, 6	Total, Model 4	Total, 5	Total, 6
D. (continued)																					
From Area III																					
Maize, local white										3.5									4		
Oil, red palm				43															43		
Kola nuts	49	49	49	20	20	20													69	69	69
Subtotal (Area III)	49	49	49	63	20	20				3.5									116	69	69
From Area IV																					
Gari							6.2							2.0	2.9				6	2	3
Yam							5.0	2.8					54	23	64				59	26	64
Subtotal (Area IV)							11.2	2.8					54	25	67				65	28	67
From Area V																					
Oil, red palm										7.2									7		
Subtotal (Area V)										7.2									7		
From Area VI																					
Maize																					
Local white													3.8		9.8				4		10
High lysine														4.0						4	
Rice														19	13					19	13
Gari															13						13
Yam													105	138	90				104	138	90
Okra													.049						0		
Oil, red palm				34	77	77													34	77	77
Beef													0	0	0				0	0	0
Goats														0					0	0	0
Mutton													0	0	0				0	0	0
Subtotal (Area VI)				34	77	77							109	161	126				142	238	203
Total: Section D	61	61	61	127	97	97	193	88	96	37	21	29	246	277	265	73	23	15	736	566	563

a We assume that all hides and skins are sold for export.
b Our data give the amounts spent on fertilizer, but do not specify which kinds are purchased.
c Zero transportation costs for meat animals indicate that the animals are brought in on foot.
d The nomadic herds identified as Area I animals in the model actually spend about two-thirds of their time within the geographical boundaries of Area II.
e The oil originated in either Area III or Area VI.

Model 5 to 928 million shillings in Model 6 (see section A of Table 11). This increase is due to the introduction of prospective varieties of groundnuts and cotton, making possible a higher revenue for the area.

<u>Area III</u>.--The revenue producing activities of Model 5 are exports of hides and skins, cocoa, rubber, and oil palm products. Among these activities, exports of cocoa and red palm oil (by yielding 2,550 and 1,553 million shillings respectively) are the principal sources of revenue. The revenue from palm kernel oil exports is 255 million shillings and from palm kernel cake exports 109 million shillings. The revenue from the export of rubber for this area is 30 million shillings, and from the export of hides and skins (beef, goat, and sheep together), 39 million shillings (section A of Table 11).

In the solution of Model 6, the revenue producing activities, with the exception of revenue from export of sheep skins, are the same as in Model 5. Revenue from exporting sheep skins in Model 6 is higher than in Model 5 because of the increased consumption of mutton in Model 6.

<u>Area IV</u>.--In the solution of Model 5, the revenue yielding activities are exports of hides and skins, cocoa rubber, palm kernel, and red palm oil. Among these activities cocoa exports yield the highest revenue (589 million shillings), and red palm oil exports, yielding 271 million shillings, are second highest. Cocoa exports yield 91 million shillings and the export of palm kernel

produces 59 million shillings (see section A of Table 11).

In the solution of Model 6, the revenue yielding activities and total revenue from these activities are exactly the same as in Model 5.

Area V.--In the solution of Model 5, the revenue producing activities for Area V are exports of hides and skins, rubber, palm kernel, and red palm oil. The total revenue in this area is 3,773 million shillings of which 2,901 million shillings comes from red palm oil exports and 658 million shillings from exporting of palm kernel. Cocoa exports earn 59 million shillings and exports of hides and skins (beef, goat, and sheep together) yield 155 million shillings (section A of Table 11).

In the optimal solution of Model 6 the revenue producing activities are the same as in Model 5. But the export of red palm oil increases from 2,091 million shillings in Model 5 to 3,015 million shillings in Model 6.

Area VI.--In the solution of Model 5, the revenue yielding activities are the export of hides and skins, cotton, soya bean, palm kernel, and red palm oil. The export of red palm oil and palm kernel with the revenue of 862 and 243 million shillings respectively are the principal export activities (see section A of Table 11). Soya bean exports yield 82 million shillings and the export of cotton produces 9 million shillings. Hide and skin exports in this area earn 19 million shillings.

In the solution of Model 6 the export activities are the same as in Model 5. With the exception of sheep skins, the revenue from these activities is the same in both models. The revenue from exporting sheep skins increases from 2.5 million shillings in Model 5 to 9.5 million shillings in Model 6 because of the increased consumption of mutton.

Imports

Import activities can be divided into two categories: foods and fertilizers. With the exception of dried fresh-water fish, some of which comes from the non-agricultural sector of Nigeria, Section B of Table 11 shows the expenditures on food items imported from abroad and Section C of the same table shows the expenditures on fertilizer imports.

In the solution of the benchmark model (Model 4), some food items such as wheat, sugar, and European beer are imported from abroad. But as we introduced the new production techniques in Models 5 and 6, with the exception of whole wheat in Area V, there is a general import substitution in all areas and for all imported food items (see section B of Table 11). In the solutions of Models 5 and 6 the expenditures on dried fresh-water fish bought from the non-agricultural sector go to zero in Area II and decline in other areas.

The new production techniques generally require fertilizers as an input, substantially increasing the expenditures on fertilizer imports in Models 5 and 6 (see section C of Table 11). The largest fertilizer expenditures are for Area I. For Areas I through IV the expenditures in Model 5 are higher than in Model 6, but for Areas V and VI the reverse is true. To examine fertilizer expenditures the different areas will be described separately.

Area I.--In the solution of Model 5 the total amount of expenditures on fertilizers is 382 million shillings. Of this amount, 168 million shillings is spent on import of sulphate of ammonia and 214 million shillings for single superphosphate.

In Model 6 the total expenditures for fertilizers decline to 347 million shillings, of which 108 million shillings is for sulphate of ammonia and 239 for single superphosphate.

In this area there are no expenditures on muriate of potash in either Model 5 or 6 (see section C of Table 11).

Area II.--The total expenditures on fertilizers in the solution of Model 5 is 312 million shillings. The expenditure on sulphate of ammonia, with 184 million shillings, ranks the highest among all types of fertilizers imported for this area. The expenditures on single superphosphate and muriate of potash are 127 and .7 million shillings respectively (see section C of Table 11).

In the solution of Model 6 the expenditures on sulphate of ammonia and single superphosphate decrease to 164 and 113 million shillings respectively. There are no imports of muriate of potash for this area in Model 6.

Area III.--The total amount of expenditures on fertilizers in Model 5 is 135 million shillings. The application of new production practices to cocoa and oil palm requires fertilizers. The fertilizer expenditures for these two crops are 93 and 25 million shillings respectively. The expenditure on imports of sulphate of ammonia is 17 million shillings, but single superphosphate and muriate of potash expenditures are negligible (see section C, Table 11).

The solution of Model 6 for this area differs from the solution of Model 5 only in one figure--expenditures on sulphate of ammonia, which decrease from 17 to 16 million shillings.

Area IV.--In the optimal solution of Model 5 the expenditures on fertilizers are 18 million shillings, of which 10 million shillings are spent for importing sulphate of ammonia and 4.5 and 3.6 million shillings, respectively, on fertilizers for application in the new production practices for oil palm and cocoa.

In the solution of Model 6 expenditures on sulphate of ammonia decline from 10 to 9.2 million shillings (see section C of Table 11).

Area V.--The total expenditure on fertilizers is 80 million shillings in Model 5. Of this amount, 28 and 4.8 million shillings are spent for importing sulphate of ammonia and single superphosphate respectively. The expenditures on fertilizers for application in the new cultural practices for oil palm are 48 million shillings (see section C of Table 11).

In the solution of Model 6 the expenditures on sulphate of ammonia and single superphosphate increase to 36 and 8.4 million shillings respectively, while the expenditure on fertilizers for oil palm is the same as in Model 5.

Area VI.--The total expenditures on fertilizers in Model 5 are 127 million shillings, of which 64 and 44 million shillings were spent on sulphate of ammonia and single superphosphate, respectively, and the remaining 19 million shillings on fertilizers for oil palm.

In the solution of Model 6 the expenditures on sulphate of ammonia and single superphosphate increase to 106 and 72 million shillings respectively (see section C of Table 11).

<u>Internal Trade</u>

The payments for transportation each consuming area makes to bring foods from the producing areas are shown in section D of Table 11.

The quantities of food transported between different areas are shown in Table 12. Among the foods traded most frequently between areas are millet, sorghum, maize, rice, groundnut, cowpea, kola nuts, and red palm oil.

In the solution of Models 5 and 6, some areas are less dependent than others for food. To examine this aspect of the solution each area will be described separately.

<u>Area I</u>.--This area is the most self sufficient of them all concerning the number of food items bought from other areas. In the solutions of both Models 5 and 6, Area I buys red palm oil from Area II (which originated in III or VI) and kola nuts from Area III (see Table 12).

<u>Area II</u>.--This area is dependent on Area I for beef and goats (only in Model 6), on Area III for kola nut (in both Models 5 and 6), and on Area VI for red palm oil (see Table 12).

<u>Area III</u>.--Table 12 shows that Area III is dependent on Area I for beef. But it buys local white maize (only in Model 6), sorghum, cowpeas, melon seeds, and cutton (only in Model 6) from Area II. Area III buys yams from Area IV only in Model 5.

Table 12. **Quantities of Foods Transported between Areas**

Activity	Receiving Area: I, Model 4	I, Model 5	I, Model 6	II, Model 4	II, Model 5	II, Model 6	III, Model 4	III, Model 5	III, Model 6	IV, Model 4	IV, Model 5	IV, Model 6	V, Model 4	V, Model 5	V, Model 6	VI, Model 4	VI, Model 5	VI, Model 6	Total, Model 4	Total, Model 5	Total, Model 6
	Weight at farm, in millions of pounds																				
From Area I																					
Millet													77	77	77	185	31	16	262	108	93
Rice							580												580		
Wheat, whole				72															72		
Groundnuts										11						268			279		
Oil, groundnut				106			26			5.3			11			37			185		
Beef				228	136	136		505	507	98									326	641	507
Goats				117		117					12					27	133	27	144	145	27
Mutton										12	174	174				47	47	77	59	221	251
From Area II																					
Maize, local white									202				301	341	139				301	341	341
Rice												114									114
Sorghum								77	77				77	77	77	29	216	216	106	370	370
Potato																					
Irish													13						13		
Sweet													74						74		
Cowpea								666	666	146	146	146		.72	.72				146	813	813
Groundnuts														145	145		64			209	145
Melon seed								65	65											65	65
Oil, red palm[a]	310	310	311																310	310	311
Beef																305	214	214	305	214	214
Goats										12		12	149	438	149				161	438	161
Mutton									12							22	22	9.6	22	22	22
From Area III																					
Maize, local white										50									50		
Oil, red palm				255															255		
Kola nuts	114	114	114	55	55	55													169	169	169

a This originated in Area III or Area VI.

Table 12. Quantities of Foods Transported between Areas

Activity	Receiving Area																		Total		
	I			II			III			IV			V			VI					
	Model			Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
	Weight at farm, in millions of pounds																				
From Area I																					
Millet													77	77	77	185	31	16	262	108	93
Rice							580												580		
Wheat, whole				72															72		
Groundnuts										11						268			279		
Oil, groundnut				106			26			5.3			11			37			185		
Beef				228	136	136		505	507	98									326	641	507
Goats				117		117					12					27	133	27	144	145	27
Mutton										12	174	174				47	47	77	59	221	251
From Area II																					
Maize, local white									202				301	341	139				301	341	341
Rice												114									114
Sorghum								77	77				77	77	77	29	216	216	106	370	370
Potato																					
Irish													13						13		
Sweet													74						74		
Cowpea								666	666	146	146	146		.72	.72				146	813	813
Groundnuts														145	145		64			209	145
Melon seed								65	65											65	65
Oil, red palm[a]	310	310	311																310	310	311
Beef																305	214	214	305	214	214
Goats										12		12	149	438	149				161	438	161
Mutton									12							22	22	9.6	22	22	22
From Area III																					
Maize, local white										50									50		
Oil, red palm				255															255		
Kola nuts	114	114	114	55	55	55													169	169	169

a This originated in Area III or Area VI.

Table 12 (Cont'd.)

Activity	Receiving Area																		Total		
	I			II			III			IV			V			VI					
	Model			Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
From Area IV																					
Gari							137							66	95				137	66	95
Yam							1249	691					900	380	1070				2149	1071	1070
From Area V																					
Oil, red palm										103									103		
From Area VI																					
Maize																					
Local white													126		328				126		328
High lysine														133						133	
Rice														312	217					312	217
Gari															537						537
Yam													3484	4609	2996				3484	4609	2996
Okra													4.9						4.9		
Oil, red palm				200	456	456													200	456	456
Beef													218	218	218				218	218	218
Goats														105						105	
Mutton													74	74	74				74	74	74

a This originated in Area III or Area VI.

<u>Area IV</u>.--This area is dependent only on two areas for food. It buys mutton and goats (only in Model 5) from Area I. It also buys rice (only in Model 6), cowpeas and goats (only in Model 6) from Area II (see Table 12).

<u>Area V</u>.--This area is the most dependent as far as the number of food items bought from other areas is concerned. It is dependent on Areas I, II, IV, and VI. Area V buys millet from Area I; maize (local white), sorghum, cowpeas, groundnuts, and goats from Area II; gari and yams from Area IV; and maize (local white in Model 6 and high lysine in Model 5), rice, gari (only in Model 6), yams, beef, goats (only in Model 5), and button from Area VI (see Table 12).

<u>Area VI</u>.--This area is dependent on Areas I and II for foods. It buys millet, goats, and mutton from Area I and sorghum, groundnuts (only in Model 5), beef, and mutton from Area II (see Table 12).

CHAPTER VI

THE MOST ECONOMICAL FOODS AND THE OPPORTUNITY-COST VALUES OF THE NUTRIENTS

New production techniques change production patterns. Consumption patterns, the most economical foods, and the opportunity-cost values of nutrients change as the result of a change in the production pattern. This chapter will examine these aspects of the models.

The Most Economical Foods[1]

There are three categories of restraints on consumption activities in this model. The first category is on the consumption activities for kola nuts. The model sets minimum limits on the kola nut consumption in certain areas.[2] In the optimal solution of the model, if the level of a consumption activity for kola nuts is greater than this minimum limit, lowering the requirement for this

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[1]There are many economical foods not mentioned here. These are only the cases in which very large quantities of foods are economical.

[2]The model requires that per capita consumption of kola nuts be at least as much as the estimate of the kola nut consumption in 1963.

activity does not involve a potential gain. But if the level of this activity is at its minimum, contracting the minimum restraint generally involves a potential gain.

The second category of restraints is on the consumption of alcoholic beverages. The model requires the per capita consumption of alcoholic beverages to be equal to the estimate of 1963 levels. This restraint must be fulfilled by one or more of the alcoholic beverages consumed in a particular area. In the optimal solution of the model, if the consumption of alcoholic beverages is uneconomical, this restraint works as a minimum limit. In this case, since any one of the alcoholic beverages consumed in a particular area can staisfy the requirement, the kind of alcoholic beverage or beverages which appears in the solution is the least uneconomical among those allowed to be consumed in that area. But if the consumption is economical this restraint works as a maximum limit. In this case raising the limit would involve a potential gain. Although the nature of the restraint (an equality) is the same for all areas, it works either as a maximum or a minimum limit, depending whether the consumption activity at that level is economical or uneconomical (see Table 13).

The third category of restraints is on the consumption of the rest of the foods. There are maximum

Table 13. Consumption Activities Significantly Constrained* by Their Maximum or Minimum Levels

Activity	Area I Model 4	Area I Model 5	Area I Model 6	Area II Model 4	Area II Model 5	Area II Model 6	Area III Model 4	Area III Model 5	Area III Model 6	Area IV Model 4	Area IV Model 5	Area IV Model 6	Area V Model 4	Area V Model 5	Area V Model 6	Area VI Model 4	Area VI Model 5	Area VI Model 6
At Maximum Levels																		
Maize													a	b	b		c	b
Millet													x	x	x	x	x	x
Rice															x			x
Sorghum								x	x				x	x	x	x	x	x
Wheat																		
Whole				x									x			x		
Flour							x			x								
Potato																		
Irish	x	x	x										x					
Sweet													x					
Cowpea								x	x	x	x	x	x	x	x			
Groundnut, seed										x				x	x	x		
Bean, soya																x	x	x
Onion		x	x	x	x	x												
Oil																		
Groundnut	x			x			x			x						x		
Red palm										x								
Fish, dried, freshwater				x			x			x			x			x		
Beef										x			x	x	x			
Goat meat (chevon)										x	x	x	x	x	x			
Mutton										x	x	x	x	x	x			
Sugar, white				x			x									x		
Beer																		
Millet																x		
Guinea corn																		x
European										x			x					
At Minimum Levels																		
Beer																		
Millet	x	x	x	d	e	f												
Guinea corn					e	f											x	
European				d			x											
Wine, palm								x	x		x	x		x	x			
Kola nut	x	x	x	x	x	x		x	x									

* If the maximum level were raised, or the minimum lowered, the revenue provided by the solution would increase.

a Includes both local white and yellow maize.

b Includes both local white and high lysine maize.

c Includes only high lysine maize.

d The minimum limit is satisfied jointly by 1671 million kilograms of European beer plus 6 million kilograms of millet beer.

e The minimum limit is satisfied jointly by 1611 million kilograms of guinea corn (sorghum) beer plus 66 million kilograms of millet beer.

f The minimum limit is satisfied jointly by 1344 million kilograms of guinea corn beer plus 333 million kilograms of millet beer.

limits on consumption of these foods.[3] In the optimal solution of the model, if the levels of these consumption activities are less than their limits, raising the limits will not involve a potential gain. But if the levels are at their maximum, these foods are economical and expanding their consumption generally will involve a potential gain.

Given the technical coefficients of the models used in this study, Table 13 shows the foods for which the expansion or contraction of their consumption activities would involve a potential gain.

In Area I the most economical and the uneconomical foods are the same in both Models 5 and 6. Consumption of Irish potatoes and onions is economical at their maximum levels but consumption of millet beer and kola nuts is uneconomical at the levels required by the models (see Table 13).

In Area II the solutions of both Models 5 and 6 have the same most economical and uneconomical foods. In this area the consumption of onions is economical at its maximum level but the consumption of kola nuts, guinea corn beer, and millet beer is uneconomical at the minimum level required by the models (see Table 13).

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[3]These limits are generally four times as great as the estimate of per capita consumption in a specific area in 1963.

In Area III the most economical and the uneconomical foods are again the same in Models 5 and 6. Consumption of sorghum and cowpeas is economical, but the consumption of palm wine and kola nuts is uneconomical (see Table 13).

In Area IV the most economical and the uneconomical foods are the same in both Models 5 and 6. The consumption of cowpea, goat meat, and mutton is economical and the consumption of palm wine is uneconomical (see Table 13).

In Area V the solutions of Models 5 and 6 are different for only one food. The consumption of rice is at its maximum limit in Model 6, but not in Model 5 (see Table 13). The expansion of rice consumption beyond its maximum limit involves a potential gain in Model 6 but not in Model 5. Aside from rice, the other most economical and uneconomical foods are the same as in Models 5 and 6: maize, millet, sorghum, cowpeas, groundnuts, beef, goat meat, and mutton are the most economical foods and palm wine is uneconomical in both models (see Table 13).

In Area VI the solutions of Models 5 and 6 differ in two items: the consumption of rice is at its maximum limit in Model 6 but not in Model 5. Its expansion beyond this limit will have a potential gain only in Model 6. Guinea corn beer is an uneconomical food in Model 5 but economical in Model 6. For the rest, the most economical foods are the same: millet, sorghum, and soya bean are economical foods in both models (see Table 13).

The Opportunity-Cost Values of the Nutrients

The optimal solutions of the models use production patterns which provide the required quantities of nutrients most economically. In these solutions many nutrients exceed the required quantities. The cost of increasing the intake of these nutrients by a small amount is zero.

On the other hand, in the solutions of the models some nutrients are provided in the exact required quantities--those nutrients which are costly to provide. Increasing the intake of these nutrients would involve expanding food crops at the expense of cash crops, thus decreasing the revenue obtainable from the agricultural sector.

The costly nutrients are shown in Table 14. Since the production coefficients and the availability of resources differ among areas, the cost of nutrients will be different in each particular area. The total cost of the average daily allowances for all nutrients decreases in all areas, from Model 4 to Models 5 and 6. Only for calories is expansion costly in all areas and models. To examine the cost of expanding the intake of nutrients they will be described by areas.

In Area I, the total cost of the average daily allowances for all nutrients in Model 6 is lower than in

Table 14. Costs of Nutrient Elements in Average Daily per Capita Allowance*

Nutrient	Area I Model 4	I 5	I 6	Area II Model 4	II 5	II 6	Area III Model 4	III 5	III 6	Area IV Model 4	IV 5	IV 6	Area V Model 4	V 5	V 6	Area VI Model 4	VI 5	VI 6
									Shillings									
Calories	.554	.142	.052	6.42	.258	.104	6.42	.086	.012	.870	.069	.069	.664	.487	.487	6.42	.324	.344
Protein[a]					.014			.373	.380		.321	.320		.202	.201		.243	.157
Calcium[b]	.057[b]	.064[b]	.066[b]											.012	.012		.028	.042
Iron																.105		
Vitamin A	.526	.039	.047	.008	.026	.040		.035	.042		.038	.038					.012	.011
Riboflavin										7.14			9.68	.145	.145			
Sulfur-containing amino acids[c]					.014			.373	.380		.321	.320		.202	.201		.243	.140
Methionine[c]																		.017
Total cost of average daily allowances for all nutrients[d]	1.14[e]	.245[e]	.165[e]	6.43	.298	.144	6.42	.494	.434	8.01	.428	.427	10.3	.846	.845	6.53	.607	.554

* These are the least costs of expanding the intake of a single nutrient by one unit, in a single area, subject to all the limits on the levels of production and consumption activities and the constant quantities of resources available. Except when indicated, the daily per capita nutrient allowance used as a unit is the average for Nigeria as a whole.

a The unit in each area is the amount of fully utilizable protein required daily per person in that area.

b The unit for all areas is 388.7 mg, although in Area I the actual allowance is much lower--only 330.0 mg.

c The unit is each area is the amount required daily per person in that area.

d The costs of the sulfur-containing amino acids and methionine are excluded from the total. These costs are already included as the cost of protein.

e This figure includes the same amount of calcium (388.7 mg) as in the other areas, although only 330.0 mg were actually required in Area I.

Model 5. Calories are cheaper in Model 6 than in Model 5. But in Model 6 calcium and vitamin A are more expensive than in Model 5.

In Area II, in addition to calories and vitamin A, fully utilizable protein is also costly in Model 5. Protein becomes costly in this model because the sulfur-containing amino acids needed to form fully utilizable protein are costly. But in Model 6, since the sulfur-containing amino acids are not costly, protein is not costly.

In Area III, the costly nutrients are calories, protein, and vitamin A in both Models 5 and 6. Protein is again costly in this area because of the cost of sulfur-containing amino acids.

In Area IV, the costly nutrients are the same as in Area III. Calories, protein, and vitamin A are costly in both Models 5 and 6. In this area, the costs of daily allowances of nutrients are almost the same in both Models 5 and 6.

In Area V, the costly nutrients are calories, protein, calcium, and riboflavin. This area is the only area in which riboflavin is costly in both Models 5 and 6. The cost of calories in this area is the highest among all areas in Models 5 and 6.

In Area VI, the costly nutrients are calories, protein, calcium, and vitamin A. In Model 6 methionine, required to form fully utilizable protein, becomes costly. But the cost of the sulfur-containing amino acids and the total cost of the average daily allowances for all nutrients in Model 6 are lower than in Model 5.

CHAPTER VII

A MODEL WITH FERTILIZER AND EXTENSION SERVICES LIMITED

Model 7

In the short run, the supplies of some resources such as fertilizer and extension services are assumed to be limited. Model 7 is designed to consider these limitations. We want to know, when these resources are limited, how they should be allocated among crops and between areas.

In this model the maximum limits for the importation of single superphosphate and sulphate of ammonia are 60 and 30 thousand tons respectively.[1] At the same time the maximum limit on the supply of extension services is assumed to be equal to the quantity of extension services needed to apply the new techniques of production to 4.5 million acres of land.

The number of activities and the individual limits on each particular activity are the same as in Model 5.

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[1]There is no limit on the importation of muriate of potash, but in the optimal solution of the model the level of this activity is zero.

The maximum limits on resources other than fertilizers and extension services are also the same as in Model 5. The effects of limiting fertilizer and extension services on the optimal solution of the model will be described in this chapter very briefly.

Cropping Activities

Table 15 shows that restrictions on the supply of fertilizer and extension services change the solution of the model in favor of traditional practices which do not use these resources. As the result of these restrictions, new crop practices must compete with each other for the limited supply of fertilizer and extension services. In addition, they must compete with the traditional practices for the acreage available for each crop and with all other production activities in a specific area for the other resources. In the optimal solution of Model 7 the cultural practices which appear at their maximum level are those which have survived after competing in all three stages.

Food Crops

The levels of food crop activities in the optimal solution of Model 7 are shown in Table 15. This table shows that, in many cases, because of the restrictions on the supply of fertilizer and extension services, new cultural practices cannot compete with traditional

Table 15. Levels of Food Crop Activities: Model 5 with Fertilizer and Extension Services Limited

Activity	Area											
	I		II		III		IV		V		VI	
	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution
					1000 acres							
Maize												
Traditional practices												
Sole	9.3	9.3	190	140	691	0	1.8	1.8	--	--	16	16
Mixed	28	28	440	440	646	0	66	0	437	0	425	0
New practices												
Commercial	--	--	--	--	1349	0	68	0	444	340	455	438
Recommended practices	37	0	630	0	--	--	--	--	--	--	--	--
Western White 1, early	--	--	--	--	674	674	34	34	222	0	227	0
Western White 1, late	--	--	--	--	674	674	34	32	222	0	227	0
Millet												
Traditional practices												
Sole	2309	1444	20	20	--	--	--	--	--	--	5	0
Mixed	8224	8224	20	20	--	--	--	--	--	--	--	--
New practices												
Recommended practices	10533	0	40	0	--	--	--	--	--	--	5	0
Rice, upland												
Traditional practices												
Sole	140	140	25	25	--	--	--	--	--	--	--	--
New practices												
Recommended practices	140	0	25	0	--	--	--	--	--	--	--	--
Rice, swamp												
Traditional practices												
Sole	426	426	74	74	--	--	13	13	101	0	78	0
Mixed	--	--	--	--	--	--	26	26	7	0	4.1	0
New practices												
Recommended practices	426	0	74	0	--	--	--	--	--	--	--	--
New variety	--	--	--	--	--	--	--	--	108	0	82	0
Sorghum												
Traditional practices												
Sole	2002	2002	889	889	--	--	--	--	--	--	5	0
Mixed	6260	6260	2629	2629	--	--	--	--	--	--	--	--
New practices												
Recommended practices	8262	0	3518	0	--	--	--	--	--	--	5	0
Dwarf variety	3300	0	1400	0	--	--	--	--	--	--	--	--
Wheat												
Traditional practices												
Sole	73	73	--	--	--	--	--	--	--	--	--	--
New practices												
Irrigated	8	0	--	--	--	--	--	--	--	--	--	--

Table 15 (cont'd.)

Activity	Area											
	I		II		III		IV		V		VI	
	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution
Cassava, bitter, root[a]												
Traditional practices												
Sole	--	--	--	--	512	0	164	0	188	0	293	0
Mixed	--	--	--	--	640	213	143	133	525	0	647	0
New practices												
New variety	--	--	--	--	1153	1.1	297	41	713	0	940	633
Cassava, sweet, fresh[a]												
Traditional practices												
Sole	317	317	940	940	--	--	--	--	--	--	--	--
Mixed	317	317	840	840	--	--	--	--	--	--	--	--
New practices												
Recommended practices	634	0	1780	0	--	--	--	--	--	--	--	--
Potato, Irish												
Traditional practices												
Sole	9.7	5.2	84	84	--	--	--	--	--	--	--	--
Mixed	4.2	0	8.4	8.4	--	--	--	--	--	--	--	--
New practices												
Recommended practices	14	0	93	0	--	--	--	--	--	--	--	--
Potato, sweet												
Traditional practices												
Sole	6	6	12	12	--	--	--	--	--	--	--	--
Mixed	18	18	36	36	--	--	--	--	--	--	--	--
Cocoyam												
Traditional practices												
Sole	--	--	--	--	25	25	5	5	62	0	--	--
Mixed	--	--	--	--	136	136	75	75	248	248	--	--
Yam												
Traditional practices												
Sole	455	455	449	449	470	287	39	39	277	0	240	110
Mixed	241	241	269	269	235	235	394	394	917	0	504	504
New practices												
Recommended practices	695	0	718	0	--	--	--	--	--	--	--	--
New variety	--	--	--	--	705	0	432	0	1194	471	744	129
Cowpea												
Traditional practices												
Sole, seed	15	0	20	0	--	--	--	--	--	--	1.4	0
Mixed												
Seed	3020	0	4325	3174	--	--	--	--	24	0	884	0
Seed and hay	3020	0	--	--	--	--	--	--	--	--	--	--
New Practices												
Sole, seed												
Recommended practices	3034	0	4346	0	--	--	--	--	--	--	--	--
New variety	3034	0	4346	0	32	0	8	0	24	0	885	243
Mixed, seed and hay												
Improved variety	3034	0	--	--	--	--	--	--	--	--	--	--

Table 15 (cont'd.)

Activity	Area I Maximum	I Solution	II Maximum	II Solution	III Maximum	III Solution	IV Maximum	IV Solution	V Maximum	V Solution	VI Maximum	VI Solution
Melon seed												
Traditional practices												
Sole	19	19	53	53	75	75	3.2	3.2	1.8	0	7.7	7.7
Mixed	39	39	78	78	85	85	133	133	316	0	96	96
Okra												
Traditional practices												
Sole	--	--	--	--	--	--	--	--	--	--	9.6	0
Mixed	--	--	--	--	264	0	89	0	60	0	30	0
Onion												
Traditional practices												
Sole	350	0	175	0	--	--	--	--	--	--	--	--
New practices												
Recommended practices	350	0	175	0	--	--	--	--	--	--	--	--
Tomato												
New practices												
Recommended practices, early	--	--	--	--	3	0	--	--	--	--	--	--
Recommended practices, late	--	--	--	--	3	0	--	--	--	--	--	--
Irrigated	1	0	--	--	--	--	--	--	--	--	--	--

-- The activity is not available in this area.

a The figures are for an acre of cassava of which half was planted in the current year. The other half, planted in the previous year, is being harvested during the current year.

practices. To describe the effects of the restrictions on the levels of food crops we will examine each crop separately.

Maize.--The optimal solution shows that sole cropping practices are profitable in Areas I, IV, and VI. The solution levels for these activities are at the maximum (Table 15). Mixed cropping practices are at maximum limits in Areas I and II. Among the new practices of production the early crop of Western White 1 can compete with the rest of the activities in Areas III and IV, while the late crop of this variety can go to its maximum limit only in Area III.

Millet.--Table 15 shows that the level of sole and mixed cropping of millet is at the maximum in Area II. But in Area I, the principal area for millet production, the level of sole cropping is positive (but not maximum) while the level of mixed cropping is at maximum in this area. The recommended practices of millet cannot compete with the traditional practices in this model.

Rice.--Table 15 tells us that the traditional sole cropping practices of upland rice are superior to the recommended practices. The solution level for sole cropping of upland rice is at the maximum in Areas I and II, while the recommended practices for this kind of rice are at zero level in both areas.

The mixed cropping practices of swamp rice can compete with other production activities in Area IV, while the sole cropping activities are at their maximum level in Areas I, II, and IV. The recommended practices and the new varieties of rice cannot compete with the other activities. The solution level for these activities is zero in all areas where these activities exist.

Sorghum.--The traditional practices of sole and mixed cropping are profitable in Areas I and II, principal sorghum growing areas. The solution levels for these activities are at their maximum in both areas (Table 15). The recommended practices and dwarf variety of sorghum are not profitable in this model. The solution level for these activities is zero in Areas I, II, and VI.

Wheat.--The production of sole cropping of wheat in Area I (the only wheat growing area) is profitable in this model. The solution level for this activity is at the maximum while the level of irrigated wheat is zero because of the high cost of irrigation and other expenses (Table 15).

Cassava.--The new practices for cassava production are the new variety of bitter cassava and recommended practices for sweet cassava. In the solution of the model the level of traditional practices of sole cropping of bitter cassava is at zero in Areas III through VI, but the level of mixed cropping practices is positive (but not maximum) in Areas III and IV. The new variety of bitter cassava is at positive level in Areas III, IV, and VI and at zero level in Area V (see Table 15).

The traditional practices of sweet cassava production (sole and mixed cropping) can compete with recommended practices and exhaust the total capacity allowed for the production of this crop in Areas I and II.

Irish Potato.--The recommended practices for Irish potatoes cannot compete with the traditional practices (sole and mixed cropping) for the capacity allowed for this crop in either area. In Area I the level of sole cropping practices is positive and mixed cropping practices is zero. In Area II the sole and mixed cropping practices exhaust the total capacity allowed for this crop (see Table 15).

Sweet Potato.--The traditional practices for this crop can compete with all old and new activities of model for resources. Table 15 shows that the levels of sole and mixed cropping are at the maximum in both Areas I and II. This crop is profitable even with traditional methods of production.

Cocoyam.--Table 15 shows that the traditional sole cropping practices for this crop can compete with other activities of the model for the resources in Areas III and IV. The levels of these activities are at the maximum in both Areas III and IV. The levels of mixed cropping practices of this crop are at their maximum in Areas III, IV, and V, where this crop is grown.

Yam.--The new practices of yam production are the recommended practices (in Areas I and II) and the new variety of yam (in Areas III through VI). In the solution of the model, the level of traditional practices of mixed cropping in all areas (with the exception of Area V) is at the maximum and the level of traditional practices of sole cropping is at the maximum in Areas I, II, and IV, positive in Areas III and VI, and zero in Area V. Among the new practices, the level of the new variety of yam is positive in Areas V and VI. The level of the other new activities for yam is zero (see Table 15).

Cowpea.--The new practices of cowpea production are sole cropping of recommended practices (in Areas I and II), the new variety of cowpea (in Areas I through VI) and mixed cropping of improved variety (in Area I). In the solution of the model the level of traditional sole cropping practice in Area I and the new variety of cowpeas in Area VI are positive and the level of the rest of the activities is zero.

Melon Seed.--No new practices of melon seed production were introduced in this model. The traditional sole and mixed cropping practices of melon seeds must compete with the rest of activities for resources. Table 15 tells us that this crop is superior in most areas. Only in Area V the solution level for sole and mixed cropping is zero. In all other areas the level of sole and mixed cropping of this crop is at the maximum.

Okra.--There are no new practices of okra production in this model. Neither the sole cropping activity (in Area VI) nor the mixed cropping activities (Areas III through VI) can compete with the rest of the production activities for resources. The level of these activities is zero in all areas where this crop is grown (see Table 15).

Onion.--The only new practices of onion production are the recommended practices in Areas I and II. In the solution of this model neither the traditional practices nor the new practices of onion production can compete with the rest of the production activities for the resources (Table 15).

Tomato.--There are no traditional practices of tomato production in this model. The new practices of tomato production are the recommended practices (early and late crops) in Area III and irrigated tomatoes in Area I. Neither of these activities can compete with the rest of the activities of the model for the resources. Their level in the optimal solution of the model is zero (see Table 15).

Cash Crops

Since the supply of fertilizer and extension services are limited in Model 7, some of the new practices of cash crops, which were at their maximum levels in Model 5, cannot compete with the traditional practices in this model. In other words, the traditional cultural practices of cash crops were not profitable in Model 5, when fertilizer and extension services were not limited, but they become profitable when these factors are limited.

To examine the effect of the restriction, each cash crop will be described separately.

Groundnuts.--The new practices of production of groundnuts in this model are recommended practices of groundnuts in Areas I, II, and VI. This activity can compete with the traditional practices of groundnuts production in Area II and its level in the solution of model is at the maximum (Table 16). But in Area I the recommended practices can take over part of the capacity from sole cropping. The level of sole cropping and the recommended practices are positive in Area II. In the solution of the model, the level of groundnuts production is zero in Area VI (both for traditional and new practices).

Soya Bean.--The new practices introduced in this model are improved practices of soya bean production only in Area VI. The level of this activity in the solution of the model is positive but not maximum. The level of sole cropping practices at at the maximum in Areas I and II and zero in Area VI (Table 16).

Cotton.--The new practices of cotton production introduced in this model are the recommended practices. With the restrictions on the supplies of fertilizers and extension services, the recommended practices of cotton production are not profitable. In the solution of the model the levels of traditional sole and mixed cropping

Table 16. Levels of Cash Crop Activities: Model 5 with Fertilizer and Extension Services Limited

Activity	Area											
	I		II		III		IV		V		VI	
	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution
						1000 acres						
Groundnut[a]												
Traditional practices												
Sole	1543	1543	220	0	--	--	--	--	--	--	67	0
Mixed	3416	2456	370	0	--	--	--	--	--	--	101	0
New practices												
Recommended practices	4959	958	590	590	--	--	--	--	--	--	168	0
Bean, soya[a]												
Traditional practices												
Sole	10	10	10	10	--	--	--	--	--	--	185	0
New practices												
Improved practices	--	--	--	--	--	--	--	--	--	--	185	19
Cotton												
Traditional practices												
Sole	248	248	339	0	--	--	--	--	--	--	--	--
Mixed	248	248	359	359	--	--	--	--	--	--	52	0
New practices												
Recommended practices	495	0	698	0	--	--	--	--	--	--	--	--
Tobacco												
Traditional practices												
Sole	4	4	11	11	--	--	--	--	--	--	--	--

-- The activity is not available in this area.

a Groundnut and soya bean are food crops as well as cash crops.

Table 17. Levels of Tree Crop Activities: Model 5 with Fertilizer and Extension Services Limited

Activity	Area											
	I		II		III		IV		V		VI	
	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution
						1000 acres						
Oil palm												
Traditional practices	--	--	--	--	1265	0	223	0	2409	0	964	0
New practices	--	--	--	--	1265	1265	223	223	2409	2409	964	964
Cocoa												
Traditional practices	--	--	--	--	1325	0	52	0	--	--	--	--
New practices	--	--	--	--	1325	1325	52	52	--	--	--	--
Kola nut												
Traditional practices	--	--	--	--	603	548	--	--	--	--	--	--
Rubber												
Traditional practices	--	--	--	--	24	0	482	0	48	0	--	--
New practices	--	--	--	--	24	24	482	482	48	48	--	--

-- The activity is not available in this area.

are at the maximum in Area I. In Area II the level of sole cropping is at zero and mixed cropping at the maximum. The level of mixed cropping of cotton in Area VI (the only practice available in this area) is zero (see Table 16).

Tobacco.--No new practices of tobacco production were introduced in this model. The sole cropping practices of tobacco production can compete with the rest of the production activities for resources in both Areas I and II, where this crop is grown.

Tree Crops

Our data concerning the fertilizer requirements for implementing the new practices of oil palm and cocoa production, give the amounts spent on fertilizer but do not specify the kinds purchased. Fertilizer expenses are charged to the production activities of these crops as though these activities do not use the limited amount of fertilizer imported for other crops, but import fertilizer directly, whenever the activity can pay the expense. On the other hand, there are no new practices for kola nut production and the new rubber practices do not require fertilizer. Therefore, the restrictions on fertilizer supply imposed in this model do not affect the expansion of the new practices of tree crops directly (see Table 17).

To analyze the solution of the model for tree crops each crop will be described separately.

Oil Palm.--Table 17 shows that the new practices of oil palm production are superior to the traditional practices in all areas where this crop is produced. The solution levels for the new practices are at their maximum in Areas III through VI.

Cocoa.--The new practices of cocoa production can also compete with the traditional practices in Areas III and IV, where the crop is grown. In the solution of the model the new practices are at their maximum in both areas (Table 17).

Kola Nuts.--The production level for kola nuts is 548 thousand acres in Area III, the only area where this crop is grown (Table 17). Since the consumption level of this crop is at its minimum level (in Areas I, II, and III, where the crop is consumed) its production cannot go below 548 thousand acres even if it is uneconomical at that level.

Rubber.--The new practices of rubber production are profitable expanded to their maximum limits in this model. Table 17 shows that these activities can compete with the traditional practices for the acreage available. The levels of the new practices are at the maximum in Areas III, IV, and V.

Resource Use

In the solution of the model some resources are used totally and others only partially. Among all resources, land is 100 per cent used in all areas (I through IV) while manure is left totally unused in Areas I and II (see Table 18).

If a specific resource in a particular area is used totally there is a potential gain from having an additional unit of that resource. If a resource is not used then there is no potential gain for its additional unit.

Table 18 shows that during May and June labor is a scarce factor in Areas III, V, and VI. An additional man-day of labor in May and June in Area III contributes 6.1 shillings to the revenue, while the same labor in Areas V and VI contributes 15.6 and 11.7 shillings respectively (Table 19).

There is no shortage of labor during the rest of the year. The highest percentage of unused labor during the rest of the year is in Area I where 71 per cent of the labor is left unused. In Areas II and VI the percentage of unused labor is 67 per cent and 64 per cent respectively. Other areas also have substantial amounts of unused labor during the rest of the year (see Table 18).

Land is the only factor which is scarce in all areas. An additional acre of land in Area V, with 920 shillings per acre per year, has the highest potential gain among all areas. In Area IV the potential gain from an additional acre of land is 350 shillings per acre per year. The potential gain from an additional acre of land

Table 18. Quantities of Resources Available and Unused: Model 5 with Fertilizer and Extension Services Limited

Resource and Area	Quantity Available	Quantity Unused	Percentage Unused
Labor in May and June (1000 man-days)			
I	449,000	172,600	38.4
II	181,150	73,100	40.4
III	84,290	0	0
IV	51,580	19,400	37.6
V	92,140	0	0
VI	70,000	0	0
Labor during Rest of Year (1000 man-days)			
I	1,795,800	1,266,100	70.5
II	797,200	531,700	66.7
III	404,100	24,000	5.9
IV	247,500	157,400	63.6
V	442,400	44,200	10.0
VI	336,200	90,500	26.9
Land under Cultivation (1000 acres)			
I	15,041	0	0
II	6,534	0	0
III	5,188	0	0
IV	1,260	0	0
V	3,390	0	0
VI	2,830	0	0

Table 18 (cont'd.)

Resource and Area	Quantity Available	Quantity Unused	Percentage Unused
Additions to Land under Cultivation* (1000 acres)			
V	322	258	8.0
Bush Pasture (1,000,000 acres)			
I	784	0	0
II	847	824	97.3
III	2.64	1.9	72.0
IV	2.64	2.2	83.3
V	10.99	8.9	80.1
VI	99.55	92.0	92.4
Manure* (1000 metric tons)			
I	3,000	3,000	100
II	1,500	1,500	100

* This resource was introduced into the model only for the areas listed.

Table 19. Revenue Obtainable from an Additional Unit of Resource: Model 5 with Fertilizer and Extension Services Limited*

Resource	Unit	Area					
		I	II	III	IV	V	VI
Labor in May and June	man-day	0	0	8.1	0	15.6	11.7
Labor, other	man-day	0	0	0	0	0	0
Land, arable	acre-year	177	325	235	349	917	179
Land, arable, additional	acre-year	--	--	--	--	0	--
Pasture, bush	acre-year	1.4	0	0	0	0	0
Manure	long ton	0	0	--	--	--	--

*This table shows the potential gain from having one more unit of a specific resource to use, subject to the conditions of the model. Those conditions include maximum limits upon production and consumption activities and constant quantities of all other resources.

These values are the opportunity-cost valuations of the resources.

is 325 shillings for Area II, 235 for Area III, 179 for Area VI, and 177 shillings for Area I (Table 19).

There is a potential gain from an additional acre of bush pasture only in Area I (1.4 shillings per acre per year). Pasture is abundant in all other areas.

Manure is used only in the production of onions. Since in the optimal solution of the model the level of onion production is at zero (in Areas I and II where the crop is grown), manure is left unused by 100 per cent in both areas.

Animal Activities

In the optimal solution of the model, except for bush cattle in Area I, the levels of traditional animal industries are at their maximum in all areas. The level of bush cattle in Area I is below maximum. The commercial production of pork and poultry, as well as the production of hay-fed sheep, are at zero levels in areas where these activities exist (see Table 20).

Table 21 shows that the potential gain from the expansion of bush cattle is 314 shillings per head of output for Area III, 225 shillings for Area II, 159 shillings for Area IV, and 150 shillings for Areas V and VI. Among all areas, Area II has the highest potential gain for the expansion of goats (44 shillings per head output) and sheep (54 shillings per head output).

Table 20. Levels of Animal Industries: Model 5 with Fertilizer and Extension Services Limited

Activity	Unit	Area											
		I		II		III		IV		V		VI	
		Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution	Maximum	Solution
Cattle, bush	1,000 head -- output	1072	869	336	336	1.1	1.1	1.1	1.1	3.3	3.3	28	28
Cattle, commercial	1,000 head -- output	--	--	11	0	--	--	--	--	6	0	1.2	0
Goats	100,000 head -- output	28.9	28.9	11	11	2.96	2.96	2.08	2.08	8.9	8.9	1.8	1.8
Sheep, bush	100,000 head -- output	8.4	8.4	4.4	4.4	.56	.56	.066	.066	1.4	1.4	3.4	3.4
Sheep, hay-fed	100,000 head -- output	a	0	--	--	--	--	--	--	--	--	--	--
Swine, commercial	1,000 head -- output	28.9	0	7.2	0	--	--	--	--	--	--	--	--
Chickens, commercial	100,000 chicks -- input	--	--	5.3	0	7.9	0	--	--	b	0	b	0

-- The activity is not available in this area.
a Limited by the production of cowpea hay.
b Limited by the feed production of the Ministry of Agriculture.

Table 21. Additions to Revenue Possible if an Animal Activity were Expanded: Model 5 with Fertilizer and Extension Services Limited

Activity	Unit	Area					
		I	II	III	IV	V	VI
		Shillings					
Per Unit of Activity							
Cattle, bush	head -- output	0	225	314	159	150	150
Cattle, commercial[a]	head -- output	--	0	--	--	0	0
Goats	head -- output	40	44	40	23	32	36
Sheep, bush	head -- output	53	54	36	32	30	34
Sheep, hay-fed	head -- output	b	--	--	--	--	--
Swine, commercial	head -- output	0	0	--	--	--	--
Chickens, commercial	100 chicks -- input	--	0	0	--	b	b
Per Acre-Year of Pasture							
Cattle, bush	head -- output	0	7.5	13.1	12.7	6.3	1.1
Cattle, commercial[a]	head -- output	--	0	--	--	0	0
Goats	head -- output	3.3	5.4	22.3	11.4	17.7	7.3

Table 21 (cont'd.)

Activity	Unit	Area					
		I	II	III	IV	V	VI
Sheep, bush	head -- output	3.6	5.4	11.9	10.7	10.0	4.3
Sheep, hay-fed	head -- output	c	--	--	--	--	--
Swine, commercial	head -- output	c	c	--	--	--	--
Chickens, commercial	100 chicks -- input	--	c	c	--	c	c

* The entries show the gains possible if a single activity were to be expanded by a small amount, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a The pasture for commercial cattle makes use of arable land.

b The model imposes no direct limit on this activity.

c Not a pasture-using activity.

Patterns of Trade

The restrictions on fertilizer supply and extension services change the patterns of trade. The revenue producing activities are shown in section A of Table 22.

The export activities providing a large amount of revenue are exports of groundnuts in Area I (which provides 552 million shillings), cocoa in Area III (which provides 2,550 million shillings), rubber in Area IV (which provides 589 million shillings), palm kernels in Area V (which provides 658 million shillings), and red palm oil in Areas III and V (which provide 1,075 and 2,968 million shillings respectively).

Import activities are divided into two categories: food and fertilizer. In the optimal solution of this model, importing food items is restricted to whole wheat for Areas V and VI, wheat flour for Area III, and sugar for Area II (see section B of Table 22).

Importation of fertilizer consists of two specified fertilizers[2] (sulphate of ammonia for Areas V and VI and single superphosphate for Areas I and II) and some unspecified fertilizers (for commercial maize oil palm and cocoa for Areas III through VI, see section C of Table 22).

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[2]The import level for muriate of potash is zero for all areas.

Table 22. Summary of Revenue Transactions: Model 5 with Fertilizer and Extension Services Limited

Activity	Area						Total
	I	II	III	IV	V	VI	
	Million shillings						
A. Transactions Yielding Revenue (on balance)							
Export hides and skins[a]							
Beef			14	17	38	1.9	71
Goat			4.1	7.9	86	16	114
Sheep			.63	5.0	31	2.5	39
Sell cotton	104	62					166
Export							
Groundnut, seed	552						552
Groundnut cake	102						102
Sell tobacco	3.6	10					14
Export							
Cocoa			2550	91			2,641
Rubber			29	589	59		677
Palm kernel				59	658	235	952
Red palm oil			1075	184	2968	626	4,853
Palm kernel oil			255				255
Palm kernel cake			109				109
Total: Section A	762	72	4037	953	3840	881	10,545

a We assume that all hides and skins are sold for export.

Table 22 (cont'd.)

Activity	Area						Total
	I	II	III	IV	V	VI	
B. Expenditures on Food from Outside Nigerian Agriculture							
Wheat							
Whole					124	32	156
Flour			39				39
Fish, dried, freshwater	47		680	49	55	81	912
Sugar, white		52					52
Total: Section B	47	52	719	49	179	113	1,159
C. Expenditures on Fertilizer							
Sulphate of ammonia					14	4.2	18
Single superphosphate	23	14				1.2	38
Miscellaneous,[b] for							
Maize, commercial					36	47	83
Oil palm			25	4.5	48	19	97
Cocoa			93	3.6			97
Total: Section C	23	14	118	8.1	98	71	333

b Our data give the amounts spent on fertilizer, but do not specify which kinds are purchased.

Table 22 (cont'd.)

Activity	I	II	III	IV	V	VI	Total
D. Payments for Transportation[c]							
From Area I							
Millet					23	10	33
Wheat, whole		12					12
Groundnuts				3.0		35	38
Oil, groundnut		18				7.7	26
Beef[d]		0	0	0			0
Goats				0		0	0
Mutton				0		0	0
Subtotal (Area I)		30	0	3	23	53	109
From Area II							
Sorghum					11		11
Cowpeas				4.6			5
Groundnuts					26		26
Oil, red palm	12[e]						12
Beef						0	0
Goats					0		0
Mutton						0	0
Subtotal (Area II)	12			4.6	37		54
From Area III							
Maize, high lysine				3.1			3
Gari		15					15
Melon seed				3.3			3
Kola nuts	49	20					69
Yam				44			44
Subtotal (Area III)	49	35		50			134

c Zero transportation costs for meat animals indicate that the animals are brought in on foot.

d The nomadic herds identified as Area I cattle in this model actually spend about two-thirds of their time within the geographical boundaries of Area II.

e The oil originated in either Area III or Area VI.

Table 22 (cont'd.)

Activity	I	II	III	IV	V	VI	Total
D. Payments for Transportation							
From Area IV							
Gari					3.1		3.1
Yam					106		106
Subtotal (Area IV)					109		109
From Area V							
			None				
From Area VI							
Maize					.61		1
Yam					140		140
Gari		2.1			14		16
Cowpeas					.014		0
Oil, red palm		84					84
Beef[d]					0		0
Goats					0		0
Mutton					0		0
Subtotal (Area VI)		86			155		241
Total: Section D	61	151		58	324	53	647

Buying activities move foods from production areas to consumption locations. The levels of these activities in the optimal solution of the model determine the internal trade pattern (see Table 23).

Area I buys red palm oil from either Area III or VI. Area II buys wheat (whole), groundnuts, and beef from Area I; gari, kola nuts from II; and yams and red palm oil from Area VI. Area III buys only beef from Area I. Area IV buys groundnuts, beef, goat meat, and mutton from Area I; yams from Area III. Area V buys millet from Area I; sorghum, groundnuts, and goats from Area II; gari and yams from Area IV; and maize, yams, gari, cowpeas, beef, goat meat, and mutton from Area VI. Area VI buys millet, groundnuts, groundnut oil, goat meat, and mutton from Area I and beef and mutton from Area II (see Table 23).

The Most Economical Foods

Table 24 shows the foods that are consumed at maximum or minimum levels in the optimal solutions of the model. The expansion of maximum limits or contraction of minimum limits would involve a gain.

In Area I Irish potatoes and groundnut oil are most economical, and the consumption of kola nuts and millet beer is uneconomical. In Area II groundnut oil, red palm oil, and sugar are most economical and the consumption of beer (millet and guinea corn beer) and kola nuts is uneconomical. In Area III no food expands to its

Table 23. Quantities of Foods Transported between Areas: Model 5 with Fertilizer and Extension Services Limited

Activity	Area						Total
	I	II	III	IV	V	VI	
	Weight at farm, in millions of pounds						
From Area I							
Millet					77	69	146
Wheat, whole		72					72
Groundnuts				11		268	279
Oil, groundnut		106				37	143
Beef		147	214	262			623
Goats				12		133	145
Mutton				174		47	221
From Area II							
Sorghum					77		77
Cowpeas				31			31
Groundnuts					145		145
Oil, red palm[a]	310						310
Beef						225	225
Goats					44		44
Mutton						22	22
From Area III							
Maize, high lysine				44			44
Gari		73					73
Melon seed				47			47
Kola nuts	112	20					132
Yam				808			808

a This originated in Area III or Area VI.

Table 23 (cont'd.)

Activity	Area I	II	III	IV	V	VI	Total
From Area IV							
Gari					102		102
Yam					1759		1759
From Area V							
			None				
From Area VI							
Maize					20		20
Yam					4679		4679
Gari		18			550		568
Cowpeas					.72		1
Oil, red palm		496					496
Beef					218		218
Goats					105		105
Mutton					74		74

Table 24. Consumption Activities Significantly Constrained* by their Maximum or Minimum Levels: Model 5 with Fertilizer and Extension Services Limited

Activity	Area					
	I	II	III	IV	V	VI
At Maximum Levels						
Maize				a	b	
Millet					x	x
Sorghum					x	
Wheat						
Whole		x			x	x
Flour				x		
Gari					x	
Potato, Irish	x					
Cowpea					x	
Groundnut, seed				x	x	x
Bean, soya						x
Oil						
Groundnut	x	x				x
Red palm		x				x
Beef				x	x	
Goat meat (chevon)				x	x	
Mutton				x	x	
Sugar, white		x				
Wine, palm					x	
At Minimum Levels						
Beer						
Millet	x	c				x
Guinea corn		c				
Wine, palm			x	x		
Kola nut	x	x	x			

* If the maximum level were raised, or the minimum lowered, the revenue provided by the solution would increase.

a Includes both local white and high lysine maize.

b Includes both local white and yellow maize.

c The minimum limit is satisfied jointly by 1630 million kilograms of guinea corn beer and 47 million kilograms of millet beer.

maximum limit but the consumption of palm wine and kola nuts is uneconomical. In Area IV maize (local white and high lysine maize), wheat (flour), groundnuts, beef, goat meat, and mutton are most economical and the consumption of palm wine is uneconomical. In Area V the consumption of maize (local white and yellow maize), millet, sorghum, wheat (whole), gari, cowpeas, groundnuts, beef, goat meat, mutton, and palm wine is most economical and there is no uneconomical food in this area. In Area VI millet, wheat (whole), groundnuts, soya bean, groundnut oil, and red palm oil are the most economical foods and the consumption of millet beer is uneconomical.

CHAPTER VIII

SUMMARY BY AREAS

The Most Efficient Techniques of Crop Production

This study integrates information from different disciplines to answer some of the questions Nigeria faces in the course of expanding her agricultural sector. The objective of this research is to determine the most efficient production techniques for producing nutrition and income.

Because of the differences in production possibilities and consumption habits, Nigeria is divided into six ecological areas. Each area has its own resources and can provide the required nutrients either by producing food within the area, by buying from other areas or from outside the agricultural sector (as from fisheries), or by importing from outside the country. Thus each area has been treated as a separate model connected with the other areas through buying activities. The resources of a particular area can be used only in that area and cannot be transferred to another area or areas.

Since each area produces different crops and has different input-output coefficients, each area may have a different scarce resource or resources in the optimal solution of the model. Similarly, the values of the scarce nutrients may be different in each area. Some of the new techniques are superior in one area yet inferior in another.

Model 5

In this model we introduce improved production practices for different crops. These cultural practices (with the exception of dwarf sorghum and the new variety of cowpeas, which will be available shortly) are presently available to Nigerian farmers. The new activities must compete with traditional production practices for resources and the capacity to produce a particular crop in a specific area.

This model tests the efficiency of different techniques of crop production and tries to find the superior crops and the best methods of producing them. The test crops, as well as the set of superior techniques for those crops, differ from area to area. Therefore, each area will be discussed separately. The policy-maker interested in maximizing agricultural income without sacrificing adequate nutrition will find optimal production patterns described for each area.

Area I.--The solution of the model shows that some of the traditional sole and mixed cropping practices for food crops use resources efficiently in this area. Sole cropping practices for maize, upland and swamp rice, wheat, sweet potatoes, and melon seeds can compete with the other crops and production techniques for the available resources. The traditional sole cropping of these crops appears at the limits allowed in this study.

With regard to mixed cropping practices, the production of maize, millet, sorghum, sweet cassava, sweet potatoes, yams, and melon seeds can compete with the new methods of production for resources. These activities are profitable expanded to the limits considered in the study.

Among the new food crop production techniques, the recommended practices for many food crops are not profitable in this area. The recommended practices for sweet cassava replace the traditional sole cropping but not the mixed cropping practices. The recommended practices for onions replace the traditional practices, and total acreage under onion production decreases from 300,000 acres in Model 4 to 160,000 acres in Model 5. The recommended practices for other food crops are not profitable in this area. The new variety of dwarf sorghum is produced at a level of 167,000 acres; expansion beyond this level is not profitable. The two irrigated crops, wheat and tomatoes, are not profitable at any level because of the high cost of irrigation and other expenses.

For cash crops, the traditional sole cropping of soya beans is profitable at 10,000 acres (the limit allowed in this study). The current method of tobacco production (already at a high level of technical competence) is profitable applied to its maximum limit. Unlike food crops, the recommended practices for cash crops are efficient in using resources. The recommended practices for groundnuts and cotton should replace their traditional practices (both sole and mixed cropping) in this area.

Area II.--The traditional sole cropping practices for most food crops are not profitable in this area. Only the traditional sole cropping of swamp rice, sweet potatoes, and melon seeds are profitable at the maximum limits allowed in this study. Sole cropping of Irish potatoes is not profitable beyond 55,000 acres in this model.

Mixed cropping of food crops is relatively more profitable than traditional sole cropping in Area II. Mixed cropping of maize, millet, cassava, sweet potatoes, and melon seeds is expanded to the maximum limits. Mixed cropping of sorghum and cowpeas is profitable at levels of 2100 and 470 thousand acres respectively. Mixed cropping of other food crops is not profitable at any level.

The recommended practices for millet, upland rice, and yams are efficient in using resources. These production activities replace traditional practices at their limits. The recommended practices for maize, sweet cassava, and onions expand to 80, 310, and 160 thousand acres.

These activities utilize the unused acreage alloted to sole cropping. The recommended practices for Irish potatoes expand to 40,000 acres at the expense of both sole and mixed cropping. Dwarf sorghum is produced at the limit allowed in this study. The production of the new variety of cowpeas is profitable to 720,000 acres.

Regarding cash crops, sole cropping of soya beans with traditional methods is not profitable, but the current method of tobacco production is. The recommended practices for groundnuts and cotton replace the traditional sole and mixed cropping practices.

Area III.--The traditional practices for sole and mixed cropping of most food crops are inferior to the new techniques of production in this area. Only the traditional practices for melon seeds (both sole and mixed cropping) can compete for resources with the new techniques.[1] The traditional practices for other crops are not profitable.

The new practices for tree crops are superior to traditional practices in this area. The new practices for oil palm, cocoa, and rubber replace traditional practices at their limits.

Area IV.--The solution of this model shows that some of the traditional practices of food crops can compete

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[1]The mixed cropping of cassava is profitable only up to 1000 acres.

with the new production techniques for resources in this area. Sole cropping practices for maize and cocoyam are profitable at their limits (2 and 5 thousand acres respectively). Mixed cropping practices for swamp rice, bitter cassava, and cocoyam are profitable expanded at their limits are mixed cropping of maize expands to 32,000 acres.

Among the new methods of food crop production, the new variety of maize, Western White 1 (early crop) expands to its limit, while the new varieties of yam and cassava expand to 350 and 1.4 thousand acres respectively.

For tree crops, all the new practices are superior to traditional practices, including the new practices for oil palm, cocoa, and rubber.

Area V.--The traditional practices for food crops are not profitable in this area.

Among the new practices, the new variety of maize, Western White 1 (late crop) is profitable at the level of 80 thousand acres and the new variety of yam expands at 700 thousand acres.

The new practices for oil palm and rubber are profitable, replacing traditional practices at their limits.

Area VI.--Among the traditional practices for food crops the traditional mixed cropping for melon seeds is the only activity that can compete with the new activities for resources. This production activity is profitably carried on at its limit.

For the new practices of food crops, the new variety of maize, Western White 1 (both early and late crops) and the new variety of swamp rice are profitably expanded to their maximum limits. The new varieties of yams and cowpeas are profitably expanded to 570 and 330 thousand acres respectively.

As far as cash crops are concerned, mixed cropping of cotton is the only traditional activity which is profitably produced at its limit. The traditional practices for groundnut and soya bean are replaced by the recommended and improved practices of these crops respectively.

The new practices for oil palm--the only tree crop in this area--replace traditional practices at the maximum limit.

Conclusion

The solution of this model shows that some of the new production techniques for food crops cannot compete with all other production activities for resources as well as do some of the traditional practices. However, the new production techniques for cash crops do replace traditional practices in all areas. The reason for and the significance of these results will be explained in detail

in Chapter IX. The assumption of absolute inelasticity of the demand for nutrition and restricting the market for food crops to internal comsumption make some of the new techniques for food crops unprofitable. Since there is no outlet for the extra yield, additional food production decreases the internal (shadow) food prices, making the new techniques less profitable. With regard to the new cash crop techniques, there is an outlet for their additional yields. So long as the earnings from the additional yields are greater than the additional costs of the new techniques they are profitable.

Model 6

The new production activities included in this model are the production of prospective varieties of the various crops. These production techniques are not presently available to Nigerian farmers, but could be available in the future as research on plant breeding continues.

The model is designed to explore possible gains from further plant breeding programs for the major crops.

These new activities must compete with the traditional and the improved practices for resources and for the acreage the model allows for a given crop in a specific area. A few of the prospective varieties are superior to the traditional and improved techniques in a particular area, but are inferior in other areas. To examine the efficiency of various techniques we will discuss each area separately.

Area I.--Traditional cropping practices for some food crops can compete with the new practices (including prospective varieties) for the available resources. The traditional sole cropping practices for swamp rice, wheat, sweet cassava, sweet potatoes, and melon seeds are profitable at their limits in Area I. Sole cropping of sorghum and Irish potatoes is profitably expanded to 40 and 5 thousand acres, respectively. Among mixed cropping practices, the production of maize, millet, sorghum, sweet cassava, sweet potatoes, and melon seeds is carried on at the limits.

Among the new practices, the improved variety of cowpeas cultivated as a mixed crop is profitable produced to its limit. Recommended practices for onions occupy 160,000 acres of land. With the exception of millet, the prospective varieties of food crops cannot pay for the resources they employ. The prospective variety of millet is profitable only at the level of 1000 thousand acres in this area.

Regarding cash crops, the current method of tobacco production is profitable carried to its maximum limit. Unlike food crops, the prospective varieties of cash crops are profitable. The prospective varieties of groundnuts, soya beans, and cotton are superior to their traditional and recommended practices. These activities expand to their maximum limits.

Area II.--The traditional practices for some food crops can compete with the new practices in this area. Traditional sole cropping practices for swamp rice, Irish potatoes, sweet potatoes, yams, and melon seeds are profitable applied to their maximum limits. Traditional sole cropping of maize also expands almost to its limit. Mixed cropping practices for maize, sorghum, sweet cassava, sweet potatoes, yams, and melon seeds are carried on to their limits. The traditional mixed cropping of cowpeas is profitable at a level of 4070 thousand acres, close to the limit.

Among the new cultural practices, the recommended practices for upland rice and the prospective varieties of millet replace the traditional practices. The recommended practices for onions expand to 80 thousand acres and the levels of the prospective varieties of maize (early crop) and sorghum can expand to 2 and 760 thousand acres respectively.

For cash crops, the current method of tobacco production is applied to its maximum limits. Unlike food crops, the prospective varieties of cash crops are profitable. The prospective varieties of groundnuts, soys beans, and cotton replace the traditional practices.

Area III.--Some of the traditional practices for food crops can compete with the new practices for available resources. The traditional sole cropping practices for cocoyams and melon seeds are applied to their limits. Mixed cropping of melon seeds is employed to its maximum limit, while mixed cropping for yams is profitable to 45 thousand acres.

Among the new practices, the new variety of maize, Western White 1 (both early and late crops) is profitable as a replacement for traditional practices in this model. The prospective variety of maize cannot compete with Western White 1 in this area. The new variety of yams is applied to 520 thousand acres. Recommended practices for tomatoes (late crop) can compete with the other activities for resources. This activity expands to its limit (3 thousand acres).

Concerning tree crops, the new practices are superior to the traditional ones. The new practices for oil palm, cocoa, and rubber replace traditional practices at their limits.

Area IV.--The traditional sole cropping practices for maize and cocoyams (on 2 and 5 thousand acres of land) are the only sole cropping activities that can compete with the other production activities for resources. Among mixed cropping practices, the production of swamp rice, bitter cassava, and cocoyams is carried on at the maximum limits in this area. Mixed cropping of maize is profitable to 30 thousand acres.

Among the new practices, the new variety of maize, Western White 1 (early crop), is produced to its limit. The new varieties of bitter cassava and yams are grown to the extent of 30 and 310 thousand acres respectively. The prospective maize is not promising in this area. It cannot compete with the other activities for resources.

With regard to tree crops, all new practices are promising. The new practices for oil palm, cocoa, and rubber replace the traditional practices at their limits.

Area V.--Traditional sole and mixed cropping of the various crops cannot compete with the new practices for resources in this area.

Regarding the new cultural practices, the production of Western White 1 maize (late crop), and the new variety of yams is carried on to 90 and 680 thousand acres in this area. The prospective variety of swamp rice is profitable to 34 thousand acres.

Concerning tree crops, new practices are superior to the traditional ones. The new practices of oil palm and rubber replace the traditional practices at their limits.

Area VI.--Most of the traditional practices for various food crops cannot compete with the new practices in this area. Mixed cropping of melon seeds is the only traditional method that can compete for resources with the new production methods. This activity is carried on at its maximum limit.

Among the new cultural practices, production of the late crop of Western White 1 maize appears at the level of 140 thousand acres. The new varieties of bitter cassava and yams are produced at 580 and 410 thousand acre levels respectively. The prospective varieties of maize (early crop), millet and swamp rice are profitable produced to their maximum limits.

With regard to cash crops, mixed cropping of cotton is the only traditional activity profitable to its limit. The prospective variety of groundnuts replaces its recommended practices and the improved practices of soya beans are profitable to their limit.

The new practices for oil palm (the only tree crop in this area) replace the traditional practices to its limit.

Conclusion

In the optimal solution of this model, only a few of the prospective varieties of food crops can compete for resources and the acreages allowed for each crop with the traditional and improved techniques of crop production. But the prospective varieties of cash crops are promising. These production activities are superior in all areas to the traditional and improved practices presently available. The principal reason for this difference between food and cash crops is that there is an effective demand for additional quantities of export crops but not for additional quantities of food. The significance of these results will be discussed in Chapter IX.

Model 7

Because the supplies of fertilizers and extension services are severely limited in Nigeria, they must be used for the production of crops that contribute most to the income or nutrition of the country. This model restricts the supply of fertilizer and extension services to find an optimal production pattern under these conditions.

In Model 7 the maximum limits for the importation of single superphosphate and sulphate of ammonia are assumed to be 60 and 30 thousand long tons respectively. The maximum limit on the supply of extension services is assumed to be equal to the amount of services required to bring about the application of the new production techniques to 4.5 million acres of land.

The restriction on the fertilizer supply does not affect the use of new practices for tree crops or "commercial" maize. Because our data concerning the fertilizer requirement for these production activities give the amounts spent on fertilizer but do not specify what kinds are purchased, the model uses only expense charges to represent fertilizer use for these production activities. It does not draw the quantities of fertilizer they use from the limited amounts imported for other crops. It is as though these few activities imported their own fertilizer directly (when they could pay the expense), rather than through the normal channels of the model. The effects of these restrictions on the production patterns will be discussed by areas.

Area I.--The traditional cropping practices of many food crops are profitable in this model. Traditional sole cropping for maize, upland and swamp rice, sorghum, wheat, sweet cassava, sweet potatoes, yams, and melon seeds is carried on to the limits. The traditional sole cropping practices for millet and Irish potatoes are profitable to 1440 and 5 thousand acres. Mixed cropping of maize, millet, sorghum, sweet cassava, sweet potatoes, yams, and melon seeds is profitable to the limits.

The new practices for all food crops are at zero level in this area because of the restriction on the supply of fertilizer and extension services. These scarce resources are applied exclusively to the production of the recommended practices for groundnuts (a cash crop). This activity uses only 960 thousand acres of the area set aside for mixed cropping practices. The sole cropping of groundnuts, soya beans, and cotton are carried on to their limits. Mixed cropping of cotton is also profitable to its limit. The current method of tobacco production is promising in this model.

Area II.--In this area, the traditional sole cropping of millet, upland and swamp rice, sorghum, sweet cassava, Irish potatoes, sweet potatoes, yams, and melon seeds is profitable to the limits. But traditional sole cropping of maize is profitable only to 140 thousand acres. Mixed cropping practices for maize, millet, sorghum, sweet cassava, Irish potatoes, sweet potatoes, yams, melon seeds are profitable to their limits, and mixed cropping of cowpeas is carried on to 3200 thousand acres.

The new practices for all food crops are at zero level in this area because of the restrictions on the supply of fertilizer and extension services. These scarce resources are used again by the recommended practices for groundnuts, replacing the traditional practices for groundnut production. Traditional sole cropping for soya beans and mixed cropping of cotton are profitable to the limits. The current method of tobacco production is promising in this area.

Area III.--The traditional sole cropping practices for cocoyams and melon seeds are at their limits in this area. But traditional sole cropping for yams is profitable only at a level of 290 thousand acres. Mixed cropping practices for cocoyams, yams, and melon seeds are carried on at their limits, while mixed cropping of bitter cassava is profitable only to 210 thousand acres.

Among the new practices in food crops, the new variety of maize, Western White 1 (both early and late crop) is profitable to its limit, while the new variety of bitter cassava is profitable only to 1000 acres.

Among the tree crops, the new practices for all tree crops appear at their limits in this area.

Area IV.--The traditional sole cropping practices for maize, swamp rice, cocoyams, yams, and melon seeds occur at their limits. Mixed cropping of swamp rice, cocoyams, yams, and melon seeds is profitable to the limits, while mixed cropping of cassava is profitable to 130 thousand acres.

Among the new practices for food crops, the early crop of Western White 1 maize is produced to its limit and the late crop to 32 thousand acres (near its limit). The new variety of bitter cassava is profitable only to 40 thousand acres.

Regarding tree crops, the new practices for oil palm, cocoa, and rubber replace traditional practices at their limits.

Area V.--No traditional sole cropping for any food crop is profitable in this area. But mixed cropping of cocoyams appears at its limit.

Among the new practices, the production of commercial maize and the new variety of yams is profitable only to 340 and 470 thousand acres respectively.

For tree crops, the new practices are superior to traditional ones. These activities appear at their limits.

Area VI.--Traditional sole cropping practices for maize and melon seeds are profitable to their limits in this area. Traditional sole cropping for yams is profitable only to 110 thousand acres.

Among the new practices, the production of commercial maize and the new varieties of bitter cassava, yams, and cowpeas are profitable to (in order) 440, 630, 130, and 240 thousand acres.

Regarding cash crops, only the improved practices for soya beans are profitable (to 20 thousand acres).

The new practices for oil palm are superior to traditional practices. This activity appears at its limit.

Conclusion

Restrictions on the supply of fertilizer and extension services change the solution of the model in favor of the traditional practices which do not use these resources. On the other hand the new practices for tree crops and commercial maize, which import fertilizer directly, are not restricted by limiting the fertilizer supply. These production activities replace traditional practices. The significance of these restrictions and the results of this model will be discussed in more detail in Chapter IX.

Livestock Development

Apart from bush cattle in Area I, the traditional animal industries expand to their limits. In Area I there is a shortage of pasture land and the earnings per acre from bush cattle are less than from raising goats and sheep. Therefore, goats and sheep expand to their limits and the remaining bush pasture is allocated to raising cattle. In Areas II through VI, where bush pasture is abundant, the revenue and cost per head should be considered. Table 10 shows only the potential revenue per head from expanding an activity. The cost of raising different animals must also be considered, but we have no data on that in these models. Neither commercial swine nor commercial chickens are profitable.

Resource Development

During May and June labor is a scarce factor in Areas III, V, and VI according to the production patterns in Models 5, 6, and 7. The solutions to all three models show that additional labor contributes more to revenue if it is applied to Area V rather than the other areas

(III or VI). If Nigerians plan to use machinery to release labor during this season, priority should be given (in order of importance) to Areas V, VI, and III. In Areas I, II, and IV a substantial amount of labor will be unused during these months. If the production patterns of these models are carried out, the unused labor could be transferred to the industrial sector.

There are substantial quantities of unused labor during the rest of the year if these production patterns are implemented. Only in Area III and in Model 5 is the total available labor used, and even in this case the contribution of additional labor is negligible. Area I, with the highest, and Area II, with the second highest percentage of unused labor, can release a substantial quantity of labor for the industrial sector if the production patterns of these models are carried out. Area IV can also release more than 50 per cent of its available labor force. This labor, however, is only available for part of the year.

Land is the only factor which is scarce in all areas and in all models. To expand the land available would be highly beneficial. If the cost of expansion is equal in all areas, priority should be given (in order) to Areas V and IV, where a high percentage of available land is in tree crop production. On the other hand, since the expansion of tree crops is generally profitable, the suitability of land for tree crop production should be considered. In Area V, where additional land is accompanied by a decrease in yields, additional land is profitable in Models 5 and 6, but not in Model 7.

Bush pasture is scarce only in Area I, where the arable land expands by 9 1/2 per cent beyond the estimate for 1963 at the expense of bush pasture. However, bush pasture is abundant in other areas in all models. Research introducing a new breed of animals resistant to tsetse flies could make possible the use of abundant pasture in other areas. Improvements in the existing pasture in Area I can help solve the problem of insufficient pasture land there.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

The Models and Major Findings

This study examines different production techniques for crops grown in Nigeria, and tries to determine which techniques are most efficient as sources of income and/or nutrition. It makes use of Victor Smith's mathematical programming model,[1] which maximizes the revenue obtainable from the agricultural resources not used to provide food for Nigeria, after providing nutrients for a population of 61 million people.

Smith used a series of four models (Models 1, 2, 3, and 4) which concentrated on finding optimal production patterns given the production techniques used in 1963. This study continues his work with three models (Models 5, 6, and 7) but turns its attention to the consequences of using new production techniques.

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[1]Victor E. Smith, "Optimal Resource Allocation for Income and Nutrition," a working paper for the Consortium for the Study of Nigerian Rural Development, Working Paper No. 11, Michigan State University, East Lansing, Michigan, July, 1969. (Mimeographed.)

Model 5

This model introduces improved practices for producing both food and cash crops. These new techniques (with the exception of dwarf sorghum and the new variety of cowpeas which will be available shortly) are now available to Nigerian farmers. All these new practices and crop varieties must compete with sole and mixed cropping for acreage the model allows to given crops in specific areas. Each crop that utilizes new techniques can expand to the sum of the maximum limits of the same crop (in both sole and mixed cropping) in each area.

In the optimal solution of this model the new production practices for export crops--field crops as well as tree crops--make, generally, efficient use of resources. Export crops yield a revenue of 14,000 million shillings (Ł700 million) annually. At the same time the agricultural sector pays 1050 million shillings (Ł52.5 million) for imported fertilizers and 470 million shillings (Ł23.5 million) to buy fish and wheat from outside the agricultural sector. After subtracting these figures from the export crop revenue, the net revenue from the agricultural sector is 12,500 million shillings (Ł625 million). However, the calculation of this revenue is based on the values of export crops and fertilizer at the farm location.[2]

[2]The revenues and costs considered in this study are social revenues and social costs. Private revenues and costs differ whenever the farmer receives a subsidy,

The foreign exchange earnings are based on f.o.b. prices (for exports) and c.i.f. prices (for imports). Therefore the net foreign exchange earning is higher (Ƀ755 million) than the revenue from agriculture.

These are the possible benefits from the application of improved techniques already available to the production of food and cash crops. The improved techniques for food crops, with high yields per acre, release resources for cash crops. On the other hand the new techniques for cash crops, with high yields per acre, make these benefits possible for Nigerians.

Regarding food crops, a combination of new and traditional techniques can provide a population of 61 million with adequate nutrition. Some of the new techniques for food crops are not profitable because of the lack of effective demand and other underlying assumptions of the model, which will be explained below. The most efficient techniques for producing various crops in a particular area were discussed in Chapter VIII.

Model 6

This model is designed to explore the possible gains from further plant breeding programs for major

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pays a tax on the sale of his product, or receives from the marketing board less than his product is worth to society at his point of sale. In general, the producer of cash crops in Nigeria receives less than the social value of his product.

crops, assuming that the improved production techniques introduced in Model 5 are also available. The production activities included in this model are prospective varieties not available to Nigerian farmers at the present time--varieties that could be available in the future as research on plant breeding continues. Two of these prospective varieties are export crops (groundnuts and cotton); the others are food crops. These prospective production techniques must compete with traditional practices and the improved production techniques presently available, for resources and for the acreage the model allows for producing a given crop in a specific area.

In the optimal solution of this model, the prospective varieties introduced for the two export crops (groundnuts and cotton) make efficient use of resources. Both of these prospective production techniques replace their recommended practices to the capacity limits imposed by the model.

In the solution of the model, the export crops yield a revenue of 15,500 million shillings (£775 million). However the agricultural sector pays 1070 million shillings (£53.5 million) for the importation of fertilizers and 450 million shillings (£22.5 million) for buying fish and wheat from outside the agricultural sector. Subtracting these figures from the revenue from export crops, the net revenue from the agricultural sector is 14,000 million shillings (£700 million). Revenue from the agricultural sector is obtained by pricing the export crops and fertilizers at the farm location. The foreign exchange earnings are based on f.o.b. prices (for exports) and c.i.f. prices (for imports). The net foreign exchange earnings are 16,800 million shillings (Ⱡ840 million).

A comparison between the net revenue in Model 5 (Ⱡ625) and the net revenue in Model 6 (Ⱡ700) shows that the net gain from introducing the prospective varieties is Ⱡ75 million annually. This gain could be increased if the effective demand for food were increased or if some of the food crops were exported. It would, of course, be much larger than these figures if the model did not impose artificial capacity limits on the various export crops. If the expenses of research and extension programs are less than the net gain, the breeding programs are beneficial to Nigerians.

Only a few of the prospective varieties of food crops replace the traditional and improved techniques because of the lack of effective demand for food and the arbitrary limits on cash crop expansion in the model. These superior prospective varieties and other efficient techniques are discussed in Chapter VIII.

Model 7

To this point we have assumed, in effect, that: (1) the government has provided (at no cost to the farmer) whatever extension services are needed to bring about the adoption of the new techniques, and (2) fertilizers can be imported at will, whenever farmers find it worthwhile to use them. However, the extension services available in Nigeria are limited and the quantities of fertilizer imported are set by governmental decision. The model is designed to find the most efficient production techniques when the quantities of extension services and fertilizer are limiting factors. The solution of this model will be useful to those policy-makers who want to allocate limited fertilizer and extension services among crops and between areas to provide the maximum benefit for Nigeria.

In this model the maximum limits for the importation of single superphosphate and sulphate of ammonia are assumed to be 60 and 30 thousand long tons respectively. The maximum limit on the supply of extension services is assumed to be equal to the amount of services needed to apply the new techniques of production to 4.5 million acres of land. Activities and restraints other than those involving fertilizer and extension services are the same as in Model 5. It should be remembered that the restriction on the supply of fertilizer does not affect tree crops, because our data concerning fertilizer requirements for new practices for tree crops give the amounts spent on fertilizer but do not specify the kinds to be used. Therefore, while the model can use expense charges to the production of these crops for fertilizer use, it cannot specify the physical quantities employed. Consequently, these activities do not use the limited fertilizer imported for field crops, but are regarded as importing fertilizer directly whenever the activity can make profitable use of it.

With restrictions on the supply of fertilizer for field crops and extension services, the revenue from export crops is 10,500 million shillings (£525 million). At the same time the expenditures for the importation of fertilizer (including fertilizer for tree crops) decline from 1050 million shillings (£52.5 million) in Model 5 to 330 million shillings (£16.5 million) in Model 7. On the other hand, the expenditures for food items increase from 470 million shillings (£23.5 million) in Model 5 to 1160 million shillings (£58 million) in Model 7. Subtracting these figures from the revenue derived from export crops, the net revenue from the agricultural sector is 9,000 million shillings (£450 million), compared to 12,500 million shillings (£675 million) in Model 5. In Model 7 the net foreign exchange earning is 11,200 million shillings (£560 million), compared to 15,100 million shillings (£755 million) in Model 5. The differences between the gains obtainable in Model 5 and Model 7 result from the restrictions on fertilizer supply and extension services.

The restraints on the fertilizer supply and extension services change the pattern of production. The most efficient techniques for producing various crops under these conditions are discussed in Chapter VIII.

Modifying the Assumptions

In Chapter VIII we explained that, in the solution of the models used in this study, all the new techniques for export crops are superior to traditional practices. Regarding food crops, some of the new production techniques cannot compete with traditional methods. Such a result may be puzzling. The crucial assumptions are these: (1) an absolutely inelastic demand for nutrition, (2) a given population, (3) fixed prices for fertilizers, (4) food crop outlets restricted to internal consumption, and (5) maximum limits on acreage for each crop. If any one of these assumptions is violated, the result will be different. For example, an increase in nutritional requirements or an increase in the population of the country would increase the internal (shadow) prices of foods. In this study, some of the new techniques for food crops do not appear in the solution of the model because the food value of the additional yield cannot pay the cost of the additional resources (fertilizer or other costs) they employ. But an increase in internal (shadow) prices (caused by an increase in demand) would increase the value of the additional yield using new techniques. In this case, some or all (depending on the amount demand increased) of the new techniques not now in the optimal solution would appear in the new solution of the model.

Obviously any decrease in the cost of inputs used exclusively by the new techniques would bring some new production techniques into the solution. But the results will differ from those of an increase in demand. As some of the new techniques enter the solution of the model (because of a decrease in costs) they lower the opportunity-cost value of the nutrients, because of the decline in the cost of providing them. On the other hand, the decline in the opportunity-cost value of nutrients makes the additional yield worth less than before, preventing other new techniques from entering into the solution. In other words, the appearance of new techniques in the optimal solution of the model is self-limiting so long as demand is absolutely inelastic.

Another situation in which new techniques for food crops could become profitable (the ones not profitable now) would be that in which food crops could be exported. The introduction of export activities for food crops would prevent internal (shadow) prices from falling below international prices. Under this condition there would be an international demand as well as internal demand for the additional yield from new techniques. New techniques for food crops that do not appear in the solution of the model because of the lack of effective demand would be in the solution of the model (provided Nigeria has a comparative advantage in producing these foods) when an international demand is created.

Raising capacity limits on the expansion of export crops would also bring new techniques for food crops into the solution of the model. Tables 5 and 6 (Chapter IV) show that the new techniques for cash crops are applied to their maximum limits. On the other hand, Tables 26 and 27 (Appendix) show that the shadow prices for further expansion of these production techniques are substantial. Therefore, new techniques for export crops can expand profitably well beyond the limits imposed in the models. If this were to happen, additional new techniques for food crops would appear in the solution. The mechanism is as follows.

In these solutions export crops expand by 20 per cent above 1963 levels while the quantity of land under cultivation is allowed to expand only 9.5 per cent. Consequently the export crops use some of the land which otherwise would have been left over for the food crops. As the remaining land left over from the cash crops becomes more limited (scarce), those new techniques which have the highest nutrient yields per acre of land appear in the solution of the model. In the extreme case--if the land left over from the export crops becomes very limited--only the production techniques with the highest nutrient yields per acre of land will appear in the solution of the model. If land is scarce, as it is in these solutions, the model selects those activities which have the highest nutrient value per acre (whether new techniques or mixed cropping) in order to meet the requirements. For this reason mixed cropping in these solutions is generally superior to traditional sole cropping.

Land is scarce in these solutions because the optimal solutions shift the 1963 pattern toward land using activities so much that land becomes more limiting (scarce) than the other factors. Since traditional mixed cropping uses less land (the scarce factor) than traditional sole cropping for a given amount of nutrients,[3] it tends to be superior to traditional sole cropping.

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[3]An acre of mixed crop uses only .43 of a surface acre of land in Area III, for instance. Yields per surface acre do not usually decline in proportion to the decline in the land requirement.

Conclusions

In the solutions of the models used in this study, the new techniques for cash crops use resources very efficiently. These production activities expand to the maximum limits allowed in the models in all areas. The superiority of the new practices for cash crops justifies the direction of past research and promotional programs. Efforts devoted to increasing cash crop yields have been greater than the efforts spent on increasing food crop yields. On the other hand, part of the superiority of cash crops in this model is caused by the assumption of perfectly elastic international demands for these crops.

As for food crops, with a combination of new and traditional techniques of production, Nigeria has the capacity to feed a population of 61 million adequately if the people in each area are willing to eat foods most economical for that area, and if incomes are distributed so that everyone can buy the food he needs. Some new food production techniques do not appear in the solution because, in this model, once the goal of adequate nutrition has been attained, the demand for additional food is zero. In order to make more new production techniques profitable, either the internal demand must increase or crops must be exported. If the demand does not increase the price of food will decrease sharply as new techniques are introduced. This in turn will make some new techniques unprofitable.

Among the traditional crops, mixed cropping is generally superior to sole cropping. Some of the new techniques supersede traditional sole cropping but not mixed cropping because mixed cropping yields a higher nutrient value per acre of land and land is a scarce factor in these solutions.

Concerning breeding programs, further research for increasing the yields of all cash crops studied is promising. These solutions also show that further research devoted to increasing the yields of a number of food crops (such as maize, millet, sorghum, and rice) is justified, even under the very restrictive conditions of the model. As population grows, as higher incomes give rise to greater effective demand for food and as cash crop acreages expand beyond the limits imposed in the model, still more efficient techniques of food production will be needed. Therefore research should not, in fact, be limited to such a restricted list of crops. If research can bring the internal prices of food crops down to a level permitting their sale in world markets, food crop production on a much broader scale is justified. Priority should be given to those food crops that appear most promising in these solutions.

The results of this research are in agreement with the recommendations of the Consortium for the Study of Nigerian Rural Development (CSNRD):[4]

> In the short run, we recommend that Nigeria (a) concentrate on opportunities not previously exploited to expand agricultural production and export earnings by more fully meeting international demands for her export commodities, (b) distribute the resultant increase in income widely over a large number of rural people to provide the means of financing the expansion in production, to generate additional effective domestic demand for both farm and nonfarm products and to obtain substantial increases in welfare for her masses of rural people.[5]

With respect to recommendation (a) our solutions call for expanding the proportion of export crop production beyond the levels farmers were willing to produce in 1963, given marketing board policies at that time.

With respect to recommendation (b) our solutions reveal that where the demand for food is limited (as by our fixed and absolutely inelastic demand) there are severe limits on the extent to which improved techniques in food production are worth adopting. They show also that even with limited demand, the most efficient patterns

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[4]Glenn L. Johnson, O. J. Scoville, G. K. Dike, and C. K. Eicher, Strategies and Recommendations for Nigerian Rural Development, 1969/1985, Consortium for the Study of Nigerian Rural Development (East Lansing, Michigan: Michigan State University, July, 1969).

[5]*Ibid.*, p. 1.

of food consumption require internal trade and the use of the developing market mechanism. Reliance upon markets for a portion of one's food supply is only possible where money incomes are widely distributed among the rural population, as CSNRD recommends.

If the increases in rural incomes brought about by expanded export production are widely distributed, demand for food will increase making profitable a wider use of new techniques in food production, more specialization within agriculture, and more internal trade.

The CSNRD recommendations continue:

> _In the long run_, our strategy focuses on food crops and begins with expanded research now, to be followed with production campaigns for food crops starting 5 to 10 years in the future. The object of the research is to increase yields and reduce per-unit costs of food and feed crops and livestock to permit Nigeria to develop cheaper and better food, expanded livestock production and, possibly, exports of food, feed and beef.[6]

Our solution shows that the maximum revenue from agriculture consistent with adequate nutrition for all Nigerians cannot be attained without taking advantage of certain improved techniques yet to be developed by food crop research.

As population increases, incomes rise and the acreage devoted to export crops expands, still further improvements in the techniques of food crop production

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[6] _Ibid._, p. 2.

will be needed. Research on food crops must continue. Should such research be sufficiently effective, export markets might develop for some crops now used only within Nigeria.

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APPENDIX

APPENDIX

SHADOW PRICES OF EXPANDING VARIOUS CROPS

This appendix is to provide information about the shadow prices of expanding different crops and techniques. In this study, the crop production is not allowed to expand more than 20 per cent above the estimated levels for 1963. Thus there are shadow prices for those activities which, at their maximum levels, earn more than the resources they employ can earn in other uses. These shadow prices show the additions to revenue possible if a single cropping activity is expanded by a small amount when the total quantities of resources and the limits upon other activities remain unchanged. If the solutions of the models are carried out exactly, the shadow prices are useful for selecting the most promising crop or technique. It is possible for Nigeria to adjust production patterns toward the solutions of the models, but it is unlikely that she will implement them exactly. If Nigerians implement the solutions of the models exactly, the shadow prices are highly important for decision-making. Otherwise, to use shadow prices as criteria involves risks. Shadow prices for the food production techniques of Models 5 and 6 are shown in Table 25. Tables 26 and 27 show the shadow prices of the production techniques for cash and tree crops in Models 5 and 6. Table 28 shows shadow prices for the different techniques of food crop production in Model 7. The shadow prices of cash and tree crops in Model 7 are shown in Tables 29 and 31 respectively.

Table 25. Additions to Revenue Possible if a Food Crop Activity were Expanded*

Activity	Area																	
	I			II			III			IV			V			VI		
	Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
	Shillings per acre per year																	
Maize																		
Traditional practices																		
Sole	64	5.3	0	384	0	0	2354	0	0	5847	8.8	8.8	--	--	--	3532	0	0
Mixed	139	33	11	1130	53	21	2331	0	0	2529	0	0	1245	0	0	1597	0	0
New practices																		
Commercial	--	--	--	--	--	--	4741	0	0	--	0	0	5376	0	0	3957	0	0
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Western White 1, early	--	--	--	--	--	--	--	121	33	--	16	16	--	0	0	--	51	0
Western White 1, late	--	--	--	--	--	--	--	76	109	--	0	0	--	0	0	--	28	0
Prospective variety, early	--	--	0	--	--	0	--	--	0	--	--	0	--	--	0	--	--	9.6
Prospective variety, late	--	--	--	--	--	--	--	--	0	--	--	0	--	--	0	--	--	0
Millet																		
Traditional practices																		
Sole	0	0	0	468	0	0	--	--	--	--	--	--	--	--	--	0	0	0
Mixed	93	23	9.2	1111	19	0	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	0	0
Prospective variety	--	--	0	--	--	50	--	--	--	--	--	--	--	--	--	--	--	231
Rice, upland																		
Traditional practices																		
Sole	2137	.062	0	1176	0	0	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	0	--	34	42	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	--	--	0	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
Rice, swamp																		
Traditional practices																		
Sole	3004	23	2.0	2135	48	63	--	--	--	1069	0	0	1343	0	0	2780	0	0
Mixed	--	--	--	--	--	--	--	--	--	1857	87	87	1100	0	0	1031	0	0
New practices																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
New variety	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	281	0
Prospective variety	--	--	0	--	--	0	--	--	--	--	--	--	--	--	0	--	--	182
Sorghum																		
Traditional practices																		
Sole	41	0	0	662	0	0	--	--	--	--	--	--	--	--	--	630	0	0
Mixed	76	15	8.7	1218	0	12	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	0	0
Dwarf variety	--	0	0	--	44	0	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	--	--	0	--	--	0	--	--	--	--	--	--	--	--	--	--	--	0

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

Table 25 (cont'd.)

Activity	Area																	
	I			II			III			IV			V			VI		
	Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
<u>Wheat</u>																		
Traditional practices																		
Sole	335	93	43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Irrigated	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<u>Cassava</u>, bitter, root[a]																		
Traditional practices																		
Sole	--	--	--	--	--	--	665	0	0	1528	0	0	436	0	0	711	0	0
Mixed	--	--	--	--	--	--	706	0	0	1746	24	24	91	0	0	402	0	0
New practices																		
New variety	--	--	--	--	--	--	--	0	0	--	0	0	--	0	0	--	0	0
<u>Cassava</u>, sweet, fresh[a]																		
Traditional practices																		
Sole	30	0	0	725	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	69	5.6	6.2	815	15	6.2	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	8.4	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
<u>Potato</u>, Irish																		
Traditional practices																		
Sole	0	0	0	1572	0	7.7	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	0	0	0	416	0	0	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
<u>Potato</u>, sweet																		
Traditional practices																		
Sole	706	187	128	4259	146	67	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	406	109	74	3379	131	58	--	--	--	--	--	--	--	--	--	--	--	--
<u>Cocoyam</u>																		
Traditional practices																		
Sole	--	--	--	--	--	--	2570	0	10	2801	13	13	2689	0	0	--	--	--
Mixed	--	--	--	--	--	--	631	0	0	2531	.037	.037	2361	0	0	--	--	--
<u>Yam</u>																		
Traditional practices																		
Sole	36	0	0	2098	0	18	923	0	0	5355	0	0	3475	0	0	4071	0	0
Mixed	174	45	23	2725	0	39	2818	0	0	3621	0	0	3418	0	0	3702	0	0
New practices																		
Recommended practices	--	0	0	--	100	0	--	--	--	--	--	--	--	--	--	--	--	--
New variety	--	--	--	--	--	--	--	0	0	--	0	0	--	0	0	--	0	0

a The figures are for an acre of cassava of which half was planted in the current year. The other half, planted in the previous year, is being harvested during the current year.

Table 25 (cont'd.)

Activity	Area I, Model 4	Area I, Model 5	Area I, Model 6	Area II, Model 4	Area II, Model 5	Area II, Model 6	Area III, Model 4	Area III, Model 5	Area III, Model 6	Area IV, Model 4	Area IV, Model 5	Area IV, Model 6	Area V, Model 4	Area V, Model 5	Area V, Model 6	Area VI, Model 4	Area VI, Model 5	Area VI, Model 6
<u>Cowpea</u>																		
Traditional practices																		
Sole, seed	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	0	0	0
Mixed																		
Seed	0	0	0	0	0	0	--	--	--	--	--	--	0	0	0	0	0	0
Seed and hay	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Sole, seed																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
New variety	--	0	0	--	0	0	--	0	0	--	0	0	--	0	0	--	0	0
Mixed, seed and hay Improved variety	--	0	1.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<u>Melon seed</u>																		
Traditional practices																		
Sole	72	14	3.9	1060	29	63	1377	10	32	1304	0	0	425	0	0	1622	0	0
Mixed	111	30	14	2024	95	93	920	34	41	1205	0	0	260	0	0	1474	45	39
<u>Okra</u>																		
Traditional practices																		
Sole	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	137	0	0
Mixed	--	--	--	--	--	--	0	0	0	101	0	0	143	0	0	99	0	0
<u>Onion</u>																		
Traditional practices																		
Sole	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--
New practices																		
Recommended practices	--	0	0	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--
<u>Tomato</u>																		
New practices																		
Recommended practices, early	--	--	--	--	--	--	--	0	0	--	--	--	--	--	--	--	--	--
Recommended practices, late	--	--	--	--	--	--	--	.48	21	--	--	--	--	--	--	--	--	--
Irrigated	--	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a The figures are for an acre of cassava of which half was planted in the current year. The other half, planted in the previous year, is being harvested during the current year.

Table 26. Additions to Revenue Possible if a Cash Crop Activity were Expanded*

Activity	Area																	
	I			II			III			IV			V			VI		
	Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
	Shillings per acre per year																	
Groundnut[a]																		
Traditional practices																		
Sole	139	0	0	1538	0	0	--	--	--	--	--	--	--	--	--	0	0	0
Mixed	92	0	0	1255	0	0	--	--	--	--	--	--	--	--	--	0	0	0
New practices																		
Recommended practices	--	462	0	--	378	0	--	--	--	--	--	--	--	--	--	--	123	0
Prospective variety	--	--	636	--	--	652	--	--	--	--	--	--	--	--	--	--	--	256
Bean, soya[a]																		
Traditional practices																		
Sole	3.6	23	0	0	0	0	--	--	--	--	--	--	--	--	--	0	0	0
New practices																		
Improved practices	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	86	96
Prospective variety	--	--	92	--	--	4.6	--	--	--	--	--	--	--	--	--	--	--	--
Cotton																		
Traditional practices																		
Sole	71	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--
Mixed	99	0	0	0	0	0	--	--	--	--	--	--	--	--	--	0	26	30
New practices																		
Recommended practices	--	364	0	--	175	0	--	--	--	--	--	--	--	--	--	--	--	--
Prospective variety	--	--	578	--	--	573	--	--	--	--	--	--	--	--	--	--	--	--
Tobacco																		
Traditional practices																		
Sole	722	839	867	0	804	863	--	--	--	--	--	--	--	--	--	--	--	--

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a Groundnut and soya bean are food crops as well as cash crops.

Table 27. Additions to Revenue Possible if a Tree Crop Activity were Expanded*

Activity	Area																	
	I			II			III			IV			V			VI		
	Model			Model			Model			Model			Model			Model		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
	Shillings per acre per year																	
Oil palm																		
Traditional practices	--	--	--	--	--	--	4470	0	0	250	0	0	0	0	0	4574	0	0
New practices	--	--	--	--	--	--	--	1476	1558	--	1419	1419	--	927	998	--	1178	1186
Cocoa																		
Traditional practices	--	--	--	--	--	--	0	0	0	7.5	0	0	--	--	--	--	--	--
New practices	--	--	--	--	--	--	--	1603	1646	--	1275	1275	--	--	--	--	--	--
Kola nut																		
Traditional practices	--	--	--	--	--	--	1282	0	0	--	--	--	--	--	--	--	--	--
Rubber																		
Traditional practices	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	--	--	--
New practices	--	--	--	--	--	--	--	1037	1079	--	879	879	--	722	841	--	--	--

* The entries show the gain possible from expanding a single activity by one acre when the total quantities of resources and the limits upon the other production and consumption activities remain unchanged.

-- The activity is not available in this area.

Table 28. Additions to Revenue Possible if a Food Crop Activity were Expanded*: Model 5 with Fertilizer and Extension Services Limited

Activity	Area					
	I	II	III	IV	V	VI
	Shillings per acre per year					
Maize						
Traditional practices						
Sole	64	0	0	151	--	137
Mixed	139	179	0	0	0	0
New practices						
Commercial	--	--	0	0	0	0
Recommended practices	0	0	--	--	--	--
Western White 1, early	--	--	233	259	0	0
Western White 1, late	--	--	70	0	0	0
Millet						
Traditional practices						
Sole	0	65	--	--	--	0
Mixed	93	220	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	0
Rice, upland						
Traditional practices						
Sole	47	151	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	--

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

Table 28 (cont'd.)

Activity	Area					
	I	II	III	IV	V	VI
Rice, swamp						
Traditional practices						
Sole	131	329	--	90	0	0
Mixed	--	--	--	457	0	0
New practices						
Recommended practices	0	0	--	--	--	--
New variety	--	--	--	--	0	0
Sorghum						
Traditional practices						
Sole	41	88	--	--	--	0
Mixed	34	139	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	0
Dwarf variety	0	0	--	--	--	--
Wheat						
Traditional practices						
Sole	335	--	--	--	--	--
New practices						
Irrigated	0	--	--	--	--	--
Cassava, bitter, root[a]						
Traditional practices						
Sole	--	--	0	0	0	0
Mixed	--	--	0	0	0	0
New practices						
New variety	--	--	0	0	0	0

a The figures are for an acre of cassava of which half was planted in the current year. The other half, planted in the previous year, is being harvested during the current year.

Table 28 (cont'd.)

Activity	Area					
	I	II	III	IV	V	VI
Cassava, sweet, fresh[a]						
Traditional practices						
Sole	24	21	--	--	--	--
Mixed	65	93	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	--
Potato, Irish						
Traditional practices						
Sole	0	166	--	--	--	--
Mixed	0	45	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	--
Potato, sweet						
Traditional practices						
Sole	465	701	--	--	--	--
Mixed	275	584	--	--	--	--
Cocoyam						
Traditional practices						
Sole	--	--	170	536	0	--
Mixed	--	--	32	473	25	--
Yam						
Traditional practices						
Sole	18	269	0	293	0	0
Mixed	135	428	328	119	0	110
New practices						
Recommended practices	0	0	--	--	--	--
New variety	--	--	0	0	0	0

Table 28 (cont'd.)

Activity	Area					
	I	II	III	IV	V	VI
Cowpea						
Traditional practices						
Sole, seed	0	0	--	--	--	0
Mixed						
Seed	0	0	--	--	0	0
Seed and hay	0	--	--	--	--	--
New practices						
Sole, seed						
Recommended practices	0	0	--	--	--	--
New variety	0	0	0	0	0	0
Mixed, seed and hay						
Improved variety	0	--	--	--	--	--
Melon seed						
Traditional practices						
Sole	72	153	47	76	0	208
Mixed	111	374	98	191	0	223
Okra						
Traditional practices						
Sole	--	--	--	--	--	0
Mixed	--	--	0	0	0	0
Onion						
Traditional practices						
Sole	0	0	--	--	--	--
New practices						
Recommended practices	0	0	--	--	--	--

Table 28 (cont'd.)

Activity	Area					
	I	II	III	IV	V	VI
Tomato						
New practices						
Recommended practices, early	--	--	0	--	--	--
Recommended practices, late	--	--	0	--	--	--
Irrigated	0	--	--	--	--	--

* The entries show the gain possible if an activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a The figures are for an acre of cassava of which half was planted in the current year. The other half, planted in the previous year, is being harvested during the current year.

Table 29. Additions to Revenue Possible if a Cash Crop Activity were Expanded*: Model 5 with Fertilizer and Extension Services Limited

Activity	Area					
	I	II	III	IV	V	VI
	Shillings per acre per year					
Groundnut[a]						
Traditional practices						
Sole	47	0	--	--	--	0
Mixed	0	0	--	--	--	0
New practices						
Recommended practices	0	525	--	--	--	0
Bean, soya[a]						
Traditional practices						
Sole	3.6	32	--	--	--	0
New practices						
Improved practices	--	--	--	--	--	0
Cotton						
Traditional practices						
Sole	71	0	--	--	--	--
Mixed	99	39	--	--	--	0
New practices						
Recommended practices	0	0	--	--	--	--
Tobacco						
Traditional practices						
Sole	722	578	--	--	--	--

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.

a Groundnut and soya bean are food crops as well as cash crops.

Table 30. Additions to Revenue Possible if a Tree Crop Activity were Expanded*: Model 5 with Fertilizer and Extension Services Limited

Activity	Area					
	I	II	III	IV	V	VI
	Shillings per acre per year					
Oil palm						
Traditional practices	--	--	0	0	0	0
New practices	--	--	1298	1356	343	1093
Cocoa						
Traditional practices	--	--	0	0	--	--
New practices	--	--	1455	1212	--	--
Kola nut						
Traditional practices	--	--	0	--	--	--
Rubber						
Traditional practices	--	--	0	0	0	--
New practices	--	--	890	815	146	--

* The entries show the gain possible if one activity is expanded by one acre, with no increases in the total quantities of land or labor available, and with unchanged limits on the other production and consumption activities.

-- The activity is not available in this area.