

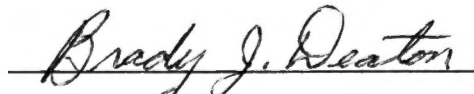
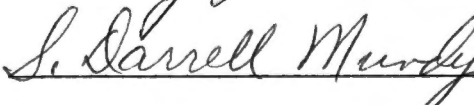
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To the Graduate Council:

I am submitting herewith a thesis written by Robert B. Mabele entitled "Crop Output Potentials of Peasant Farms in Kwimba District, Tanzania: A Linear Programming Analysis." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.


Major Professor

We have read this thesis
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Graduate Studies and Research

163
CROP OUTPUT POTENTIALS OF PEASANT FARMS IN KWIMBA DISTRICT, TANZANIA:

A LINEAR PROGRAMMING ANALYSIS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Robert B. Mabele

March 1974

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ABSTRACT

This study of crop output potentials in Kwimba District, Tanzania, was designed to illustrate the use of linear programming techniques in the analysis of agricultural production problems in peasant economies.

Linear programming methods were used to determine (i) an optimal production plan consistent with specified agricultural production constraints assumed to prevail under traditional farm conditions in the district, and (ii) an optimal production plan under "improved technology" constraints.

Both optimal production plans were subjected to sensitivity analysis using range analysis and parametric programming.

The data used in the study came from secondary sources and were accepted at their face value.

On the basis of the data available, the results of the study showed that labor during certain peak production periods was the resource that constrained greater production for farmers operating under the traditional farming system in the district. Furthermore, family subsistence requirements constraints reduced the ability of these farmers to increase production for the market in response to better monetary returns for their produce.

The general conclusion was that the solution to the problem of low income levels that faces peasant farmers in this district and elsewhere in Africa lies in widening the production bottlenecks caused by the shortage of labor during crucial production periods. Technological

changes such as the use of oxen-drawn implements, artificial fertilizers and insecticides should form an indispensable part of the strategy to raise agricultural productivity and incomes in countries like Tanzania.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
The Land and the People	1
Agricultural Development in Tanzania	4
Statement of the Problem	9
Objective	12
Methodology	13
Sources of Data	14
Limitations of the Study	15
II. AN ANALYTICAL FRAMEWORK FOR ANALYZING TANZANIAN FARM POTENTIALS	17
The Production Environment: Motivations and Constraints . .	17
Formulating the Linear Programming Problem	27
III. FARM PRODUCTION POTENTIAL WITH TRADITIONAL FARMING PRACTICES	31
Basic Information Used in the Linear Programming Model . . .	31
The Optimal Production Plan	37
The Sensitivity of the Optimal Production Plan	42
IV. THE IMPACT OF TECHNOLOGICAL CHANGE ON PRODUCTION AND INCOME	60
Changes Made in the Assumptions	60
Production and Income Under Changed Technology	66
Sensitivity of Optimal Production Plan Under Changing Technology	73
V. SUMMARY AND RECOMMENDATIONS	83
Summary	83
Implication for Further Research	88
Policy and Foreign Recommendations	90
BIBLIOGRAPHY	93
APPENDICES	96
Appendix A	97
Appendix B	100
VITA	103

LIST OF TABLES

TABLE	PAGE
1. Gross Domestic Product of Tanzania at Factor Cost by Industrial Origin (at Current Prices)	10
2. Tanzania: Production of Main Crops, 1961-1968	20
3. Tanzania: Commodity January Prices, 1961-1968	21
4. Available Resources and Crop Acreage Minimum Requirements, Typical Farm, Kwimba District	32
5. Input-Output Coefficients and Returns Per Acre of Crop Enterprises, Traditional Farm, Kwimba District	35
6. Linear Programming Tableau, Traditional Farm, Kwimba District	36
7. Crop Enterprise Mix, Traditional Farm, Kwimba District, Linear Programming Optimal Solution	38
8. Optimal Resource Allocation, Traditional Farm, Kwimba District, Linear Programming Solution	41
9. Sensitivity of Optimum Production to Changes in Constraint Levels, Traditional Farm, Kwimba District, Linear Programming Results	44
10. Sensitivity of Optimum Production Plan to Changes in Returns Per Acre, Traditional Farm, Kwimba District, Linear Programming Results	48
11. Acreage Response to Changes in Price, Traditional Farm, Kwimba District, Linear Programming Results	51
12. The Effect of a Change in the Economic Profitability of Late Maize, Cassava and Legumes (LMCL) on Its Acreage, Traditional Farm, Kwimba District, Linear Programming Results	53
13. The Effect of a Change in the Net Return Per Acre on LMCL on the Acreage of Other Crops, Traditional Farm, Kwimba District, Linear Programming Results	54
14. The Effect of Parametric Increases in the Return Per Acre of Rice on the Acreages of Other Crops, Traditional Farm, Kwimba District, Linear Programming Results	57

TABLE

PAGE

15. Linear Programming Tableau, Modernising Farm, Kwimba District	67
16. Crop Enterprise Mix, Modernising Farm, Kwimba District, Linear Programming Optimal Solution	68
17. Optimal Resource Allocation Under Changed Technology, Kwimba District, Linear Programming Solution	71
18. Sensitivity of Optimum Production Plan to Changes in Constraints, Modernising Farm, Kwimba District, Linear Programming Results	74
19. Sensitivity of Optimum Production to Changes in Returns for Acre, Modernising Farm, Kwimba District, Linear Programming Results	75
20. Acreage Response to Changes in Price, Modernising Farm, Kwimba District, Linear Programming Results	79
21. The Effect of Parametric Increases in the Return Per Acre of Rice on Acreages of Other Crops, Modernising Farm, Kwimba District	81
A1. Row Solution, Traditional Farm, Kwimba District	97
A2. Range Analysis: Rows at Intermediate Level, Traditional Farm, Kwimba District	98
A3. Range Analysis: Columns at Intermediate Level, Traditional Farm, Kwimba District	99
B1. Row Solution, Modernising Farm, Kwimba District	100
B2. Range Analysis: Rows at Limit Level, Modernising Farm, Kwimba District	101
B3. Range Analysis: Columns at Intermediate Level	102

LIST OF FIGURES

FIGURE	PAGE
1. Map of Tanzania Showing Main Agricultural Crops, Railroads and Towns	2
2. A Schematic Model of the Traditional Farm, Kwimba District .	28
3. Price Map for the Rice Activity Under Traditional Farm Conditions	56
4. A Schematic Model of the Modernising Farm, Kwimba District .	65
5. Price Map for the Rice Activity Under Changing Technological Conditions	78

CHAPTER I

INTRODUCTION

A. THE LAND AND THE PEOPLE

Tanzania¹ lies between 1° North and 11° South of the Equator and is sandwiched between the great lakes of Central Africa--Lake Victoria, Tanganyika and Nyasa. It is about 361,000 square miles in area--about 740 miles long and 760 miles wide with a coastline of about 550 miles long.² It shares its borders with eight countries--Kenya, Uganda, Burundi, Rwanda, Zaire, Zambia, Malawi and the Portuguese colony of Mozambique (see Fig. 1).

Physiographically, the country presents great diversity. However, the dominant geographic feature is flat to gently undulating plains and plateaus with altitudes ranging from a few feet on the coastal belt to above 5,000 feet on the Serengeti Plains. There are big mountains in the south and north with Mount Kilimanjaro, the highest in Africa, rising 19,340 feet above sea level. The Rift Valley branches into an eastern and western fork just above Lake Malawi. Between the two arms of the Rift Valley lies a Central Plateau with altitudes ranging from 3,000 to 5,000 feet. Most of this plateau is infested with tse-tse flies; otherwise it has great agricultural potentialities.³

¹For the purpose of this study Tanzania refers to what is now called Mainland Tanzania, formerly Tanganyika which, having acquired political independence from Britain in 1961, formed a union with the island of Zanzibar. However, the two still remain more or less separate economically.

²Carey B. Singleton, The Agricultural Economy of Tanganyika, Foreign Regional Analysis Division, Economic Research Service, U.S. Department of Agriculture (Washington: Government Printing Office, 1964).

³Ibid.

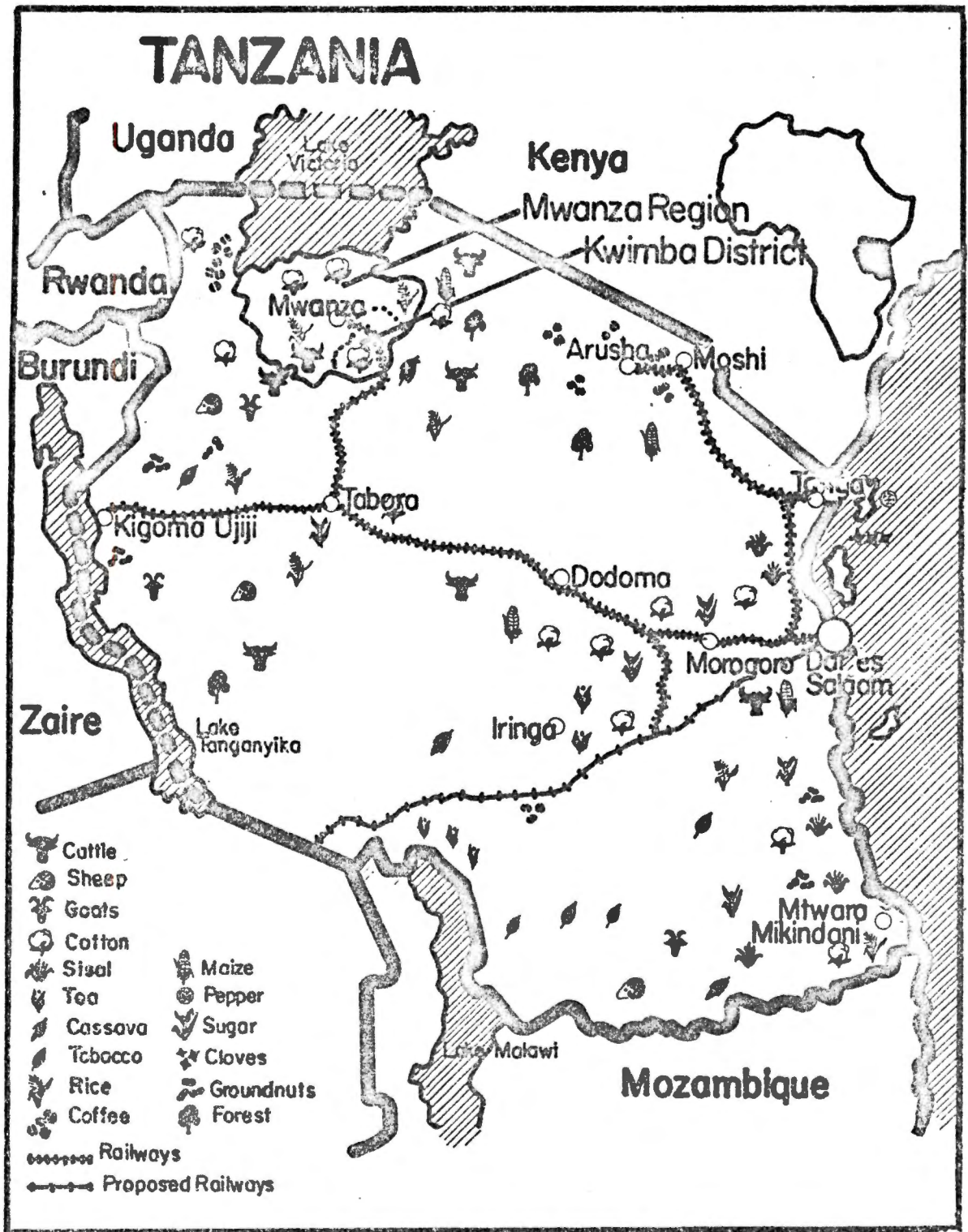


Figure 1. Map of Tanzania showing main agricultural crops, railroads and towns.

The mean temperature variation is between 69° to 81°F, the minimum range being 46° to 66°F. This allows the production of both tropical and temperate crops. Over most of the country, two seasons prevail: the wet season when rains are heavy, and the dry season when there is more or less no rain at all. However, the partial and temporal distribution of rain varies a great deal; some parts of the country receive on the average 80 inches of rainfall while others record below 20 inches annually. The development of water resources for human consumption and agricultural purposes is a developmental consideration of great urgency.

The 1967 Population Census estimated Tanzania's population at about 12 million with a 2.5 percent annual growth rate. The indigenous African peoples account for most of this population figure. The non-African population is well below 500,000, the bulk of which consists of Asians (from India, Pakistan and Arab countries). The Asians dominate the commercial sector. The few Europeans still in the country either are employed in the public and private sectors or own some of the few remaining private estate farms.⁴ The majority of the people live in rural areas, the percentage of urbanization of the Tanzanian population being very low. In 1957 it was estimated that only 4 percent out of a total population of 8,388,974 (Africans only) were living in the thirty-one "Gazetted Townships," with one-third of these living in

⁴In 1967, the sole political party in Tanzania (Mainland), the Tanganyika African National Union (TANU), after meeting in the northern town of Arusha, adopted a document called the Arusha Declaration. It provided for inter alia, the nationalization of wholesale, export and import trade, mines and major industries (with Tanzania acquiring at least 51 percent in the share of such concerns) and the complete nationalization of banks and insurance concerns. Many large farms also were affected. The provisions of this political blueprint have on the whole been implemented.

Dar-es-Salaam, the capital.⁵ The country is, therefore, predominantly rural although some shifts toward urbanization are taking place.

B. AGRICULTURAL DEVELOPMENT IN TANZANIA

Pre-Colonial Times⁶

The coast of what is now mainland Tanzania was very well known by traders from ancient civilizations. The Egyptians, Chinese, Phoenicians, Greeks and Romans established trade in ivory and gold with the coast of East Africa. This exposure to outside trade and influence, however, remained for centuries limited to the coast. The interior remained cut off from this contact mainly because of geographical factors.

The predominant agricultural pattern in Tanzania up to the early part of the nineteenth century was the cultivation of millet grains by means of shifting cultivation. The bush was cleared and cultivated for about two years and then left fallow for six to twelve years.⁷ Around the well-watered mountain regions like Kilimanjaro in the north, banana cultures flourished. In addition, livestock production, in many cases, supplemented crop husbandry.

Meanwhile by the nineteenth century Arab traders had established trade routes into the interior in search of ivory and slaves. It is believed that rice and maize were introduced to many parts of Tanzania

⁵Tanzania Government, African Census Reports, Table IV and Notes, reproduced in Hadley Smith (ed.), Readings in Economic Development in Tanzania (Dar-es-Salaam: Institute of Public Administration, 1967), p. 401.

⁶This section is based on John Ilife, Tanganyika Under German Rule 1905-12 (Cambridge: University Press, 1969), pp. 10-35.

⁷Ibid.

sometime during this century, presumably following the trade routes. By the end of the century these crops had become staples in many parts of the country. Moreover, trade in these commodities developed between the interior and the coast. In fact some hinterland areas grew rice solely for export to the coast, especially to Zanzibar island. Thus, by the time the Germans began to colonize mainland Tanzania in 1884, there was a flourishing trade between the coast and the interior in rice and maize.

The Colonial Period

According to a British historian, the most fundamental and consistent policy of colonial governments during both the German and British⁸ periods was "to exploit the country's resources for the benefit of Europe."⁹ In the words of an early British Governor,

The first objective of the Government is to induce the native to become a producer directly or indirectly, that is to produce or to assist in producing something more than the crops of local foodstuffs that he requires for the sustenance of himself and his family.¹⁰

This policy objective was implemented in two ways. First, European settlements where export crops were grown were established. The first German settlers experimented with cotton and tobacco production. Later rubber, coffee and sisal were introduced. The indigenous

⁸After Germany was defeated in the first World War, its colonies were distributed among the members of the League of Nations. Tanzania was given to the British.

⁹John Ilife, Agricultural Change in Modern Tanzania, mimeo, pp. 1-17.

¹⁰Sir Donald Cameron, Agriculture and Labour, 1926 Tanzania National Archives, quoted by Ilife, ibid.

people provided the necessary labor on these settlements. Initially this was done by using direct force. Later taxation was used to force people to seek employment on the plantations in order to earn money for the taxes. Eventually, however, wages provided the economic incentive for those who sought employment on the plantations.

Second, the Germans introduced what they called volksculturs. These so-called "people's crops" were cash crops which the indigenous people were made to grow.¹¹ Again a combination of coercive measures and economic incentives was initially used to induce people to enter cash crop production. Cotton and coffee were the main two crops that were introduced as volksculturs. Coffee was also a plantation crop. This later led to conflict of interests between the settlers and the indigenous people, who in some areas were expanding coffee production in response to economic incentives.¹²

At the end of British rule in 1961, the pattern of production had not basically changed from what it was during the German period. The changes were mainly quantitative, such as the introduction of more cash crops like tea and pyrethrum and the decline of rubber production to zero. The volume of production in most crops showed an upward increase with declining export prices in some years causing downward fluctuations. Along with these quantitative changes some qualitative changes in the form of research, extension and marketing institutions

¹¹Ibid.

¹²Ibid.

also took place. These however were mostly directed toward export crops and were not, in most cases, sufficiently funded.¹³

Development Since Independence

The leaders of independent Tanzania were not satisfied with the heavily export oriented agricultural economy they had inherited from the foreign rulers in 1961. The emphasis on cash crop production for exports had two undesirable effects. First it meant that areas that did not produce cotton, coffee, tea or another cash crop were left almost completely under a subsistence mode of production. This meant that these areas were condemned to a permanent position of economic backwardness.

Second, the neglect of food crop production and marketing had meanwhile translated itself into increasing food imports to feed the growing urban centers. Thus in 1962 the value of the imports of cereals and cereal preparations from Kenya and Uganda was 23.4 million shillings.¹⁴ Tanzania was capable of producing all or most of its needed cereal and cereal preparations if the necessary policies designed to boost food crop production were followed.

The new leaders, therefore, immediately after independence began correcting what they considered over-emphasis on export crops. One indication of this was that, in the five-year plans that they began

¹³Griffiths L. Cunningham, The History of Agricultural Production in Tanganyika 1919-1968 (mimeo.; paper delivered at the IDEP/MISR Conference, Maherere University College, January 4-9, 1968).

¹⁴Tanzania Government Economic Survey 1971-72 (Dar-es-Salaam: Government Printer, 1972).

making, food production received equal attention with export crop production. Crop priorities were earmarked and targets set. While in the past, institutional changes in the way of cooperative societies and marketing boards were limited to export crops; after independence, institutional changes were geared toward stimulating the production and marketing of food crops as well. One notable change was the creation of the National Agricultural Product Board which dealt solely with the marketing of food crops. Another measure was the creation of state farms where highly mechanized techniques could be used to produce crops which could be produced more efficiently on bigger farms than on smaller farms. Wheat was the major crop where the introduction of state farms led to a significant increase in the output of this crop. These state farms also served as centers of extension services to nearby farmers around.

One of the prerequisites of success for government policies is that the people are aware of them and accept them. This awareness of government policies by the people must be at the grassroots. Tanzania has used its grassroot political party structure as the main communication link between the government and the people. This structure was built up during the peaceful struggle for independence. After independence, the structure was kept and in many ways strengthened. The people were told that just as they had worked together to bring about political independence, they had to go on working hard to bring about economic independence. It was the duty of local party functionaries to say that "the party was sponsoring just what is the current

preoccupation of the government."¹⁵ The idea for self-sufficiency in food production for each area and for the country as a whole was advanced as being a step toward economic independence.¹⁶

The result of these efforts has been an increase in the marketable surplus of foodcrops. As an indication of this, the value of imports of cereals from Tanzania's two East African neighbors¹⁷ in 1971 had declined from the 23.4 millions shillings in 1961 (quoted above) to 2.2 million shillings.¹⁸

C. STATEMENT OF THE PROBLEM

In 1971 Tanzania's Gross Domestic Product (GDP) was estimated at about 8,704 million shillings (about \$1,243 million) (see Table 1).¹⁹ The per capita GDP would, if these figures are correct, be about

¹⁵Cunningham, loc. cit.

¹⁶A few studies exist on the role of the Party and its organs in promoting Tanzania's economic development. One of the best of such studies is H. Bienen's Tanzania Party Transformation and Economic Development (Princeton: Princeton University Press, 1967).

¹⁷Tanzania, Uganda and Kenya constitute the East African Community (EAC). The community runs common services like railways, telecommunications and research in agriculture and other fields. It is also a common market but due to the fact that vast areas in the so-called "white highlands" in Kenya were occupied by white settlers and became a basis for a relatively modern agricultural and industrial economy, the other two partner states became the market--buying much from Kenya but selling little. The fall in imports of food products referred to here is due, in part, to an attempt by Tanzania to rectify this unfavorable position in the market. However, it is also in part due to an attempt by the country to free itself from dependence on imported food generally.

¹⁸Economic Survey.

¹⁹One U.S. dollar is equal to about 7.00 shillings. The Tanzania shilling is divided into 100 cents.

Table 1. Gross Domestic Product of Tanzania at Factor Cost by Industrial Origin (at Current Prices)

	1964	1965	1966	1967	1968	1969	1970	1971
	----- Million shillings -----							
Monetary and subsistence production:								
Agriculture, hunting, forestry and fishing	2,790	2,596	2,952	2,855	2,973	3,074	3,378	3,324
Mining and quarrying	134	139	192	198	134	172	108	122
Manufacturing and handicrafts	371	429	525	594	657	724	794	893
Electricity and water supply	42	46	62	64	69	74	83	92
Construction	168	184	222	309	325	316	387	465
Wholesale and retail trade, restaurants and hotels	661	704	825	862	974	1,000	1,107	1,192
Transport, storage and communications	349	386	482	536	621	668	713	800
Finance, insurance, real estate and business services	516	586	618	729	759	804	844	922
Public administration and other services	592	647	689	746	788	814	919	1,025
(less) Imputed bank service charges	29	46	49	101	85	92	111	131
Total GDP at factor cost	5,594	5,671	6,518	6,792	7,205	7,554	8,222	8,704
Subsistence production:								
Agriculture, hunting, forestry and fishing	1,342	1,361	1,550	1,574	1,646	1,630	1,731	1,738
Construction	43	47	51	53	57	59	63	67
Owner-occupied dwellings	385	418	453	477	511	530	559	601
Total subsistence production	1,770	1,826	2,054	2,104	2,214	2,219	2,353	2,406
Production in the monetary economy	3,824	3,845	4,464	4,688	4,991	5,335	5,869	6,298
Subsistence and monetary GDP	5,594	5,671	6,518	6,792	7,205	7,554	8,232	8,704

Source: Tanzania Government Economic Survey 1971-72 (Dar-es-Salaam: Government Printer, 1972).

700 shillings (\$100). Furthermore, of the total GDP, 40 percent was attributed to agriculture, hunting and fishing (Table 1). Subsistence production accounted for 26.8 percent of total production. Agriculture and related primary industries accounted for 3,143 shillings of total GDP, out of which 1,598 million was produced in the subsistence sector.²⁰ This means 52 percent of agriculture production was subsistence oriented.

Faced with such a low per capita income and an economy where the subsistence mode of production is still a significant way of earning a living for many people in the country, Tanzania has decided to mobilize all the resources at its disposal to bring about rapid economic change and development.

Development planning in a situation like Tanzania, designed to raise the income and social welfare of the majority of the people, becomes an imperative exercise. To bring about balanced interregional economic and social development the emphasis in Tanzanian planning is at the regional level. As the planners see it:

The first objective of introducing regional planning is to enable us explicitly to take into account the growth potential of each region, and the part each region can best play in the development of the country. In this way, Government can ensure that regional specializations in production and the related transport and marketing systems, are such as to maximize the growth potential of a country as a whole.²¹

In consonance with this objective, crop and livestock zones have been

²⁰Economic Survey 1972-73.

²¹United Republic of Tanzania, Tanzania Second Five-Year Plan for Economic and Social Development, July 1, 1969-June 30, 1974, Volume III, Regional Perspectives (Dar-es-Salaam: Government Printer, 1970), pp. 1-25.

delineated and for each zone, crop and livestock priorities have been specified. The specification of these priorities is the basis on which regional plans are formulated.

Economic planning in Tanzania is therefore carried beyond its traditional scope of emphasizing "setting targets for the country and for the various sectors and devising investment plans and policies to reach these targets."²²

These national and regional plans need to be formulated on the basis of accurate information about the production possibilities at the farm level in each economic zone. Otherwise they will be of very limited utility to policymakers in their efforts to bridge the gap between what exists now and what is desired to be achieved in a given planning period. Yet very few studies have been done on the micro-allocative issues that face the average Tanzania farmer. It is suggested in this study such studies must form the basis for more reliable development plans at the regional and national levels.

D. OBJECTIVE

This study sought to provide an analytical framework that can be used to study the farm level production possibilities in any economic zone in Tanzania. One region, the Mwanza Region which lies south of Lake Victoria (Fig. 1, p. 2) was selected to illustrate how this framework can be used to study production possibilities in other zones in Tanzania and elsewhere. Specifically, the aims of this analysis were to:

²²Ibid.



✓ a) Determine the optimal level of income that can be earned by the average farmer in Kwimba District in Mwanza Region, given the resources available, the family's subsistence and cash requirements and the prices prevailing in the market for the various agricultural products that the farmer produces.

✓ b) Estimate what part of the farmer's output can be realized as cash income, and what part is in the form of subsistence income.

✓ c) Identify the resource endowments and subsistence minimum requirements which would act as constraints if an attempt to realize higher income were to be made.

✓ d) Evaluate the impact that a change in resource availability would have on the present production plan of the average farmer in Kwimba District.

✓ e) Assess the impact of changes in the relative prices of crops on feasible crop combinations of the typical traditional type of farm in the district--especially whether such price changes have any effect on the production of cash crops on which the country depends for its foreign exchange earnings.

✓ f) Assess the impact of the introduction of a more superior technological mode of production on a typical traditional type of farm.

✓ g) Indicate the implications of the study with regard to government policy and the need for further research.

E. METHODOLOGY

First, a verbal-diagrammatic model of the production environment facing the typical farmer in this region was developed (see Chapter II).

This model included: (i) the level of resources on an average farm in Kwimba District; (ii) the minimum level requirements for food crops and cash income for an average family of five in the district; (iii) the range of enterprises the farmer can engage in, given climatic and economic conditions prevailing in the district and his own motivations for choosing a particular combination of enterprises; (iv) the economic principles that can be used to describe the production decisions of the farmer in this particular district and of other farmers in similar situations in Tanzania and elsewhere.

Secondly, the facilities of the MPS-360 computer routine available at the University of Tennessee Computing Center were used to develop a mono-period linear programming model. The linear programming results included: (i) an optimal production plan that is consistent with the traditional farm constraints specified in the schematic model (Chapter III), and (ii) an optimal production plan under "improved technology" constraints.

Both optimal production plans were subjected to sensitivity analysis using range analysis and parametric programming. This was done to determine the sensitivity of the production plan, under both agricultural techniques, to changes in resource availability and net returns per acre of each crop enterprise.

F. SOURCES OF DATA

Data related to the input-output relationships and resource availability on a typical "traditional" farm in Kwimba District came

from two recent studies--one by Collinson²³ and the other by Ruthenberg.²⁴ Returns per acre reported in Collinson's²⁵ study were used since more recent prices were not available for all the enterprises included in the model. Data related to the technological innovations in the extended model came from Collinson,²⁶ as well as a study sponsored by the United States Agency for International Development (USAID).²⁷

G. LIMITATIONS OF THE STUDY

The data used in the study came from secondary sources and have been accepted at their face value. It would have been more desirable to collect farm data on input-output relationships and resource availability, and to use more current prices. Neither of these things could be done due to the writer's being in the U.S. at the time of the study. Efforts were made through correspondence and review of materials in Washington, D.C. and at the University of Missouri (which has a program in Tanzania) to obtain more detailed and current data for the linear programming analysis. However, little of relevance could be found.

²³M. P. Collinson, Farm Management in Peasant Agriculture, A Handbook of Rural Development Planning in Africa (New York: Praeger Publishers, 1972).

²⁴Hans Ruthenberg (ed.), Smallholder Farming and Smallholder Development in Tanzania (Smbtt Munich: Welt Forum-Verlag, 1968).

²⁵Collinson, loc. cit.

²⁶Ibid.

²⁷Anders J. Passey, et al., Tanzania: Land Use and Agricultural Diversification (Washington: U.S. Department of Agriculture/U.S. Agency for International Development, 1962).

With regard to returns per acre (prices), the main emphasis was on relative prices and how they affect the micro-allocative decisions of smallholder farmers in Kwimba District. It was hoped that the use of less current data would not render the study invalid from the analytical point of view. As mentioned earlier, the main intent of this study was to demonstrate what information is needed and what methodological procedures can be used to analyze this information so as to give a clearer idea of the production-management problems that confront the peasant farmer in Tanzania. On this better understanding more realistic solutions which will form the policies embodied in the regional and national plans can be proposed. This is a task of utmost urgency in Tanzania and elsewhere in developing countries where such studies are scanty.²⁸

²⁸ Researchers in Tanzania are aware of the problem that the scantiness of such studies poses in trying to work out new institutions and policies designed to improve agricultural production and marketing. See for example, P. M. Newhouse, A Review of the Production and Marketing Arrangements for Maize, Paddy and Wheat with Particular References to the Milling Sector (Dar-es-Salaam: Marketing Development, Development Bureau, U.N.D.P./FAO, S.F. Tan. 27, 1972.

CHAPTER II

AN ANALYTICAL FRAMEWORK FOR ANALYZING TANZANIAN FARM POTENTIALS

A. THE PRODUCTION ENVIRONMENT: MOTIVATIONS AND CONSTRAINTS

Many studies have been written on the behavior of peasant farmers in Africa and in other parts of the world. One of the issues discussed in such studies is whether peasant farmers behave rationally in accordance with the economic principle of profit maximization.

According to Jain, one can identify three hypotheses from studies made on this question.¹

(a) The peasant farmer does indeed respond to changes in relative prices.²

(b) The marketed surplus of subsistence farmers is inversely related to price. The peasant farmer has a target income he aims to procure in order to meet fixed monetary obligations, e.g., purchases of consumption goods, government taxes, rent to the landlords, etc. The higher the prices, the less will be produced for sale.³

¹S. C. Jain, Principles and Practice of Agricultural Marketing and Prices (Bombay: Bombay Publishing House, 1971).

²Among those who support this view are R. Krishna, "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region," The Economic Journal, LXXMI (September 1963), 477-487 and W. P. Falcon, "Farmers' Response to Price in a Subsistence Economy: The Case of W. Pakistan," American Economic Review, LIV (May 1964), 589-90.

³For example, S. Neumark, "Some Economic Problems of African Agriculture," Journal of Farm Economics, XLI (February 1959), 43-50; P. Malthus and H. Ezekiel, "The Marketable Surplus of Food and Price Fluctuations in a Developing Economy," Kylos, XIV (1961), 396-406.

(c) Due to institutional constraints, response is almost insignificant. Limited knowledge, limited tastes, market imperfections are some of the constraints that have been mentioned by those advancing this hypothesis.⁴

This study essentially accepts hypothesis (a) above. However, it does not entirely dismiss the points raised by hypotheses (b) and (c).

Hypothesis (b) is not accepted in its entirety in this study. The concept of a target income is accepted here if one means by it that an individual (or group of individuals) considers a certain level of income to be the minimum he must have in order to meet what that individual has come to consider to be essential expenditures. If the price of the service or commodity the individual sells in order to earn his income falls to the extent that the income earned falls below this target income, the individual will be forced to produce more in order to earn this target income. Unless there are other opportunities open to him, there is no choice but to produce more at a lower price. If he was already earning more than this minimum level of income, we can expect him to produce less when the price falls. Given the low level of income in countries like Tanzania, it is not surprising if the peasant farmers increase their production in spite of a decrease in prices offered for their agricultural commodities.

It is, however, misleading to conclude as Cunningham did, that "prices, therefore, are not a very important determinant of peasant production and it would seem, production will continue to increase

⁴E.g., C. Wharton, Jr., "The Inelasticity of Southeast Asian Agriculture. Problems of Monocultural Perennial Export Dominance" (unpublished paper).

if the Government wants it as long as prices do not fall disastrously."⁵

Cunningham was examining output and price movements in Tanzania over several years. He drew this conclusion when he noticed that for some years output had increased in spite of a decrease in prices (see Tables 2 and 3). This conclusion led him to make the following policy observation.

This is very important, especially with respect to cotton where the long term prospects are for falling prices if cotton is to remain competitive with synthetic fibres.⁶

The implication here is low prices will not lead to reduced output. This is true only if a farmers' income already is so low that he would rather increase output to maintain it rather than reduce it and suffer from what he regards as inferior economic well-being. Clearly, there is a trade-off here and if farmers choose the first option, their response is economically rational.

Second, the data used by Cunningham are aggregate data at the national level. The increase in output may be due to the introduction of cotton in areas hitherto almost entirely under subsistence production. For the cotton producing areas an increase in output in the face of lower prices may be explained by the fact that there are no other crops that are relatively more profitable even at the lower cotton prices. A relative increase in the prices of other crops will bring about a decline in the production of cotton.

Finally, changes in technology may allow greater output at lower prices.

⁵Cunningham, loc. cit.

⁶Ibid.

Table 2. Tanzania: Production of Main Crops, 1961-1968 (in Tons)

	1961	1962	1963	1964	1965	1966	1967	1968
Cotton (lint)	33,000	35,100	45,700	54,400	65,000	77,600	69,000	48,800 ^a
Coffee	19,200	26,500	28,200	33,200	33,600	48,700	47,700	up? ^a
Tea	4,400	4,200	4,900	4,700	5,600	6,700	7,000	up ^a
Tobacco (fine cured)	1,000	580	710	330	1,071	5,200	7,700	n.a.
Tobacco (fine cured)	1,600	1,100	1,090	1,740	3,540	---	---	5,616
Pyrethrum	1,270	1,890	2,250	2,260	3,600	4,400	6,600	down? ^a
Sisal	198,000	214,000	214,300	229,900	214,200	221,500	216,600	200,000 ^a
Oilseeds	90,700	106,900	116,800	127,800	126,560	n.a.	n.a.	up ^a

Source: Griffiths L. Cunningham, The History of Agricultural Production in Tanganyika 1919-1968 (mimeographed paper delivered at the IDEP/MISR Conference, Makerere University College, January 4-9, 1968).

^aBest available estimate from Ministry of Agriculture.

Table 3. Tanzania: Commodity January Prices, 1961-1968

	1960	1961	1962	1963	1964	1965	1966	1967	1968
	----- Shillings/ton -----								
Coffee	322	285	307	253	348	276	316	254	273
Cotton	202	188	201	199	177	197	187	182	185
Sisal	1440	1500	1300	1740	2360	1520	1220	1120	830
Maize	240	380	380	360	280	273	292	263	--
Simsim	940	940	1020	1000	960	875	868	677	1584

If one accepts hypothesis (b) above in its entirety, one is saying in effect that an increase in price will lead to lower output because this enables the farmers to earn their target income at a lower output. Historical evidence does not support this statement. During boom years when prices of primary commodities went up (for example, during the Korean War), output of these commodities from peasant economies also increased tremendously.

Hypothesis (c) above has some validity. However, these constraints cannot all be categorized in negative terms like "limited tastes" or "lack of knowledge," etc., as has been done by the proponents of hypothesis (c) above. These constraints need to be examined more closely.

It is hypothesized that peasant farmers' response is a function of both economic factors and non-economic factors which determine their production environment. The farmer is considered to be reacting to this environment when he decides what to produce and how to dispose of the product thereof.

Collinson observes that two types of motivations guide this reaction.⁷ First and foremost, there are survival motivations. These are primary in the sense that they must be satisfied and are directed to such basic needs as food and shelter. Then there are the secondary achievement-oriented motivations. Profit maximization falls into this category rather than the first.

If this is true, the emphasis on food production on the part of

⁷Collinson, loc. cit.

the peasant farmer is rational. With respect to this emphasis on food production, the farmer has to consider (a) the quantity of food required, (b) its nutritional quality, (c) its reliability of supply, and (4) family taste preferences. The agricultural practices peculiar to farmers in this Tanzanian region are apparently an attempt on their part to operationalize these motivating considerations. These practices include:

- (1) Intercropping: for example, maize planted with legumes.

(This ensures a nutritional balance throughout the year especially when combined with (b) below.) However, in cases where intercropping may be harmful, pure stands are planted.

- (2) Staggered planting--planting key staples at different periods to make sure that, should rain come sooner or later than expected, essential staples will grow. This also allows a continuous supply (in quantity and quality) throughout the year.

- (c) The planting of cassava as an "insurance crop."⁸ This crop can be left in the ground for a number of years. This then provides relief in famine years which are caused by almost complete failure of other crops due to climatic aberrations.

The average farm therefore grows a variety of crops to ensure that it meets the food needs of the family. For the average farm in Kwimba District, Collinson considers the following crop enterprises

⁸Collinson, loc. cit. Most of the work done by Collinson was in Kwimba District of Mwanza Region, Northern Tanzania.

as being essential to cater for the primary and secondary motivations of farmers in this area.

- (a) Early legumes and maize-ELM⁹
- (b) Early maize, cassava and legumes-EMCL
- (c) Early sweet potatoes-ESP
- (d) Late maize, cassava and legumes-LMCL
- (e) Rice-RICE
- (f) Late maize, legumes and sweet potatoes-LMLSP
- (g) Late sweet potatoes-LSP
- (h) Old cassava (planted in previous years)-OC
- (i) Cotton-COTTON

It is assumed that enterprises (a) to (h) are produced primarily for subsistence and cotton is produced wholly for cash. However, the distinction between cash crops and food crops is not entirely valid since the food crops (other than cotton) are sold after due consideration has been given to the food needs of the family. The amount and quality of cotton sold will depend (i) on the price of cotton, (ii) the cash needs of the family, and (iii) the prices of the other crops. When the price of cotton rises, more cotton is likely to be produced. If the price of cotton falls, and especially if this is not followed by a rise in the marketed surplus of the other crops, it is assumed that farmers will not reduce their cotton production beyond the point where they cannot meet their cash needs. They may, therefore, produce the same quantity or even increase their cotton production. However,

⁹ These abbreviations were used to denote the nine crop enterprises in the computer program. They also appear instead of the actual labels in some tables and in the text.

should prices rise, it is assumed production will increase as well. But, given the existing technology and the needs of the other crops (for subsistence) the farmers may fail to give maximum response to such a change.

Should the prices of subsistence crops rise, their marketable surplus will increase. If this should be accompanied by a relative stagnation or decline in the price of cotton, then there will be less cotton produced. The marketable surplus of the subsistence crop is therefore determined by the quantity required for subsistence given preferences and tastes; if in one area people prefer rice to maize, less maize will be produced. However, beyond the food requirements, the marketable surplus is determined by the relative prices (both among subsistence crops and between a particular subsistence crop and cotton).

The basic technology in Kwimba District is a hand-hoe and other manual tools. Automated or animal-draught tools are very little used due to lack of capital. For the same reasons, chemical inputs, other than animal manure supplied from each household's own animals, is hardly used. The main variable input is labor, which usually is supplied almost entirely by the family. However, a number of farms hire labor. The amount of labor available is determined by the size of the family. In Kwimba District this is estimated to be about six people on the average.¹⁰ Due to the demand of off-the-farm activities for family labor, which varies from one time of the year to another, the amount

¹⁰Collinson, loc. cit.

of total family labor available for farm work differs from season to season. In the dry season--June to October--attention must be directed to rebuilding or repairing the physical facilities of the homestead (huts, fences, etc.)¹¹ as well as purely social engagements like traditional ceremonies. This is not to argue that the peasant farmer devotes more attention to these rather than to economic activities. Beyond a certain point, incomes (in terms of food or money) must be sacrificed in favor of leisure and social engagements. Indeed it is assumed that the more the economic incentives the farmer has to produce rather than enjoy leisure, the more he will produce. Finally, different crops require different amounts of labor units at different times of the year. It is hypothesized that, while labor is idle during certain months of the year, it is a real bottleneck to greater production during certain peak months.

In Kwimba District land is abundant. Even after taking into consideration land that must be set apart for communal grazing, land is not a restricting resource. However, it is not homogenous and equally suitable to all crops. Most of the land, nevertheless, can be used to grow maize or cotton which are respectively the main staple food and cash crop in the area. Rice is grown only in valleys and low-lands, where cassava and a number of other food crops can be grown as well.

While it would be useful to distinguish types of land according to fertility and crop suitability, due to unavailability of data this

¹¹This is a primary motivation for shelter. If some crop is not harvested because of this, it does not mean irrational behaviour. The family would rather sacrifice some cash income than risk a leaking roof or a fallen house in the rainy season.

could not be done. In any case there is a fair degree of substitutability of crops on most land. Land is therefore treated in this study as if it were homogenous.

To sum up, the peasant farm firm can be represented schematically in Figure 2. The essence of the schematic model presented in Figure 2 is that the peasant production system is a balance between subsistence, cash requirements, family and social obligations on the one hand and resources availability on the other hand. The firm, using its own land and labor, produces subsistence crops and cash crops. The surplus subsistence crops can be sold for cash. Cash income is spent on necessities and savings are very low. The expanded model discussed in Chapter IV brings in hired labor and/or animal draught/mechanized machinery and chemical inputs. On the whole these are devoted to the provision of more cash income since they are likely to have emanated from meager family saving or credit from outside (in the case of Tanzanian public credit programs, through cooperatives mainly).

B. FORMULATING THE LINEAR PROGRAMMING PROBLEM

"A linear programming problem does not exist unless there are limited resources or restrictions."¹² Nor is it useful to apply linear programming to a problem if it does not involve a choice among alternative means of obtaining the desired objective. With budgeting techniques we can present a farmer faced with the problem of maximizing

¹²R. Agrawal and E. O. Heady, Operations Research Methods for Agricultural Decisions (Ames: Iowa State University Press, 1972), p. 29.

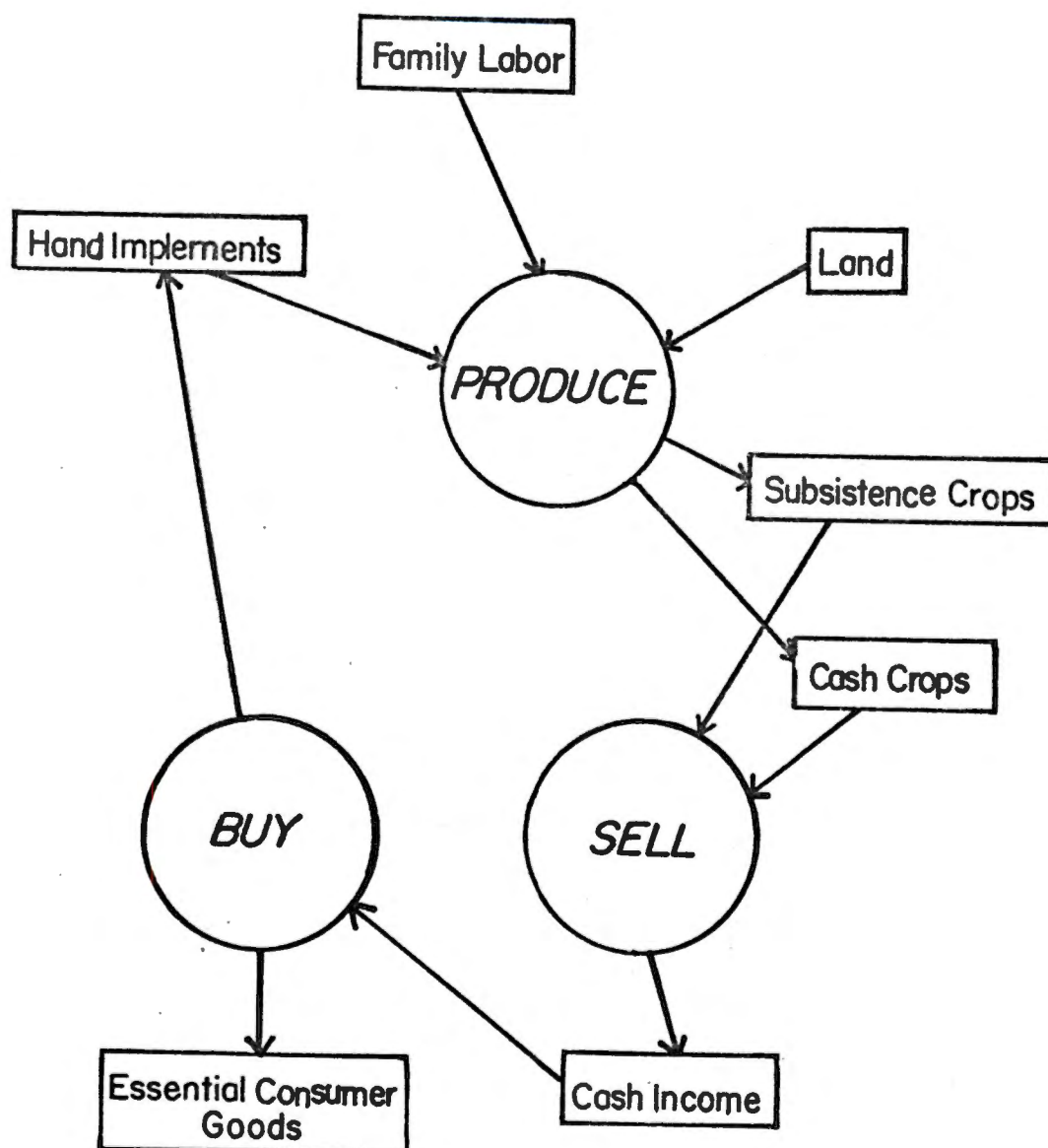


Figure 2. A schematic model of the traditional farm, Kwimba District.

his income given his limited resources and alternative ways of utilizing these resources to achieve his goal of income maximization. The superiority of the linear programming technique lies in the fact that it is a more efficient way of devising such a plan.

The components of a linear programming problem are:

- (a) the objective function to be maximized or minimized.
- (b) alternative means for achieving the objective function.
- (c) the available resources and/or other restrictions.

Translated into linear programming terminology the problem the peasant farmer faces is that of maximizing his income subject to the resources available to him and to the food and money minimum requirements constraints.

Mathematically, the problem may be stated as follows:

Maximize:

$$Y = c_1 x_1 + c_2 x_2 + \dots + c_9 x_9$$

Subject to:

$$a_{11} x_1 + a_{12} x_2 + \dots + a_{19} x_9 \leq b_1$$

$$a_{21} x_1 + a_{22} x_2 + \dots + a_{29} x_9 \leq b_2$$

$$a_{131} x_1 + a_{132} x_2 + \dots + a_{139} x_9 \leq b_9$$

$$x_1 \leq z_1$$

$$x_2 \leq z_{21}$$

.

.

.

$$x_9 \leq z_9$$

where:

Y = Gross farm income

$(c_1, c_2 \dots c_9)$ is a 9×1 vector of price returns per acre of enterprise.

$(x_1, x_2 \dots x_9)$ is a 9×1 vector of crop enterprise.

$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{19} \\ a_{21} & a_{22} & \dots & a_{29} \\ \vdots & \vdots & \vdots & \vdots \\ a_{131} & a_{132} & \dots & a_{139} \end{pmatrix}$ is a 13×9 matrix of technical coefficients.

$\begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ \vdots \\ \vdots \\ b_{13} \end{pmatrix}$ is a 13×1 vector of resource constraints.

and

$\begin{pmatrix} z_1 \\ z_2 \\ \vdots \\ \vdots \\ \vdots \\ z_9 \end{pmatrix}$ is a 9×1 vector of minimum requirement constraints.

In the above mathematical formulation x 's stand for the nine crop enterprises described in Section A of this chapter. Land and the availability of labour for farm operations in the twelve months of the year constitute the resources denoted by the 13 b 's. The c 's represent the returns per acre of enterprise while the z 's specify the minimum requirement for each crop enterprise.

CHAPTER III

FARM PRODUCTION POTENTIAL WITH TRADITIONAL FARMING PRACTICES

A. BASIC INFORMATION USED IN THE LINEAR PROGRAMMING MODEL

The Level of Resources Available to the Farmer

On the whole, in the Tanzanian situation, resources consist of family labor and land. Tanzanian farmers find themselves in the same conditions that confront peasant farmers in many other African countries. Speaking of Nigeria, Helleiner noted that "the overwhelming bulk of production takes place in 'traditional fashion' without the use of mechanic, or frequently, animal power."¹

It was hypothesized that labor during certain peak periods is the scarce resource. Data on the availability of labor for every month of the year were taken from the Collinson study.² These data show that, due to off-farm activities and seasonal climatic conditions, the supply of labor on any one farm varies from season to season. Table 4 shows the availability of labor and land on a typical farm in Kwimba District.

It was hypothesized that land is relatively more plentiful in this part of the country than in many others, e.g., the Kilimanjaro and Tanga regions in the north. The average amount of available land for each household of fifteen acres was taken from Rotenham.³ The figure

¹Gerald K. Helleiner, Peasant Agriculture and Economic Growth in Nigeria (Homewood, Illinois: Richard Irwin, 1966), p. 44.

²Collinson, loc. cit.

³Von Rotenham, in Rutenberg, loc. cit.

Table 4. Available Resources and Crop Acreage Minimum Requirements,
Typical Farm, Kwimba District

Resource or Requirement	Constraint Level
Land (acres)	15
Labor (mandays)	
October	55
November	55
December	55
January	60
February	60
March	60
April	55
May	55
June	50
July	45
August	40
September	40
Minimum Crop Acreages (acres)	
✓Early Legumes and Maize (ELM)	.65
✓Early Maize, Cassava and Legumes (EMCL)	1.46
Early Sweet Potatoes	.05
Late Maize, Cassava and Legumes (LMCL)	1.56
Late Maize, Legumes and Sweet Potatoes (LMLSP)	.53
Rice	.03
Late Sweet Potatoes (LSP)	.09
Old Cassava (OC)	.55
Cotton	1.00

might actually be higher but, since this analysis does not include live-activities which require a lot of land for grazing purposes, this figure was felt to be adequate. In any case, since this area is under a customary communal land tenure system, the size of a family farm is determined by the amount of land the family can actually cultivate, allowing the fallowing of some tracts of land during certain years.

Minimum Food Requirements

Table 4 also shows the minimum food and cash crop acreage requirements which conform to the motivations of the peasant farmers as hypothesized in Chapter II. Collinson estimated the minimum food requirements and how much each food crop activity used in this study contributed to the supply of the minimum requirements for essential foodstuffs in the district. These figures were used to compute the minimum acreage requirement for each crop by dividing the minimum required for a crop activity by its yield per acre.

To the extent that these minimum requirements must be met before production for the market can be carried out, they are serious constraints and must be considered when analyzing the production potential of the system.

These constraints were formulated in terms of crop enterprises acres and not individual food items because it was believed to be more realistic to assume that farmers would not depart very much from their accustomed cropping pattern. They might adjust the amounts of various enterprises, but would not be likely to eliminate any enterprise. Had family needs been the only consideration, it would have been better to

use specific commodities as constraints and not "force" all existing enterprises into the solution. A minimum acreage for cotton was also specified to ensure that the production plan included an activity which produced some cash income.

Input-Output Coefficients

The empirical model must also include the input-output relationships. Collinson's⁴ figures showed how much labor each crop activity needed for each month. To get the per acre labor requirements, the monthly labor needs of each crop activity were divided by the number of acres of that activity actually grown on the typical farm in the district according to the results of Collinson's surveys.⁵ This computation resulted in the input-output coefficients shown in Table 5.

The returns per acre of enterprise shown in this table also come from Collinson's study.⁶ The prices quoted are based on average farm price levels for cotton and rice for the years 1966-1970. For the other crop enterprises the prices used by Collinson were merely approximate market valuations for these crop activities since most of them are consumed on the farm and not sold on the market. To ensure consistency and in the absence of other farm-level sources of information, the prices reported by Collinson were used in this study.⁷

The Linear Programming Tableau

The information contained in Tables 4 and 5 was then combined into a linear programming tableau as shown in Table 6. For brevity

⁴Collinson, loc. cit.

⁵Ibid.

⁶Ibid.

⁷Ibid.

Table 6. Linear Programming Tableau, Traditional Farm, Kwimba District

Limiting Resource or Minimum Requirement	Enterprise									Restrictions	
	ELM	EMCL	ESP	LMCL	RICE	LMLSP	LSP	OC	COTTON		
Land (acres)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	≤	15
Labor (mandays)											
October	12.54							7.52		<	55
November	12.54	25.35			3.33				2.97	<	55
December	10.75	10.13	32.56	4.97					12.90	<	55
January		4.79		18.25			10.00		8.96	<	60
February			2.56	10.26	15.26	24.13			4.96	<	60
March					35.63	10.34	8.00		2.97	<	60
April	3.58		2.46		13.33		2.15			<	55
May	2.55		4.79						7.94	<	55
June				9.86	18.76	3.34			9.92	<	50
July					12.25	2.54			9.92	<	45
August			6.16	4.11					7.94	<	40
September	2.55								6.94	<	40
Minimum Acreages											
ELMEQ	1.00									>	0.65
EMCLEQ		1.00								>	1.46
ESPEQ			1.00							>	.05
LMCLEQ				1.00						>	1.56
RICEEQ					1.00					>	.53
LMLSPEQ						1.00				>	.03
LSPEQ							1.00			>	.09
OCEQ								1.00		>	.55
COTTOEQ									1.00	>	1.00
OBJ (Return per acre) (Shillings)	149.00	193.00	150.00	180.00	350.00	123.00	120.00	45.00	425.00		

and ease of presentation abbreviations were used to denote the crop activities (as listed in Chapter II) and the labor requirements by month. OBJ refers to the objective function. Total farm income was to be maximized subject to the labor availability and minimum acreage requirements constraints as postulated in Chapter II. The minimum crop acreage requirements are indicated by EQ following the name of the crop enterprise.

The information in the linear programming tableau contains all the data used in the computer program that was run to obtain the results discussed in this chapter.

B. THE OPTIMAL PRODUCTION PLAN

Crop Combinations and Level of Income

The linear programming optimal solution obtained showed that if all resources were fully as possible (given the present farming techniques), the typical farm in Kwimba District was capable of producing food and cash crops valued at Shs. 1941.20, at prices used in the model (see Table 7).

The linear programming optimal solution also gave the optimal crop acreage for each crop activity in the plan. All the enterprises were forced into the solution to meet the minimum requirements specified by the model. Table 7 therefore lists all the crop activities in the model and their respective contributions to total production (in acres) and gross farm income (in shillings).

Assuming that the farmer could sell all the food crops that remained after his family's minimum subsistence requirements, family

Table 7. Crop Enterprise Mix, Traditional Farm, Kwimba District, Linear Programming Optimal Solution

Enterprise	Acreage		Marketable Surplus	Value		
	Total	Required for Subsistence		Per Acre (Shs.)	Total ^a (Shs.)	Sales (Shs.)
ELM	.83	.65	.18	149.00	123.67	26.82
EMCL	1.46	1.46		193.00	281.78	
ESP	.05	.05		150.00	7.50	
LMCL	1.56	1.56		180.00	280.00	
RICE	.77	.03	.74	350.00	269.50	259.00
LMCLSP	.98	.53	.45	123.00	120.54	55.35
LSP	.93	.09	.84	120.00	111.60	100.80
OC	.55	.55		45.00	24.75	--
COTTON	1.68	0.00	1.68	425.00	722.50	714.00
Total	8.81	4.92	3.89		1942.64	1155.97

^aThis is given by multiplying total acreage times value of production per acre and is equal to income in subsistence and monetary farm.

income was divided into money and subsistence income (Table 7). In the linear programming solution, cash sales accounted for about 60 percent of total farm production. The actual share of agricultural production sold might be less if the availability of marketing channels for the food crops is taken into consideration. For some crops, cassava and sweet potatoes, for example, transportation costs to urban centers might be so high that it would not be worthwhile for farmers to engage in the marketing of any surpluses of such crops. Farmers might also prefer to keep more than the minimum requirements for subsistence to insure against famine and to meet social and economic needs which are often transacted in kind rather than in money.

In his study about Malawi peasants, Chipeta points out that one of the reasons for the preference of "customary money" (i.e., making payments in the form of crops, livestock, etc.) over "modern money" is the fact that sometimes "there is little or no opportunity to sell agricultural produce due to lack of adequate marketing facilities."⁸

Constraining and Non-Constraining Resources and Minimum Food Requirements

The level of farm income is determined by the quantity and quality of resources available to the farmer. No attempt was made in this study to classify land according to fertility or other criteria which may be used to indicate the suitability of land for the production of particular crop activities. To the extent that some crops can grow well only on

⁸W. Chipeta, "The Roles of Customary and Modern Money in the Rural Exchange Economy of Malawi," East Africa Journal of Rural Development, III (1970), 25.

certain types of soil, the availability of land suitable for a particular crop activity becomes a limiting factor for the production of that crop activity. However, only minor crops like sweet potatoes present this problem to an appreciable degree in the Kwimba District.

The problem of heterogeneity aside, the linear programming results showed that the 15 acres assumed to be available by this model were more than the available labor could handle. In Table 8 abundant resources are identified by having a zero marginal value product (MVP). MVP is the term used in production economics to refer to the value added to total output by using one more unit of a resource. For an abundant resource the MVP is zero. Further use will lead to a negative MVP--to a reduction in income.

In Table 8 land, labor in October, March, April, May, July, August and September have a zero marginal value product. If the farmer were to use one more of these resources, he would lose income. For example, if the farmer were to use more than 8.81 acres of land, he would lose income.

The constraining resources are labor in November, December, January, February and in June. All the labor available during these months is used up. The MVP for labor during these months is greater than zero. An additional manday in June, for example, would mean an increase in income of Shs. 15.65 per manday added. This would seem to be the month when the farmer could make the best use of hired labor, assuming the wage paid per manday was less than the MVP labor for June. Should non-farm activities demand more labor, or should any member of the family get sick and be unable to work for a day or more during the crucial months, the result would be less income.

Table 8. Optimal Resource Allocation, Traditional Farm, Kwimba District, Linear Programming Solution^a

Resource	Level in Optimal Plan	Amount Available	Amount Unused	Opportunity Cost
Land (acres)	8.15	15.00	6.85	--
Labor (mandays)				
October	15.98	55.00	39.02	--
November	55.00	55.00	--	3.78
December	55.00	55.00	--	9.45
January	60.00	60.00	--	13.66
February	60.00	60.00	--	2.87
March	40.85	60.00	19.15	--
April	12.20	55.00	42.80	--
May	20.19	55.00	34.81	--
June	50.00	50.00	--	15.65
July	23.49	45.00	21.51	--
August	27.41	40.00	12.59	--
September	2.41	40.00	37.59	--

^aThe complete solution is shown in Appendix Table A1.

Besides the availability of resources, the necessity to ensure that a certain percentage of resources is committed to subsistence production to meet the needs of the family can also be an income constraint. The minimum level requirements which were not economically justifiable at the given prices were early maize, cassava and legumes (EMCL), early sweet potatoes (ESP), and late maize, cassava and legumes (LMCL). Decreasing the minimum requirement for any one of these enterprises would lead to higher income through a more profitable utilization of scarce resources. Thus, the farmer could divert resources from an acre of early maize, cassava and legumes to other more profitable activities and increase his income by Shs. 277.70 (see Appendix Table A1).⁹ An innovation that could increase yield per acre for any one of these three activities would have this effect and therefore be a very desirable economic investment in the effort by the Tanzania government to raise family income.

C. THE SENSITIVITY OF THE OPTIMAL PRODUCTION PLAN

Range Analysis

The opportunity cost of obtaining a scarce resource is also referred to as its shadow price. As long as the farmer could buy additional units of a scarce resource at a market price less than the shadow price of that resource in his production, he would buy it so as to expand production and earn more income. Equally, if the return per

⁹ In the computer output shown in the Appendix Table A1, the opportunity cost of a unit change in the use of a resource or the minimum level requirement of an enterprise is called the dual activity value.

acre to an activity increased, that activity could profitably be expanded. Conversely, if the net return to an activity decreased, the farmer would find it necessary to produce less of that crop enterprise. However, there would be a limit above or below which an activity could be increased or decreased in response to changes in resource availability or net returns to crop activities without upsetting the activity mix in the current plan. There is need, therefore, to determine "the range within which b_i or c_j coefficients (i.e., resource endowment and prices) may vary without changing the set of activities in the optimal solution."¹⁰

The computer programming model included a range analysis component designed to answer two questions:

- a) How sensitive is the optimal set of enterprises to changes in resource availabilities and minimum acreage constraints?
- b) How sensitive is the optimal set of enterprises to changes in their estimated net revenues (prices)?

The range analysis results with regards to question a) are summarized in Table 9. It was assumed that the farmer would not use the abundant resources over their optimal levels. If he did, he would lose income. Only the ranges for the limiting resources were therefore considered.

For each resource there was a lower limit and an upper limit. A scarce resource could be decreased down to its lower limit or increased to its upper limit without upsetting the current activity

¹⁰R. Perrin, Use of the Linear Programming Facility of IBM Mathematical Programming System (MPS 360) (Raleigh: Department of Economics, North Carolina State University, 1968), p. 8.

Table 9. Sensitivity of Optimum Production to Changes in Constraint Levels, Traditional Farm, Kwimba District, Linear Programming Results^a

Unit cost column

Constraint	Level in Optimal Plan	Range Within Which Optimal Plan Not Affected	Income Effect of Unit Change
	----- Mandays -----		Shs.
Labor			
November	55	52.9-58.4	2.72
December	55	52.1-66.2	10.69
January	60	51.6-66.9	12.00
February	60	50.3-84.7	2.82
June	50	35.9-53.9	15.87
	----- Acres -----		Shs.
Activity Minima			
EMCL	1.46	1.24-1.55	41.82
ESP	.05	0.00-0.14	205.41
LMCL	1.56	1.30-2.19	277.70

^a Summarized from computer output. For full details, see Appendix Table A2.

mix, though income would be decreased or increased accordingly.

If a scarce resource was forced below its lower limit level, this would lead to a reduction in the production of a hitherto economic activity to the minimum subsistence specified in the model. This would mean that this crop activity would no longer be sold to get cash income and therefore cash income would be decreased. The income effect of the unit change column shows the income that would be sacrificed for each unit of labor lost in November, December, January, February and June.

Increasing a scarce resource to its upper limit would result in a net gain in income. The per unit gain in income shown in the last column of Table 9 is equal to the shadow price of the scarce resource.

For example, November labor could be decreased to 52.9 mandays (from its current level of 55 mandays) at a loss of Shs. 2.72 per manday decreased. If November's labor were to be decreased further, early legumes and maize (ELM) would have to be decreased to its minimum subsistence level. On the other hand, November labor could be increased to 58.4 mandays at a net gain of Shs. 2.72 per manday added. It would not be possible to profit from an increase of November labor beyond its upper limit because, at this level, March labor would be exhausted. Both November and March labor must be increased simultaneously in order to expand the program further.

In short, the range results showed that a reduction in the level of any scarce resource would result in loss of income. If this reduction were pushed below the lower limit, it would lead to even further loss in cash income since a crop enterprise with a marketable surplus would be reduced

to its subsistence level only. Sickness, weather aberrations, and unforeseen reductions in family labor force would have this effect. The consequences of this happening in November and/or December would be great since the downward range for both of these months is very narrow; a shortage of about ⁽⁵⁵⁻⁵²⁾ three mandays in either month would have considerable impact on the whole production plan.

On the upward side, the availability of more June labor would have the greatest impact on the level of income--Shs. 15.87 per each additional manday added. However, a slight increase in the amount of November labor available would soon lead to the exhaustion of March labor.

Forcing early maize, cassava and legumes (EMCL); early sweet potatoes (ESP); and late maize, cassava and legumes (LMCL) into the program meant sacrificing income because resources were diverted from relatively profitable enterprises to less profitable ones. The shadow price in this case represents the income that would be gained if anyone of these activities were reduced by one acre. If the minimum requirements for EMCL, ESP and LMCL were reduced to 1.24, 0 and 1.30 acres respectively, they would no longer be constraining. Resources could then be channeled to more profitable activities. *output constraints* ?

The reduction of any one of these activities below their lower limits shown in Table 9, page 44, would lead to the exhaustion of some of the resources not fully used up in the current plan. For example, EMCL could be reduced to 1.24 acres at a gain of Shs. 41.82 per acre reduced. A further reduction in this activity would not be possible unless it was accompanied by an increase in the availability of March

labor. The unprofitable activities (EMCL, ESP, and MLCL) could be increased to the upper limits indicated in Table 9, page 44, without affecting the optimal combination of activities, *even if - altho.* albeit at a loss of income. If the minimum subsistence requirements for the three activities in Table 9 were actually higher than those used in this study, the level of income realized on the typical farm would be less. If any one of these activities were forced in the program above the upper limit of the range shown in the third column in Table 9, it would mean that one more crop activity would have to be reduced to its minimum requirement; there would be no more marketable surplus for one of the crop activities produced above minimum requirements. Thus, producing more than 2.19 acres of late maize, cassava and legumes would force late sweet potatoes to the level required for the family's own consumption needs.

The range analysis provided an answer to a second question: "How sensitive are the optimal enterprise levels to changes in their estimated net revenues (c_{ij} 's)?"¹¹ The result showed the lower and upper limits within which enterprise returns per acre could fluctuate without affecting the acreage mix of the optimal production plan (see Table 10).¹² Higher income would be earned with upward changes in net returns and income would be decreased with downward changes in net returns of crop enterprises. However, as long as these fluctuations were within

¹¹Perrin, op. cit., p. 12.

¹²For the complete results of this part of the range analysis see Appendix Table A3.

Table 10. Sensitivity of Optimum Production Plan to Changes in Returns Per Acre, Traditional Farm, Kwimba District, Linear Programming Results^a

Enterprise	Level in Optimal Plan		Lower Limit		Upper Limit	
	Return Per Acre (Shs.)	Acreage	Return Per Acre (Shs.)	Acreage	Net Return Per Acre (Shs.)	Acreage
ELM	149.00	.83	129.15	.65	1014.71	.85
EMCL	193.00	1.46	0.00	1.46	234.82	1.55
ESP	150.00	.05	0.00	.05	355.42	.14
LMCL	180.00	1.56	0.00	1.56	457.70	2.19
RICE	350.00	.77	281.92	.68	483.91	.91
LMLSP	123.00	.98	62.13	.53	382.48	1.01
LSP	120.00	.93	88.96	.81	204.24	1.16
COTT	425.00	1.70	349.53	1.45	462.82	1.85

^aSummarized from computer output. For full details see Appendix Table A3.

the ranges shown in Table 10 for each crop enterprise, the activity mix of the plan would remain the same.

296.3 For example, if the return per acre for cotton fell to Shs. 12

349.53 per acre, cotton would have to be reduced from 1.70 (the current optimal level) to 1.26 1.16 acres. Below this level of return, ~~early~~ ^{1.26} ~~sweet potatoes~~ ^{Price} would become relatively more profitable and would begin to replace cotton. If the return for cotton were to be increased to Shs. 462.82, it would be profitable to increase its acreage to 1.85. November labor would be exhausted at this point and further expansion of cotton production would have to be halted unless extra November labor could be obtained.

For the relatively uneconomic crop enterprises--early maize, cassava and legumes (EMCL); early sweet potatoes (ESP); and late maize, cassava and legumes (LMCL)--returns per acre could fall to zero but it would not be possible to decrease their acreage since they are already at their minimum level requirements.

The upper limits in the return per acre column in Table 10 for these enterprises indicate the point where these enterprises become more profitable. Thus, if government wanted to induce farmers to grow more early sweet potatoes, it would have to offer a price to the farmer that gave him a return of not less than Shs. 457.70 per acre of early sweet potatoes. 355.42

From the theoretical point of view, range analysis provides us with a technique of trying to evaluate in a more objective way what value the farmer places on subsistence crops vis-a-vis cash crops. The prices used here were based on estimated prices in the market. Farmers

are likely to place a higher value on subsistence crops than that reflected in the marketplace. The demand for farm products in the market may be low for the following reasons: (1) low wages in the non-farm sector; (2) transportation costs; (3) a small urban population; and (4) the non-farm population has adjusted itself to less diversified types of diets on the one hand, and to cheap imported canned foodstuffs on the other.

A clearer picture of how sensitive the level of enterprise were to changes in net returns was obtained by comparing the percentage increase in crop acreages to their corresponding percentage increases in net returns. This information is compiled in Table 11. Generally, it is seen from Table 10 that increases in the returns per acre of an enterprise did not result in a proportionate increase in the acreage of that enterprise. Cotton was the only crop where an increase in price (2.85 percent) resulted in a more than proportionate change in the acreage of cotton (8.82 percent).

A study on the more aggregate (regional and national) aspects of cotton production by Malima also showed that cotton production in Tanzania was significantly responsive to changes in its price.¹³

Parametric Variations in Returns to Enterprises

The range analysis procedure defined the limit within which changes in either resource availability or returns per acre to enterprises could vary without altering the activity mix of the optimal plan.

¹³Koghoma A. Malima, "The Economics of Cotton Production in Tanzania: An Examination of the Factors That Influence Agricultural Development" (Ph.D. dissertation, Princeton University, 1971).

Table 11. Acreage Response to Changes in Price, Traditional Farm,
Kwimba District, Linear Programming Results^a

Enterprise	Change in Price		Change in Acreage	
	Shs.	Percent	Acres	Percent
ELM	865.71	581.01	.02	2.41
EMCL	41.82	21.67	.08	5.48
ESP	205.42	136.95	.09	180.00
LMCL	117.70	65.39	.63	40.38
RICE	133.91	38.26	.14	18.18
LMLSP	259.48	210.96	.03	3.06
LSP	139.48	116.23	.23	24.73
COTTON	12.82	2.85	.15	8.82

^aOld cassava does not appear in this table because it is assumed to have a fixed acreage.

However, this procedure did not show that the production plan would be below or above the limits defined in the range output. Parametric programming allows one to increase price or the availability of a resource in regular increments, up to a specified maximum increase. At each increment an optimal solution is produced, enabling the activity mix and the level of income to be determined stage-by-stage.

Parametric Variations in the Price of LMCL

Late maize, cassava and legumes (LMCL) was a relatively uneconomic enterprise. Range analysis showed that LMCL would remain at its minimum level (1.56 acres) until its return per acre was increased to Shs. 457.70. Parametric programming gave similar results. There was no change in the acreage of LMCL until its price had reached Shs. 480.00.¹⁴

At its initial price (return per acre) of the optimal plan of Shs. 180.00, LMCL had a shadow price of Shs. 277.70; each acre of this activity removed from the program would mean an increase of Shs. 277.70 to income. As its price was increased in increments of Shs. 25, its shadow price was reduced by the amount shown in Table 12.

An increase in the acreage of LMCL from 1.56 to 2.19 acres as a result of a change in its price led to a simultaneous increase in some crop activities and a decrease in others as shown in Table 13.

Table 13 shows that relative changes in prices resulted in a

¹⁴ The previous increment brought the price of LMCL to Shs. 455.00 (below Shs. 457.70) and therefore did not change acreage. Adding another Shs. 25.00 bring the price of LMCL to Shs. 480 (above the Shs. 457.70 defined in the range analysis).

Table 12. The Effect of a Change in the Economic Profitability of Late Maize, Cassava and Legumes (LMCL) on Its Acreage, Traditional Farm, Kwimba District, Linear Programming Results

Net Return Per Acre (Shs.) +25	Shadow Price (Shs.) -25	Acreage
180.00	277.70	1.56
205.00	252.70	1.56
230.00	227.00	1.56
255.00	202.00	1.56
280.00	177.00	1.56
305.00	152.00	1.56
330.00	127.00	1.56
355.00	102.00	1.56
380.00	102.00	1.56
405.00	77.00	1.56
430.00	27.00	1.56
455.00	2.00	1.56
480.00	0.00	2.19

Table 13. The Effect of a Change in the Net Return Per Acre on LMCL on the Acreage of Other Crops, Traditional Farm, Kwimba District, Linear Programming Results

Enterprise	Acreages of All Enterprises	
	LMCL at Shs. 180.00 Per Acre	LMCL at Shs. 480.00 Per Acre
ELM	.83	.94
EMCL	1.46	1.46
ESP	.05	.05
LMCL	1.56	2.19
RICE	.77	.64
LMLSP	.98	.87
LSP	.93	.09
OC	.55	.55
COTTON	1.70	1.36

acreage at the
optimal plan
(Table 10)

?

reallocation of resources. This led to an increase in the acreages of some crop activities--late maize, cassava and legumes (LMCL); early legumes and maize (ELM)--and a decrease in the production of other crop activities--rice, late maize, legumes, and sweet potatoes (LMLSP); late sweet potatoes (LSP); and cotton.

Parametric Variations in the Net Return Per Acre of Rice

Rice was one of the most profitable crop enterprises in the optimal plan. Upward parametric changes in its price made it even more profitable.

Range analysis results indicated that rice production would remain at .77 acres until its price was increased to Shs. 483.00. When the net return per acre of rice was parametrically varied to Shs. 500.00, the optimal production level for rice in the plan increased to .91 acres. Further increases in the net return per acre of rice would not change its acreage until the price of Shs. 625.00 was reached, when acreage of rice would increase to 1.02 acres. The next change did not occur until the net return per acre of rice was increased to Shs. 1.21936. This resulted in 1.23 acres being allocated to rice production.

From the results of this parametric analysis, a price map¹⁵ can be drawn showing how the production (acreage) to rice responds to changes in its price. This price map (Fig. 3) corresponds to the orthodox supply curve in economic theory.

Table 14 shows how changes in the relative price of rice affected the activity combination of the optimal plan. As the price

¹⁵The terminology came from Perrin, loc. cit.

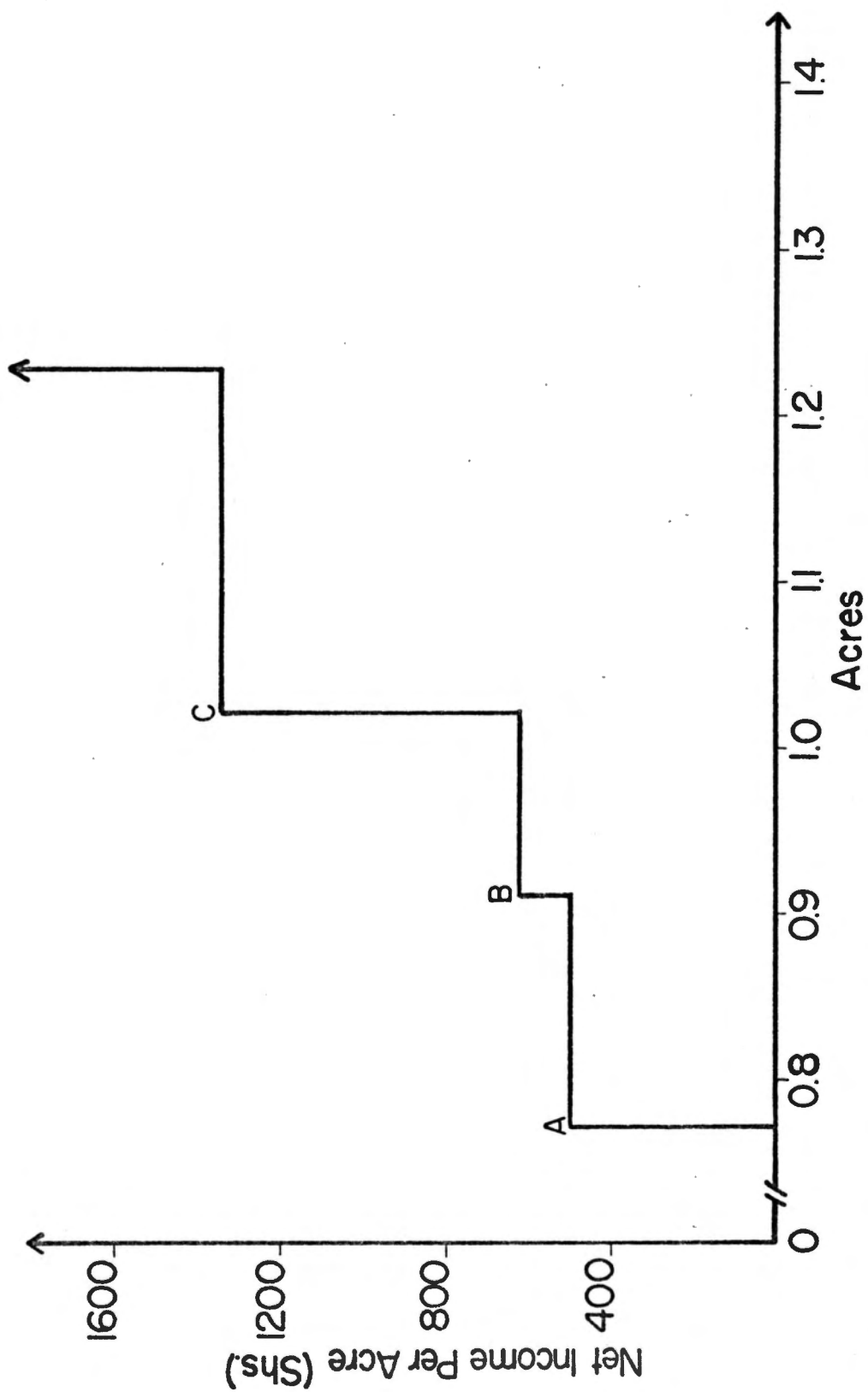


Figure 3. Price map for the rice activity under traditional farm conditions.

Table 14. The Effect of Parametric Increases in the Return Per Acre of Rice on the Acreages of Other Crops, Traditional Farm, Kwimba District, Linear Programming Results

Return Per Acre of Rice (Shs.)	Crop Acreages						COTTON
	ELM	EMCL	ESP	LMCL	LMLSP	RICE	
350.00	0.83	1.46	.05	1.56	.98	.77	1.70
500.00	0.85	1.46	.14	1.56	.94	.91	1.45
625.00	0.84	1.46	.17	1.56	.53	1.02	1.38
1350.00	0.88	1.46	.31	1.56	.53	1.23	1.00

of rice reached Shs. 500.00 there was an increase in the acreage of rice, early legumes and maize (ELM); early sweet potatoes, and late sweet potatoes to .91, .85, .14, and 1.16 acres respectively. In a model with no minimum enterprise requirements specified, early sweet potatoes would enter the optimal solution at this point. This was shown by the fact that the shadow price for its minimum level requirement fell from Shs. 167.07 to zero as the price of rice increased from Shs. 350.00 to 500.00 per acre. Similarly, late sweet potatoes became relatively profitable enough to enter the production plan at this point.

Table 14 also shows that cotton and late maize, legumes and sweet potatoes (LMLSP) was reduced in acreage as a result of this relative change in the price of rice. Cotton was reduced from 1.70 to 1.45 acres and LMLS was reduced from .98 to .94 acres when the price of rice was increased from Shs. 350.00 to 500.00 per acre.

As the price of rice reached Shs. 625.00, the acreage of rice, early sweet potatoes and late sweet potatoes continued to show an increase. Cotton; late maize, legumes, and sweet potatoes (LMLSP); and early legumes and maize (DLM) declined (Table 14). In fact, LMLSP fell to its minimum level. If there were no minimum level requirement for it, production of this enterprise would cease.

Finally, when the price for rice was increased to Shs. 1350.00, its acreage reached 1.22 acres. There was a simultaneous increase in the acreage of early sweet potatoes but a decline in the acreage of late sweet potatoes. Curiously, early legumes and maize (ELM) at this point showed an upward shift to .88 acres.

The most significant change in the production plan as a result of an increase in the net return per acre of rice was that cotton continued to decline as the price of rice was increased. This established the fact that rice and cotton, the two important sources of cash income in the area, compete with each other for scarce resources. As the price of rice increases, more of these resources are diverted to it and hence the production of cotton is reduced.

Furthermore, some of the other crops supplement rice production and, therefore, are able to utilize some of the resources set free as cotton production declines. However, the opportunity to market such crops as sweet potatoes and legumes in the area is very uncertain. Transportation problems and limited demand for these commodities in the urban areas may be cited as two of the problems that face the farmer who wants to market these products to take advantage of a change in the relative net returns per acre for the various crop enterprises on his farm.

Finally, cotton is one of the main export crops of Tanzania. About 80 percent of this crop is produced in the Mwanza region.¹⁶ In the absence of other export commodities, an increase in the relative price of rice vis-a-vis the price of cotton may lead to lower foreign exchange earnings for Tanzania as a result of farmers producing less cotton.

¹⁶Malima, loc. cit.

CHAPTER IV

THE IMPACT OF TECHNOLOGICAL CHANGE ON PRODUCTION AND INCOME

In Chapter II a verbal-schematic model of the typical peasant farm in Kwimba District was developed. Chapter III presented the mathematical formulation of this "traditional" model using linear programming techniques. This chapter reflects an extension of the original model to include the use of chemical inputs, hired labor and oxen power to supplement family labor. These were assumed to be the main characteristics of the modernising peasant farm in Kwimba District as distinguished from the typical traditional type of peasant farm described in the previous chapters. A study to determine the number of farmers who have adopted these innovations has yet to be done in Tanzania. Both Collinson¹ and von Rotenham² mentioned in their studies that an increasing number of farmers, albeit still the minority, were adopting these innovations.

It is hypothesized in this chapter that these innovations are the basis for the technological transformation of agriculture in Tanzania which is needed in order to achieve the developmental goals envisaged in the economic plans.

A. CHANGES MADE IN THE ASSUMPTIONS

The results in Chapter III showed that the availability of labor during critical months was the main constraint towards expended production

¹von Rotenham, loc. cit.

²Collinson, loc. cit.

of marketable crops. The fact that scarce resources had to be tied to the production of subsistence crops made the availability of labor during the peak months an even more crucial factor in considering increased marketable surplus output. Any technological change introduced must be in response to this problem.

It was assumed that the needs of the family for subsistence crops would not change, at least not in the short run. Furthermore, in the absence of marketing outlets for most of the food crops except maize and rice, there was no opportunity to increase the production of these enterprises. Therefore the farmer would go on producing food crops other than rice and maize in the traditional way--without bought inputs and using family labor only. Whatever new inputs he bought, he would use them as far as possible to increase the production of the more commercial crop enterprises.

Moreover, given the low level of savings on a typical peasant farm in Kwimba District and elsewhere in Tanzania, these inputs bought will have to be financed from funds borrowed through co-operatives, the rural development bank and other public institutions. These institutions on the whole administer supervised credit schemes. The supervision usually includes the stipulation by the lending agency as to what use the money must be put or, as in the case of fertilizers, lending in kind rather than in money form.

In view of the preceding considerations, the model of the modernising farm developed in this chapter was built around several assumptions:

1. With regards to the availability of resources the following assumptions were made:

(a) That there would not be any change in the availability of family labor. However, the farmer was allowed to hire outside labor at cost of Shs. 3.00 per manday during the months of October-May and Shs. 4.50 for labor hired June-September. Collinson justifies these rates by the fact that during the cotton harvesting months, people in the district have more money and therefore can be persuaded to work only at a higher wage.³

(b) That not more than Shs. 500.00 would be available to the farmer to finance the innovations envisaged in this chapter. Very little of this money could come from the farmer's own resources, though there may be few farmers who are in possession of such savings. The greater part would have to come from such agencies as the cooperatives and the rural development bank.

Another important source is the Rural Development Fund. This was set up in 1967 to stimulate development projects deemed to be beneficial to a region by a Regional Development Committee in the country. Each region in turn distributes the money among its districts. A study by Collins showed that a significant part of the Regional Development Fund was allocated to the purchase of agricultural inputs, which were then distributed freely to the people engaged in that project in a given district.⁴

³Collinson, loc. cit.

⁴Paul Collins, "The Working of Tanzania's Rural Development Fund: A Problem in Decentralization," East African Journal of Rural Development, V(1&2), (1972), 141-162.

(c) That available money could be spent on hiring labor or buying chemical inputs. Very little research has been done on the use of fertilizers and insecticides in rice production. Some work on higher yield varieties of maize and the use of chemical inputs to increase the yield of maize has been done. But attempts to disseminate the results of this research at the farm level have been meager. Furthermore, fertilizers have been supplied or loaned to the farmers through highly supervised schemes administered by the cooperatives or the Rural Development Fund for use on priority crops. The cooperatives in the Mwanza Region are cotton-based cooperatives and have therefore concentrated on the provision of insecticides and fertilizers to increase cotton output.

For these reasons it was assumed that the use of fertilizers and insecticides would be limited to cotton production only. One acre of cotton would require an expenditure of Shs. 70.00 for twenty units of phosphate in the seedbed, twenty units of nitrogen top-dressed four weeks after germination and six sprays (using a knapsack sprayer) of a DDT wettable powder insecticide.⁵

(d) That either through his own efforts or aided by public agencies the farmer was allowed to have a plough driven by two oxen. The district has a lot of cattle which are not put to much economic use. The farmer can easily train, with the help of the extension agents, two oxen to draw the plough. From the study by Passey⁶ and von Rotenham,⁷ it was estimated that the simplest ox drawn plough

⁵ Collinson, op. cit., pp. 344-354.

⁶ Passey et al., loc. cit. ⁷ von Rotenham, loc. cit.

available in the country could do about 80 percent of all the work done by human labor in the first four cultivation months. The family labor requirements per acre (input output coefficients) of cotton and rice were therefore reduced to 20 percent of their level in the typical traditional farm.

As there are no studies available on the use of ox-drawn plough in the cultivation of the other crops, the use of the plough was restricted to cotton and rice cultivation only. Moreover, while cotton and rice can be grown using flat cultivation techniques, some of the crops in the area are grown using ridge cultivation. This made a more expensive type of plough which is more complex to operate.

2. Returns per acre used in the typical farm model were retained for the modernising farm model. However, as a result of the use of fertilizers, the yield per acre of cotton increased to about two and a half times above the field on the typical farm.⁸ This meant an increase in the return per acre of cotton from Shs. 425.00 to 1062.50.

3. The minimum level requirements for subsistence crops remained in force for the modernising farm as well.

Incorporating the above assumptions, the model of the typical traditional type of peasant farm in Kwimba District could be expanded into the model of the modernising peasant farm. A schematic representation of this expanded model is shown in Figure 4. The essence of this diagram is that technological change enables the farmer to

⁸Collinson, loc. cit.

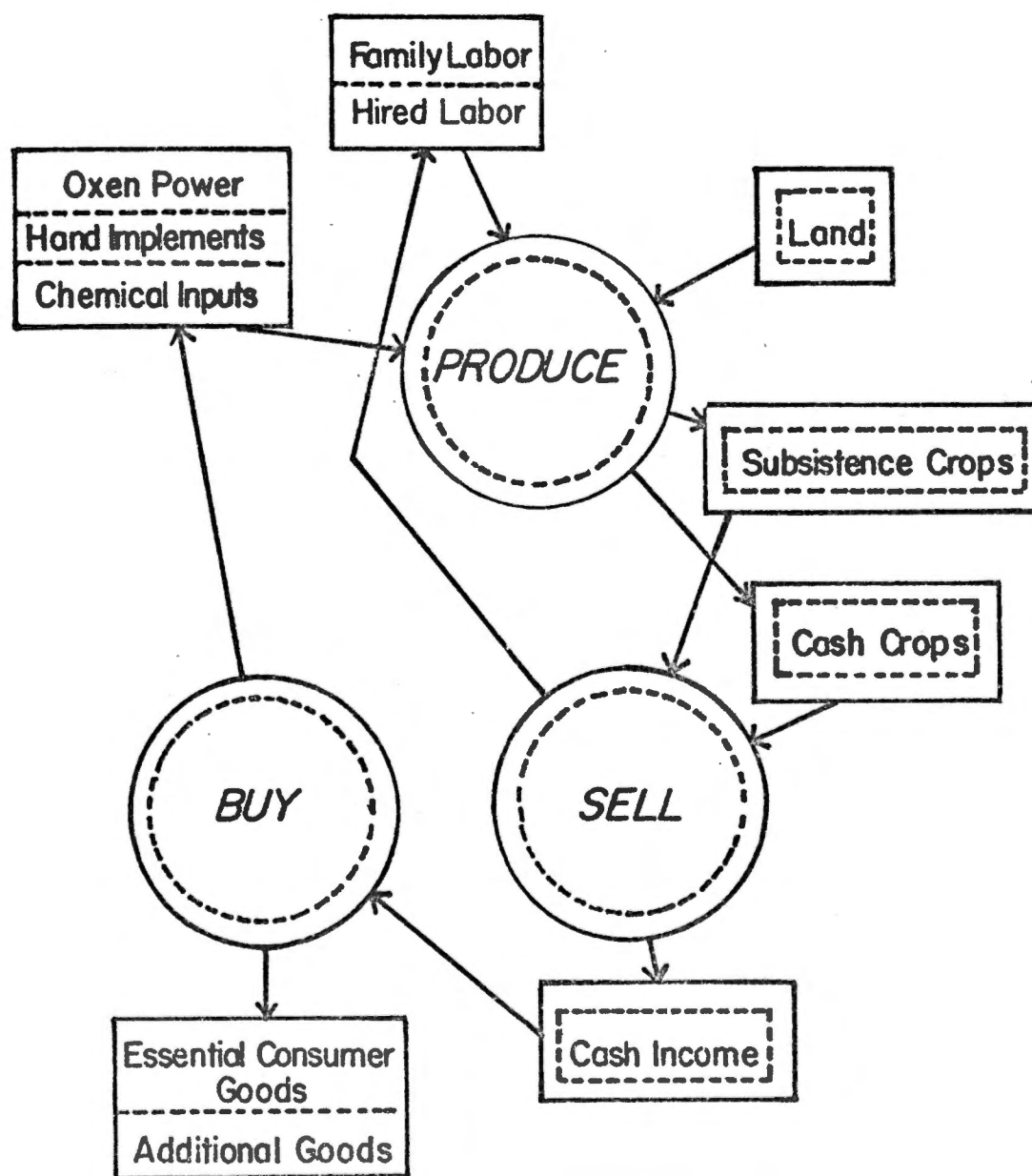


Figure 4. A schematic model of the modernising farm, Kwimba District.

expand output and therefore his income. With more income the farmer can buy more inputs for further expansion of his production plan. Some of the extra income would be spent on consumer goods to improve the family's level of living. This would mean better housing and even better food.

In effect these technological changes would allow the farmer to buy food from the market rather than produce it himself. In view of the marketing difficulties mentioned earlier this possibility is not introduced in the quantitative linear programming tableau presented in Table 15.

B. PRODUCTION AND INCOME UNDER CHANGED TECHNOLOGY

Income and Crop Combinations

With the technological changes envisaged in this chapter, the optimal linear programming solution obtained showed that the modernising farm in Kwimba District was capable of producing subsistence and cash crops valued at Shs. 6967.00. Due to marketing bottlenecks, especially with regards to some of the subsistence crops, the income that could actually be realized would be much lower.

Table 16 lists the crop activities on the modernising farm and their respective contribution to total production (in acres) and gross farm income (in shillings). Again the assumption is that all the marketable surpluses of subsistence crops could be marketed, as was the case in Chapter III. With this assumption, it was possible to determine what part of total income was earned in monetary form. Money income accounted for about 90 percent of total income compared to the 60 percent in the typical traditional farm. Cotton accounted

Table 15. Linear Programming Tableau, Modernising Farm, Krimha District

Rows ^a	Activities										Hire Labor (Mandays)												Sept. Restriction
	ELM	EMCL	ESP	LMCL	RICE	LMSP	LSP	OC	COTTON	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.		
LAND ^b	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-1												15.0	
LABOCT ^c	12.54							7.52	.59		-1											55.0	
LABNOV	12.54	25.34			.6				2.58													55.0	
LABDEC	10.75	10.15	32.56	4.97					1.80			-1										55.0	
LABJAN		4.79		18.25			10.0		4.96				-1									60.0	
LABFEB				10.26		3.0	24.10		2.97					-1								60.0	
LABMAR						7.2	10.34	8.0							-1							60.0	
LABAPR	3.58		2.46		13.33											-1						55.0	
LABMAY	2.5	5.79					2.15	8.0								-1						55.0	
LABJUN				9.86	18.76	3.34			7.94								-1					50.0	
LABJUL				4.11	12.25	2.54			9.92									-1				45.0	
LABAUG																			-1			45.0	
LABSEP		6.16							7.94													40.0	
PLANOV ^d	2.55				1.25				6.94													20.0	
PLADEC																						20.0	
PLAJAN																						20.0	
PLAFEB																						20.0	
PLANAR																						20.0	
CASH ^e																						20.0	
ELEM ^f	1.0	1.0								70.00	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	500.0	
EMCLEQ			1.0																			.65	
ESPEQ				1.0																		1.46	
LMCLEQ					1.0																	.05	
RICEEQ						1.0																1.46	
LMLSPEQ							1.0															.03	
LSPEQ								1.0														.53	
OCEQ																						.09	
COTTEQ																						.55	
OBJ	149.0	193.0	150.0	150.0	350.0	123.0	120.0	45.0	1062.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	1.00	

^aResources, minimum requirements,

^bMeasured in acres. ^cMeasured in mandays. ^dPloughdays in ploughdays.

^eIn shillings. ^fMinimum requirements.

Table 16. Crop Enterprise Mix, Modernising Farm, Kwimba District, Linear Programming Optimal Solution

Enterprise	Acreage		Marketable Surplus	Value		
	Total (acres)	Subsistence Requirement (acres)		Per Acre (Shs.)	Total (Shs.)	Sales (Shs.)
ELM	.65	.65	0	149.0	96.86	0
EMCL	1.72	1.46	.26	193.0	331.96	50.18
ESP	.27	.05	.22	150.0	40.50	33.00
LMCL	1.46	1.46	0	150.0	219.00	
RICE	.03	.03	0	350.0	10.50	
LMCLSP	.71	.53	.18	123.0	87.33	22.00
LSP	1.50	.09	1.41	120.0	180.00	253.80
OC	.05	.55	0	45.0	24.75	0
COTTON	5.62	0	5.61	1062.50	5960.62	5960.62
Total	11.95	4.27	7.68		69651.51	6321.74

for about 85 percent of total income, an increase of about 45 percent. Rice was reduced to its minimum level requirement and contributed only .15 percent to total income. This would indicate that the mechanical innovation (from hand power to animal power) was not as instrumental in increasing output as was the chemical innovation.

The income envisaged in this model assumes that the farmer, in addition to the use of the new inputs, followed the recommended production practices with regards to planting, spacing, weeding, and harvesting. Failure to do so would mean lower yields per acre for cotton and therefore a lower income level than that obtained from the linear programming solution presented in Table 16.

Resource Allocation Under Changing Technology

(a) Land use: The area under cultivation in the modernising farm was about 12 acres--compared to the 9 acres under the typical traditional type of farm model. The increase in acreage was mostly due to increased cotton production. This would lead one to the conclusion that increased cotton production can come about more as a result of technological change rather than as a result of more favorable prices.

(b) Labor use: In the typical traditional farm, family labor was the constraining resource in the months of November, December, February and June. These were the months which had non-zero values in the opportunity cost column in Table 8, p. 41. With the use of a plough and chemical inputs, the constraining months as far as family labor was concerned were November, December, January, February, June and September. The use of the ox-plough reduced the need for March labor

sufficiently enough to make it change from a scarce resource to an abundant resource. The use of the chemical insecticides increased yield and therefore increased the demand for September labor sufficiently enough to change it from an abundant resource into a scarce one.⁹

(c) Hired labor use: The cost of hiring labor was Shs. 300 for the pre-cotton harvesting months and Shs. 4.50 during the harvesting months. With the exception of June and December labor, no labor was hired according to the linear programming results.

The opportunity cost entries with respect to the hiring of labor had a different interpretation from that which applied to the use of family labor. In linear programming terms, hiring labor is an activity and comes into the solution only if it does not lead to a reduction of income. In this case with the exception of June and September, hiring labor would result in less income being earned. The income reduced by hiring a unit of labor in a given month is called its reduced cost in linear programming terminology. In Table 17 labor hiring activities which had greater than zero reduced cost values were uneconomic.

The reduced cost value showed by how much the cost of hiring labor in a given month must be reduced before it was economic to hire labor during that month. For example, until the cost of hiring labor in October was decreased by Shs. 22.52, it was unprofitable to do so. Alternatively the opportunity cost of hiring one manday in October would be Shs. 22.50. This is the income the farmer would have to

⁹The complete solution from the linear programming computer output is reproduced in Appendix Table B1.

Table 17. Optimal Resource Allocation Under Changed Technology, Kwimba District, Linear Programming Solution^a

Resource	Total Available	Level in Optimal Plan	Left Unused	Opportunity Cost
Land (acres)	15.0	12.05	2.95	0
Labor (mandays)				
Family labor				
October	55.0	12.29	42.71	0
November	55.0	55.00	0.0	3.50
December	55.0	55.00	0.0	4.61
January	60.0	60.00	0.0	12.00
February	60.0	60.00	0.0	.42
March	60.0	36.24	23.76	0.0
April	55.0	11.02	43.98	0.0
May	55.0	54.50	.50	0.0
June	50.0	50.00	0.0	33.78
July	45.0	2.16	42.84	0.0
August	45.0	16.58	28.42	0.0
September	40.0	40.00	0.0	33.78
Hired labor				
October		0		22.52
November		0		19.01
December		0		17.91
January		0		10.52
February		0		22.09
March		0		22.52
April		0		22.52
May		0		22.52
June		23.05		0
July		0		33.78
August		0		33.78
September		.65		0
Plough use (ploughdays)				
November	20.0	7.06	12.94	0
December	20.0	7.02	12.98	0
January	20.0	7.02	12.98	0
February	20.0	.04	19.06	0
March	20.0	.04	19.06	0
Cash requirements (Shillings)	500.0	500.00	0.0	6.51

^a Condensed from Appendix Table B1.

sacrifice if he were to hire a manday of October labor.

Under the given assumptions, therefore, it would appear that hiring labor would be economical only in June and to a very small degree in September.

(d) The use of cash: All the available cash was used up. One more shilling available would mean a Shs. 6.5 increase to income. Considering that it is uneconomic to hire labor during most months, if there were more money available it would be more profitable to spend it on chemical inputs rather than on hired labor. This would suggest that chemical inputs are more vital to the expansion of agricultural output under the present conditions in Kwimba District.

(e) Plough use: About half of the plough time available in November-February was used. Very little plough time was used in February and March. The plough, according to the results obtained here, would remain idle most of the time. In actual fact this would be unlikely due to the following reasons:

(1) The plough could probably be easily adapted for use in the production of other crop activities other than rice and cotton.

(ii) Farmers do rent ploughs from those with some to help them overcome availability of labor bottlenecks during crucial production periods.

Constraining Minimum Requirements

In the modernising farm model three crop activities--late maize, cassava and legumes (LMCL); early legumes and maize (ELM); and rice were forced into the solution. The opportunity cost of reducing these crops by one acre would be a net income gain of Shs. 287.0, 429.26

and 30.57 respectively. If the innovations introduced on the modernising farm (especially the chemical components) were extended to LMCL and ELM, they would make these crops more competitive since the application of fertilizers and insecticides would increase yields per acre.

C. SENSITIVITY OF OPTIMAL PRODUCTION PLAN UNDER CHANGING TECHNOLOGY

Range Analysis

Results obtained from the computer linear programming range output are summarized in Tables 18 and 19.¹⁰ The information presented in these tables deals with the following major points:

Table 18 provides the information required to evaluate the sensitivity of the optimal plan, under the assumptions made in this chapter, to changes in resource availability and minimum requirement constraints. As was done in Chapter III, the range within which a constraint level can vary without affecting the activity mix of the optimal plan was defined by its lower and upper limits.

The results in Table 18 show that, in the modernising farm model, labor in the harvest months was relatively more important than it was in the typical traditional farm model. This is shown by the much higher opportunity cost values of a unit change in the availability of June and September labor shown in the unit change income effect column. Under traditional farming systems it was seen in Chapter III (Table 8, page 41) that the availability of labor during the peak

¹⁰The range analysis results for this section are reproduced fully in Appendix Tables B1 and B2.

Table 18. Sensitivity of Optimum Production Plan to Changes in Constraints, Modernising Farm, Kwimba District, Linear Programming Results^a

Constraint	Level in	Within Which	Unit Change	<u>Limiting Activity</u>	
	Optimal Plan	Optimal Plan Not Affected	Income Effect	Lower	Upper
	-----	Mandays -----	Shs.		
Labor					
November	55.0	48.5-57.7	3.50	EMCLEQ	LAMAY
December	55.0	47.8-154.1	4.61	ESPEQ	LAND
January	60.0	45.9-89.7	12.00	LSPEQ	LABMAR
February	60.0	55.8-81.5	0.42	LMLSPEQ	HILSEP
June	50.0	47.0-52.0	33.78	HILSEP	LABNRY
September	40.0	39.3-40.8	33.78	HILJUN	HILSEP
	-----	Shs. -----			
Cash	500	486.6-509.2	6.51	HILSEP	EMCLEQ
	-----	Acres -----			
Constraining Activity Minima					
ELM	.65	.32-1.17	30.58	HILSEP	EMCLEQ
LMCL	1.46	1.21-1.81	429.26	LABMAY	HILSEP
RICE	.03	0-.19	287.00	RICE	HILSEP

^aCondensed from Appendix Table B2.

Table 19. Sensitivity of Optimum Production to Changes in Returns Per Acre, Modernising Farm, Kwimba District, Linear Programming Results^a

Enter- prise	Optimal Level		Lower Limit			Upper Limit		
	Return		Return		Limiting	Return		Limiting
	Per Acre (Shs.)	Acres	Per Acre (Shs.)	Acres		Per Acre (Shs.)	Acres	
ELM	149.00	.65	0	.65	None	179.58	1.17	ELMEQ
EMCL	143.00	1.72	130.18	1.46	ELMEQ	668.91	1.90	HILNOV
ESP	150.00	.27	0	.05	LABDEC	343.73	.35	LABNOV
LMCL	180.00	1.46	0	1.46	None	579.26	1.81	LMCLEQ
RICE	350.00	.03	0	.03	None	637.00	.19	RICEEQ
LMLSP	123.00	.71	113.03	.53	LABFEB	595.93	.88	HILFEB
LSP	120.00	1.50	0	.09	LABJA	221.57	1.96	HILJAN
COTT	1062.52	5.62	682.02	5.58	ELMEQ	1159.30	5.64	LABFEB

^aCondensed from Appendix Table B3.

cultivation period was more or less as important as the availability of labor in June--the peak harvesting month.

Secondly, should June labor fall to its lower limit, it would not be necessary to hire labor in September. The same applied to September labor, mutatis mutandis. This would lead to the reduction of early maize, cassava and legumes (EMCL), early sweet potatoes (ESP) and late sweet potatoes (LSP) to their minimum level.

In contrast to the typical traditional farm model, land could become a constraining resource at the upper limit when more December labor is available (Table 18). Given the upper limit specified for December labor (154.1 manday), land is not likely to be exhausted. However, if the use of the plough were to be extended to other crop enterprises besides rice and cotton, land would become a constraining resource.

Table 18 also showed that, if the amount of cash available fell to its lower limit of Shs. 486.60, it would no longer be economic to hire September labor.

Finally, Table 18 shows the opportunity cost of a unit change in the minimum level requirements for the three relatively uneconomic crop enterprises in the optimal plan. A decrease in the acreage of early maize, cassava and legumes (EMCL), early sweet potatoes (ESP) and late maize, Cassava and legumes (LMCL) would result in an increase in income of Shs. 30.58, 429.26 and 287.00 respectively. The farmer would probably be willing to give up rice production since it forms a small part of his subsistence requirements. If this were to happen, he would find it unnecessary to hire labor and could spend the money on other

inputs for the expansion of production in more profitable activities.

Table 19 shows the upper and lower limits within which the net return per acre for each enterprise could fluctuate without affecting the optimal plan under the modernising farm assumptions.

The percent upward change in the net revenues of a crop enterprise and its corresponding percent change in acreage for each crop enterprise were calculated and the results obtained tabulated in Table 20.

Compared to the range analysis results obtained under the assumptions made about the typical traditional farm (Tables 9-11, pp. 44, 48, 51) showed that the modernising farm production plan was more responsive to changes in the net revenues of its crop enterprises. With the spread of technological innovations to the entire plan and with the willingness of farmers to abandon production of relatively uneconomic crop combinations, crop acreages would even be more responsive to changes in crop enterprise returns per acre.

Parametric Variations of Prices

For the modernising farm model, the net return per acre of rice was parametrically varied from Shs. 350.0 to Shs. 1350.0 in constant increments of Shs. 25.00. Figure 5 was the rice price map which resulted from the parametric programming results obtained from the computer output.

In contrast to Figure 2, p. 28, Figure 4, p. 65, shows that more modifications in the plan could be made as the net return for rice increased within the chosen parametric range. Under the typical traditional farm conditions only three modifications could be made. Under modernising farm conditions if an increase in the net return

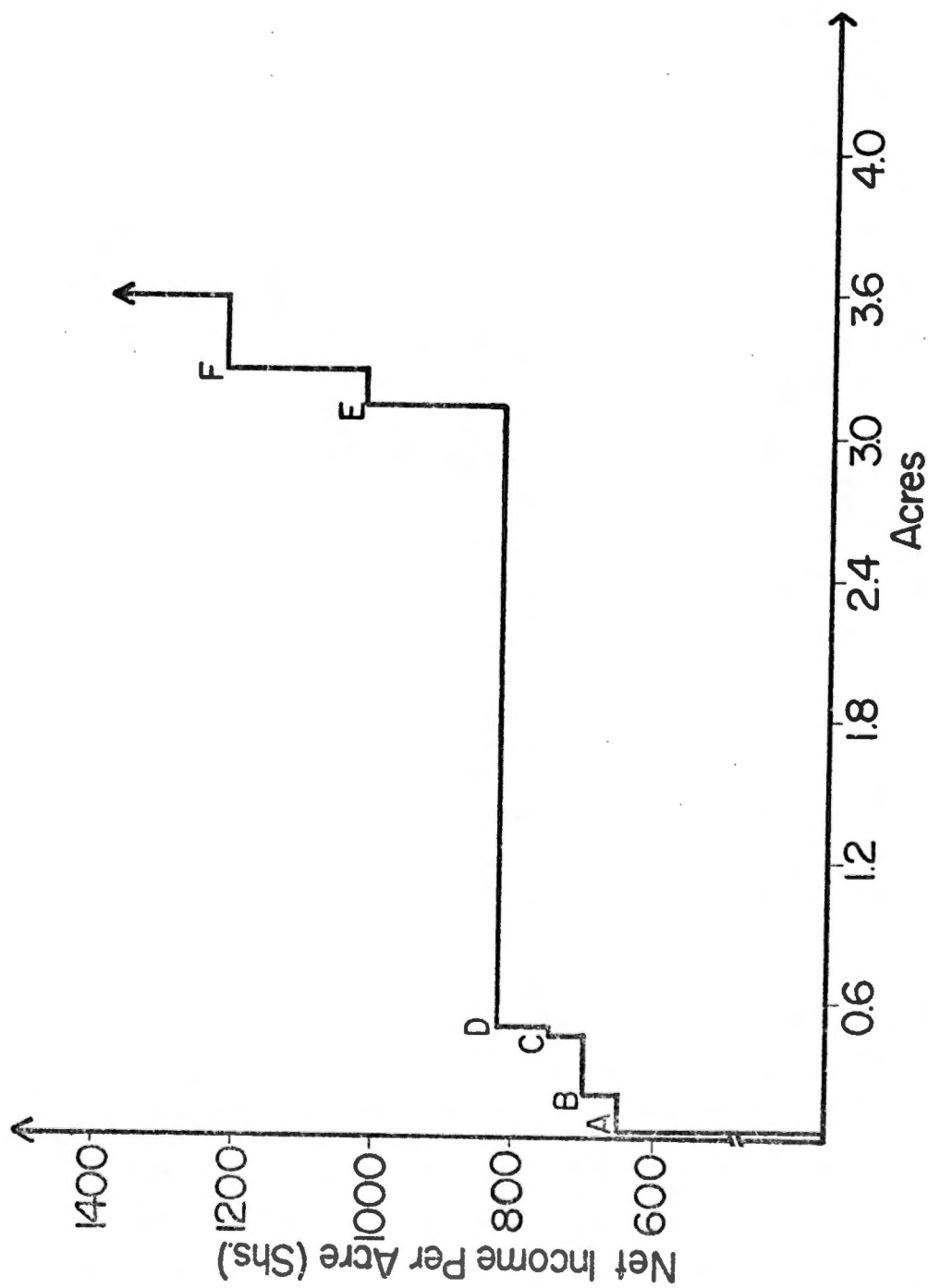


Figure 5. Price map for the rice activity under changing technological conditions, Kwimba District.

Table 20. Acreage Response to Changes in Price, Modernising Farm,
Kwimba District, Linear Programming Results

Enterprise	Change in Price		Change in Acreage	
	Shs.	Percent	Acres	Percent
ELM	30.58	20.52	.52	10
EMCL	475.91	246.59	.18	10.47
ESP	284.73	189.82	.08	29.63
LMCL	399.26	221.81	.35	23.97
RICE	287.24	82.07	.16	533.33
LMLSP	467.70	318.16	.17	23.94
LSP	101.57	84.64	.46	30.67
COTT	96.80	9.11	.02	.36

per acre of rice was to take place from Shs. 350.00 to 1350.00 in constant increments of Shs. 25.00, the optimal production plan could be varied at points A, B, C, D, E, and F (Figure 5, p. 78). The activity mix for each one of these points was tabulated in Table 21.

As was the case in the typical traditional farm model, an increase in the return per acre of rice caused acreages of some crop activities to decline. This was particularly true of cotton, which decreased from 5.62 to 2.94 acres when the return per acre of rice increased from Shs. 350.00 to Shs. 1350.00. However, cotton was not forced to its minimum level of one acre. This suggests that, with improved technology, it is possible to increase the net return per acre of one crop enterprise without severely curtailing the production of another crop. That this could be the case was shown by the fact that the increase in the return for rice led to the increase in the use of land and plough time. Thus, with the return per acre of rice set at Shs. 1350.00, the following changes would occur:

(a) Land under cultivation would be increased from its level in the optional plan of 11.96 acres to 13.32 acres.

(b) Plough time use in all months would be increased.

(c) Labor hired in June would be increased from 23.0 mandays to 62.60. No labor would be hired in September but 4.72 mandays of April labor would be hired. This indicated that more money would have to be reallocated from purchasing chemical inputs to hiring labor. As a result, the labor constraints would be relaxed and the expansion of rice cultivation would result in part from hitherto uncultivated land being brought into the production plan rather than being taken from cotton

Table 21. The Effect of Parametric Increases in the Return Per Acre of Rice on Acreages of Other Crops, Modernising Farm, Kwimba District

Return Per Acre of Rice Shs.	Acreages							RICE
	ELM	EMCL	ESP	LMCL	LMLSP	LSP	COTTON	
350.0	.65	1.72	.28	1.46	.71	1.51	5.62	.03
650.0	.65	1.72	.28	1.46	.71	1.52	5.52	.19
700.0	1.16	1.46	.20	1.46	.71	1.68	5.34	.45
750.0	1.16	1.46	.20	1.46	.53	1.68	5.34	.48
825.0	1.13	1.46	.37	1.46	.53	2.02	3.41	3.10
1025.0	.65	1.70	.46	1.46	.53	1.93	3.31	3.23
1225.0	.65	1.70	.49	1.46	.53	1.99	2.94	3.56
1350.0	.65	1.70	.49	1.46	.53	1.99	2.94	3.56

production. Under the assumptions of the typical traditional farm, the labor constraints could not be relaxed and the expansion of rice production in response to its higher net returns per acre had to take place entirely through the reduction of production of competing activities, notably cotton.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

A. SUMMARY

This study attempted to determine, using linear programming techniques, an optimal production plan for a typical traditional farm in Kwimba District, Tanzania. The optimal production plan sought was based on the assumption that the farmer wanted to maximize his income subject to the constraints imposed on him by his cultural-economic environment.

Explicitly, the economic constraints consisted of the amount of land and the family labor available for agricultural production. Implicitly, it was recognized that lack of money to spend on farm machinery, chemical inputs and hired-labor limited the farmer's capacity to expand production should economic conditions permit him to. Culturally, it was assumed that the farmer gave priority to subsistence crops to ensure the survival of his family. Resources had therefore to be committed to the production of subsistence crops to ensure minimum food requirements for the family.

The linear programming model, in addition to specifying the level of resources available to the farmer, also specified minimum acreage requirements for each of the nine crop enterprises in the model. All data used were from secondary farm survey sources and were taken at their face value.

To indicate the development potentials of the typical traditional

farm in Kwimba District, the basic linear programming model for the typical traditional farm was extended to incorporate technical changes that some Tanzanian farmers already have or are beginning to adopt. This was referred to as the "modernising" farm model. This included the introduction of an oxen-plough, the use of insecticides and artificial fertilizers. The modernising farm also had at its disposal Shs. 500.00 to spend on the chemical inputs and to hire labor to supplement family labor.

Chapter II dealt with the analytical framework upon which the linear programming model was built. Chapter III developed the linear programming model for the typical traditional farm in Kwimba District. Chapter IV dealt with the linear programming model for the modernising farm. Comparisons were made between the basic model and the extended model. The results obtained in both chapters are summarized below:

Land and Labor Use in Kwimba District

The linear programming results showed that the scarce factor of production under the traditional system in Kwimba District, assuming 15 acres of land were available, was labor during peak production periods.

The introduction of the oxen-plough helped to alleviate the problem of labor shortage. Due to unavailability of data, the use of the oxen-plough in the study was limited to two crop enterprises only, rice and cotton. The oxen-plough therefore remained idle most of the time. In the real situation the plough can be used to cultivate other crops--especially grains and legumes. It could therefore be used more often than suggested here. Nevertheless, the possibility that it might

not be possible to use the plough to its capacity would still remain. Moreover, it was pointed out that it would be more profitable for the farmer to rent his plough to those who did not own one of their own.

The income effect of allowing the farmer to have access to Shs. 500.00 to buy chemical fertilizers and insecticides was even more striking than the introduction of the plough. The use of chemical inputs was limited to cotton only. This was partly to reflect the current practice of cooperative societies in the area which distribute fertilizers specifically for use on cotton fields. Furthermore, if the subsistence crops are relatively priced lower than the cash crop (in this case cotton), the use of chemical fertilizers would have a better economic return on cotton than on the subsistence crops. Farmers would therefore find it economically justifiable to restrict the use of chemical inputs to cotton production only, given the scarcity of cash.

Shadow prices obtained from the linear programming results showed that in the typical farm situation the opportunity cost of an additional labor unit during peak cultivation months was about the same as that of an additional labor unit during the peak harvesting months. With the introduction of the technological changes described in Chapter IV, the opportunity cost of an additional manday in the peak harvesting months was much higher.

In the modernising farm model, money could be used to buy chemical inputs or hire labor. Only a little labor was hired in the peak harvesting months of June and September. Most of the money went to buy chemical inputs. Chemical inputs represented the investment with the highest economic return among the innovations introduced on the modernising farm.

Range Analysis

The range within which the shadow prices of the scarce resources operated without affecting the enterprise combination of the optimal plan for both the typical farm and modernising farm system was determined through the use of the range analysis function by the computer.

This range was very sensitive to changes in the availability of resources. Downward changes in the availability of scarce resources very quickly led to a reduction in the level of a number of crop enterprises. This happened because minimum requirements for every crop enterprise had to be met. An upward increase in one resource very quickly led to the exhaustion of another resource. This meant that very little was gained in the way of an increase in the acreage of crops.

The typical traditional optimum production plan was generally not very responsive to changes in the net return per acre in most crop enterprises. Again this had to do with the scarcity of labor in certain peak periods coupled by the fact that this labor had to be committed to the production of subsistence crops regardless of how low market prices were. As there was very little labor to reallocate to crop enterprises whose return per acre had increased, a very large increase in the return per acre of such crops was required before scarce labor resources were reallocated to them in order to increase their acreage.

Parametric Programming

Some crop enterprises were forced into the optimal linear programming solution at a relatively uneconomic returns per acre in order to meet minimum food requirements. Reducing the acreages of such enterprises would mean an increase in income since scarce resources

would be diverted from such enterprises to more profitable ones. These uneconomic enterprises were identified by having a shadow price which gave the magnitude of the gain in income per acre decreased.

As the return per acre of late maize, cassava and legumes (LMCL), one of the uneconomic enterprises, was increased parametrically in constant increments of Shs. 25.00, its shadow price decreased by the same amount. The point where the shadow price fell to zero indicated the return per acre at which this crop enterprise became profitable. It was the point where resources began to be reallocated from other enterprises to LMLC. If government wanted to promote the production of this combination of crops, then the net return per acre of LMLC realized by the farmer must at least equal the return per acre obtained in the parametric results when the shadow price of LMLC fell to zero. Below this return per acre, this crop combination will be produced for subsistence only.

The price of rice was also parametrically varied in the same way. As the return per acre increased, its acreage increased while that of cotton decreased. A point was reached when cotton became an unprofitable crop and would probably not be produced.

Under changing technology a parametric increase in the return per acre of rice of the same magnitude did not lead to cotton production being unprofitable. The introduction of technological innovations allowed for more flexible changes in the production plan.

Conclusion

The major conclusion reached in this study is that the availability of labor during peak production periods is the major limiting factor to

increased production. With the scarce labor resources being committed to subsistence production, the traditional farmer's capacity to expand production for the market in response to better economic incentives is very much limited. In order to raise the income level of the typical family in the District (and elsewhere in Tanzania), it is urgent that the farmers produce more and sell more. Even if the government uses economic and political incentive to persuade farmers to increase output, however, the farmers response will only be limited in the absence of technological changes that would enable them to increase their marketable output without upsetting their subsistence needs. As MacLoughlin put it, "economic restructuring including the changing of marketing channels, is no substitute for technological change in improving agricultural productivity."¹

B. IMPLICATION FOR FURTHER RESEARCH

The validity of the above conclusions depends on the reliability of the data used in this study. Since the studies from which the data were obtained were of a pioneering nature, it is safe to assume that their information was not completely accurate.

There is, therefore, need for further research to test the accuracy of these data. For example, not enough land might have been allowed for communal grazing purposes. Land shortage, especially after the introduction of mechanical implements, might be felt sooner than the result of the model would show. Equally, the impact on the availability

¹Peter MacLoughlin, quoted by A. Leakey, "Factors Affecting Increased Production and Marketing of Food Crops in Uganda, East Africa," Journal of Rural Development, III(1), (1970).

of farm labor of community festivities and other non-farm engagements might be bigger than the data used would indicate. Furthermore, yields per acre indicated in these studies, particularly with respect to subsistence food crops, were probably approximations of actual yields.

More research regarding the above questions would result in more reliable results.

In Chapters III and IV it was pointed out that the income levels obtained by the linear programming solutions in this study were probably higher than the actual potentials in the District. This was due to the fact that marketing constraints were not taken into consideration. This problem is particularly relevant when the modernising farm is considered. To avoid overestimation of output and income under improved technology, upper bounds for food crop activities should have been included in the model. Information regarding marketing constraints, however, was not available. Further research in this direction is needed.

In addition to the above observations, the agricultural research needs for Kwimba District and other areas in Tanzania would seem to be the following:

(a) Agricultural economists need to look more into the farm management/production economics aspects of peasant farming.

(b) Agricultural engineers need to look at the animal-powered tools that can be used to save labor for certain crucial tasks and generally raise productivity.

(c) Agronomists need to look into high yielding varieties, soil fertility and other factors which will enable the farmers to get more with the same labor.

C. POLICY AND PROGRAM RECOMMENDATIONS

Several policy observations emerged from this study.

Technological Change

From the point of view of this study two aspects of technological change may be considered:

(a) Chemical inputs: The use of these must be encouraged especially for the most commercialized crops like cotton. This will lead to increased yields, which will enable farmers to produce more with the limited labor resources they have. The use of fertilizers and insecticides on all crops, however, may not be economically justifiable at the present moment. Unless the farmers can sell increased output brought about by increased yields, it would be uneconomic to promote the use of chemical inputs for all crop enterprises. In the short run at least, the application of fertilizers and insecticides must be limited to the most profitable crop enterprises.

However, better farming practices like spacing and timely planting should be promoted for all crops. This, however, does not necessarily mean doing away with practices like staggered planting and mixed-cropping. At least these should not be changed radically. The reason farmers engage in these practices is that they minimize the danger for famines. Leakey was probably correct when he observed, "It may well be, for example, that farmers place greater value on a system which gives fairly reliable constant but low crop yields in preference to a system by which they might risk total crop failures every two or three years."²

²Ibid.

Care must be taken therefore in introducing changes which relate to current farming practices.

(b) Mechanization: The study showed that only part of the plough time allowed was used. The hiring of ploughs by those who do not have them will make buying ploughs an economic investment more than this study suggested. Furthermore, the use of the plough can be extended to other activities besides cotton and rice as was done in this study. However, this study will indicate at this stage mechanization by machine-powered tractors would not be economically justifiable at this time.³

Pricing Policy: Food Crops vs. Cash Crops

Under traditional farming conditions, an increase in the price of food crops, according to this study, would lead to a decline in cotton production. Cotton exports are likely to suffer. This would mean less foreign exchange for the country. Under the changed technology conditions assumed in this study, the impact on cotton production of an increase in the price of food crops like maize and rice, would not be as strong. It would therefore be possible to increase the price of maize and rice, without too much harm to cotton production. This is especially true if this is followed by the introduction of cotton to other regions in the country where there are no competing crops. In this way it would be possible to reconcile the goals of maximum foreign exchange earnings from cash crops and maximum self-sufficiency in

³This point is made throughout C. Kline, et al., Agricultural Mechanization in Equatorial Africa (Lansing: Institute of International Agriculture, Michigan State University, 1969).

food crop production. In the absence of technological changes the balance would be hard to maintain.

Credit

It would not be possible for the farmer to implement all these technical changes assumed in this study without government assistance. Tanzania is already in the process of building credit institutions to serve peasant agriculture. These efforts are in their preliminary stages. No specific recommendations can be made here with regards to agricultural credit policy except to say it is an essential part if the changes suggested here are to take place.

Extension and Other Services

In the past extension services were almost limited to cash crops. There is need to extend these to other crops. Furthermore, educational and health extension services form an integral part of the effort to increase productivity. Better health through cleaner water supplies, for example, would mean that people will spend more time on their farms during periods when all the labor resources available are required.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Agrawal, R., and Heady, E. O., Operations Research Methods for Agricultural Decisions. Ames: Iowa State University Press, 1972.
- Chipeta, W., "The Role of Customary and Modern Money in the Rural Exchange of Malawi," East Africa Journal of Rural Development, III (1970).
- Collinson, M. P., Farm Management in Peasant Agriculture, A Handbook of Rural Development Planning in Africa. New York: Praeger Publishers, 1972.
- Cunningham, Griffiths L., The History of Agricultural Production in Tanganyika 1919-1968. Mimeographed paper delivered at the IDEP/MISR Conference, Makerere University College, January 4-9, 1968.
- Helleiner, Gerald K., Peasant Agriculture and Economic Growth in Nigeria. Homewood, Ill.: Richard D. Irwin, 1966.
- Ilife, John, Agricultural Change in Modern Tanzania. Mimeographed.
- _____, Tanganyika Under German Rule 1905-12
- Jain, S. C., Principles and Practice of Agricultural Marketing and Prices. Bombay: Bombay Publishing House, 1971.
- Leakey, A., "Factors Affecting Increased Production and Marketing of Food Crops in Uganda," East Africa Journal of Rural Development, III (1970).
- Malima, Kighoma A., "The Economics of the Factors that Influence Agricultural Development. Ph.D. dissertation, Princeton University, 1971.
- Newhouse, P. M., A Review of the Production and Marketing Arrangements for Maize, Paddy and Wheat with Particular Reference to the Milling Sector. Dar-es-Salaam: UNDP/FAO Marketing Development Bureau, SF. Jan. 27, 1972.
- Passey, Anders J., et al., Tanzania: Land Use and Agricultural Diversification. Washington, D.C.: United States Department of Agriculture/United States Agency for International Development, 1964.
- Perrin, R., Use of the Linear Programming Facility of IBM Mathematical Programming System (MSP360). Raleigh: Department of Economics, North Carolina State University, 1968.

Ruthenberg, Hans (ed.), Smallholder Farming and Smallholder Development in Tanzania. Munich: Welt-Forum-Verlag, 1968.

Singleton, Carey B., The Agricultural Economy of Tanganyika. Washington, D.C.: United States Department of Agriculture, Economic Research Service, Foreign Regional Analysis Division, 1964.

Smith, Hadley E. (ed.), Readings in Economic Development and Administration in Tanganyika. Dar-es-Salaam: Institute of Public Administration, 1967.

United Republic of Tanzania, Economic Survey, 1971-72. Dar-es-Salaam: Government Printer, 1972.

_____, Tanzania: Second Five Year Plan for Economic and Social Development, July 1, 1969-June 30, 1974; Volume III: Regional Perspectives. Dar-es-Salaam: Government Printer, 1970.

APPENDICES

APPENDIX A

COMPUTER OUTPUT ROW SOLUTION AND RANGE ANALYSIS RESULTS,
TRADITIONAL FARM, KWIMBA DISTRICT

Table A1. Row Solution: Traditional Farm, Kwimba District

Number	Row	At	Activity	Slack Activity	Limit		Dual Activity
					Lower	Upper	
1	CBJ1	BS	1941.20	-1941.20	None	None	1.00
2	CBJ2	BS	1941.20	-1941.20	None	None	--
3	CBJ3	BS	1941.20	-1941.20	None	None	--
4	CHROW1	BS	7.80	-7.80	None	None	--
5	CHROW2	BS	3.84	-3.84	None	None	--
6	CHROW3	BS	-8.48	8.48	None	None	--
7	LAND	BS	8.83	6.17	None	15.00	--
8	LABOCT	BS	14.54	40.45	None	55.00	--
9	LABNOV	UL	55.00	--	None	55.00	-2.72
10	LABDEC	UL	55.00	--	None	55.00	-10.69
11	LABJAN	UL	60.00	--	None	60.00	-12.00
12	LABFEB	UL	60.00	--	None	60.00	-2.84
13	JABMAR	BS	54.45	5.55	None	60.00	--
14	LABAPR	BS	15.34	39.66	None	55.00	--
15	LABMAY	BS	22.58	32.42	None	55.00	--
16	LABJUN	UL	50.00	--	None	50.00	-15.87
17	LABJUL	BS	28.73	16.27	None	45.00	--
18	LABAUG	BS	27.17	12.83	None	40.00	--
19	LABSEP	BS	2.12	37.88	None	40.00	--
20	ELMEQ	BS	.83	-.18	.65	None	--
21	EMCLEQ	LL	1.46	--	1.46	None	41.82
22	ESPEQ	LL	.05	--	.05	None	205.42
23	LMCLEQ	LL	1.56	--	1.56	None	277.70
24	RICEEQ	BS	.77	-.74	.03	None	--
25	LMLSEQ	BS	.98	-.45	.53	None	--
26	LSPEQ	BS	.93	-.84	.09	None	--
27	OCEQ	EQ	.55	--	.55	.55	-45.00
28	COTTEQ	BS	1.70	-.70	1.00	None	--

subsequent
requirements

label IV

Table A2. Range Analysis: Rows at Intermediate Level, Traditional Farm, Kwimba District

Number	Row	At	Activity	Slack	Lower Limit	Upper Limit	Lower Activity	Upper Activity	Unit Cost	Lower Cost	Upper Cost	Limiting Process	At
9	LABNOV	UL	55.00	--	None	55.00	52.91	58.44	-2.72			ELMEQ	LL
									2.72			LABMAR	UL
10	LABDEC	UL	55.00	--	None	55.00	52.05	66.25	-10.69			LABMAR	UL
									10.69			LSPEQ	LL
11	LABJAN	UL	60.00	--	None	60.00	51.56	66.94	-12.00			LSPEQ	LL
									12.00			LABMAR	UL
12	LABFEB	UL	60.00	--	None	60.00	50.25	84.70	-2.84			LMLSEQ	LL
									2.84			LABMAR	UL
16	LABJUN	UL	50.00	--	None	50.00	35.88	53.88	-15.37			LABMAR	LL
									15.37			LABMAR	UL
21	EMCLEQ	LL	1.46	--	1.46	None	1.24	1.55	41.82			LABMAR	UL
									-41.82			ELMEQ	LL
22	ESPEQ	LL	.05	--	.05	None	--	.14	205.42			ESP	LL
									-205.42			LABMAR	UL
23	EMCLEQ	LL	1.56	--	1.56	None	1.30	2.19	277.70			LABMAR	UL
									-277.70			LSPEQ	LL
27	OCCEQ	LL	.55	--	.55	.55	--	1.24	45.00			OC	LL
									45.00			LABMAR	UL

resources

substit

neg. - substitution

As we decrease EMCLEQ from 1.46 to 1.24, we will increase the income by 41.82 But we can't force it below 1.24 because Ranch labor will be exhausted. The price of EMCLEQ could be reduced if we increase the availability of Ranch labor. If EMCLEQ is over 2.14, would force LSP to its substitute price level.

Table A3. Range Analysis: Columns at Intermediate Level, Traditional Farm, Kwimba District

Number	Column	At	Activity	Input Cost	Lower Limit		Upper Limit	Lower Activity	Upper Activity	Unit Cost		Upper Cost		Limiting Process	At
					Upper	Lower									
29	ELM	BS	.83	149.00	--			.65		-19.85		129.15		EMCLEQ	LL
					None			.85		-865.71		1014.71		ESPEQ	LL
30	EMCL	BS	1.46	193.00	--			1.46		-Infinity		-Infinity		None	
					None			1.55		-41.82		234.82		EMCLEQ	LL
31	ESP	BS	.05	150.00	--			.05		-Infinity		-Infinity		None	
					None			.14		-205.42		355.41		ESPEQ	LL
32	LMCL	BS	1.56	180.00	--			1.56		-Infinity		-Infinity		None	
					None			2.188		-277.70		457.70		LMCLEQ	LL
33	RICE	BS	.77	350.00	--			.68		-68.08		282.00		LABNOV	UL
					None			.91		-134.00		484.00		ESPEQ	LL
34	LMLS	BS	.98	123.00	--			.53		-60.87		62.13		LABFEB	UL
					None			1.01		-259.48		382.48		LABNOV	UL
35	LSP	BS	.93	120.00	--			.82		-31.04		88.96		EMCLEQ	LL
					None			1.16		-84.23		204.23		ESPEQ	LL
36	OC	BS	.55	45.00	--			.55		-Infinity		-Infinity		None	
					None			.55		-Infinity		-Infinity		None	
37	COTT	BS	1.70	425.00	--			1.45		-75.47		349.53		ESPEQ	LL
					None			1.85		-37.82		462.82		LABNOV	UL

APPENDIX B

COMPUTER OUTPUT ROW SOLUTION AND RANGE ANALYSIS RESULTS,
MODERNISING FARM, KWIMBA DISTRICT

Table B1. Row Solution, Modernising Farm, Kwimba District

Number	Row	At	Activity	Slack Activity	Limit		Dual Activity
					Lower	Upper	
1	CBJ1	BS	6853.57	-6853.57	None	None	1.00
2	CBJ2	BS	6855.71	-6855.71	None	None	--
3	CHROW1	BS	.15	-.15	None	None	--
4	LAND	BS	11.96	3.04	None	15.00	--
5	LABOCT	BS	12.29	42.71	None	55.00	--
6	LABNOV	UL	55.00	--	None	55.00	-3.50
7	LABDEC	UL	55.00	--	None	55.00	-4.61
8	LABJAN	UL	60.00	--	None	60.00	-12.00
9	LABFEB	UL	60.00	--	None	60.00	-.42
10	LABMAR	BS	36.24	23.76	None	60.00	--
11	LABAPR	BS	11.02	43.98	None	55.00	--
12	LABMAY	BS	54.50	.50	None	55.00	--
13	LABJUN	UL	50.00	--	None	50.00	-33.78
14	LABJUL	BS	2.17	42.83	None	45.00	--
15	LABAUG	BS	16.58	28.42	None	45.00	--
16	LABSEP	UL	40.00	--	None	40.00	-33.78
17	PLANOV	BS	7.06	12.94	None	20.00	--
18	PLADEC	BS	7.02	12.98	None	20.00	--
19	PLAJAN	BS	7.02	12.98	None	20.00	--
20	PLAFEB	BS	.04	19.96	None	20.00	--
21	PLAMAR	BS	.04	19.96	None	20.00	--
22	CASH	UL	500.00	--	None	500.00	-6.51
23	ELMEQ	LL	.65	--	.65	None	30.58
24	EMCLEQ	BS	1.72	-.26	1.46	None	--
25	ESPEQ	BS	.27	-.22	.05	None	--
26	LMCLEQ	LL	1.46	--	1.46	None	429.26
27	RICEEQ	LL	.03	--	.03	None	287.00
28	LMLSEQ	BS	.71	-.18	.53	None	--
29	LSPEQ	BS	1.50	-1.41	.09	None	--
30	OCEQ	EQ	.55	--	.55	.55	-45.00
31	COTTEQ	BS	5.62	-4.62	1.00	None	--

Table B2. Range Analysis: Rows at Limit Level, Modernising Farm, Kwimba District

Number	Row	At	Slack		Lower Limit		Upper Activity		Unit Cost	Upper Cost		Limiting Process	At
			Activity	Activity	Upper	Lower	Upper	Lower		Lower	Cost		
6	LABNOV	UL	55.00	--	None	55.00	48.48	57.67	-3.50			EMCLEQ LABMAY	LL UL
7	LABDEC	UL	55.00	--	None	55.00	47.80	154.09	-4.61			ESPEQ LAND	LL UL
8	LABJAN	UL	60.00	--	None	60.00	45.88	89.70	-12.00			LSPEQ LABMAR	LL UL
9	LABFEB	UL	60.00	--	None	60.00	55.80	81.47	-.42			IMLSEQ HILSEP	LL LL
13	LABJUN	UL	50.00	--	None	50.00	47.03	52.05	-33.78			HILSEP LABMAY	LL UL
16	LABSEP	UL	40.00	--	None	40.00	-39.25	40.83	-33.78			HILJUN HILSEP	LL LL
22	CASH	UL	500.00	--	None	500.00	486.61	509.21	-6.51			HILSEP LABMAY	LL UL
23	ELMEQ	LL	.65	--	.65	None	.32	1.17	30.58			HILSEP EMCLEQ	LL LL
26	LMCLEQ	LL	1.46	--	1.46	None	1.22	1.81	429.26			LABMAY HILSEP	UL LL
27	RICEEQ	LL	.03	--	.03	None	--	.19	287.00			RICE HILSEP	LL LL
30	OCEQ	EQ	.55	--	.55	.55	--	6.05	-45.00			OC LABAPR	LL UL

Table B3. Range Analysis, Columns at Intermediate Level, Kwimba District

Number	Column	At	Activity	Input Cost	Lower Limit		Upper Limit	Lower Activity	Unit Cost	Upper Cost		Limiting Process	At
					Upper	Lower				Lower	Upper		
32	ELM	BS	.65	149.00	--	.65	--	-Infinity	-Infinity	-Infinity	None	None	LL
					None	1.17		-30.58		179.58	ELMEQ		
33	EMCL	BS	1.72	193.00	--	1.46	--	-62.02	-62.02	130.98	ELMEQ	LL	LL
					None	1.90		-476.00	-476.00	669.00	HILNOV	LL	LL
34	ESP	BS	.27	150.00	--	.05	--	-150.00	-150.00	--	LABDEC	UL	UL
					None	.35		-284.73	-284.73	434.73	LABNOV	UL	UL
35	LMCL	BS	1.46	150.00	--	1.46	--	-Infinity	-Infinity	-Infinity	None	None	LL
					None	1.81		-429.26	-429.26	579.26	LMCLEQ		
36	RICE	BS	.03	350.00	--	.03	--	-Infinity	-Infinity	-Infinity	None	None	LL
					None	.19		-287.00	-287.00	637.00	RICEEQ		
37	LMLS	BS	.71	123.00	--	.53	--	-10.00	-10.00	113.03	LABFEB	UL	UL
					None	.88		-472.93	-472.93	596.00	HILFEB	LL	LL
38	LSP	BS	1.50	120.00	--	.09	--	-120.00	-120.00	--	LABJAN	UL	UL
					None	1.96		-101.57	-101.57	221.57	HILJAN	LL	LL
39	OC	BS	.55	45.00	--	.55	--	-Infinity	-Infinity	-Infinity	None	None	
					None	.55		-Infinity	-Infinity				
40	COTT	BS	5.62	1062.00	--	5.58	--	-380.44	-380.44	682.06	ELMEQ	LL	LL
					None	5.64		-96.80	-96.80	1159.30	LABFEB	UL	UL
49	HILJUN	BS	23.06	4.50	--	22.65	--	-4.30	-4.30	-8.80	LABFEB	UL	UL
					None	25.17		-22.07	-22.07	17.57	RICEEQ	LL	LL
52	HILSEP	BS	.65	4.50	--	12.24	--	-71.53	-71.53	-76.03	RICEEQ	LL	LL
					None	.78		-13.95	-13.95	9.45	LABFEB	UL	UL

VITA

The author, Robert B. Mabele, was born in Nassa, Mwanza Region, Tanzania, on April 18, 1941. After completing his secondary education he entered Morogororo Teachers' Training College where he obtained a Teacher's Certificate.

In 1967 he entered the University of East Africa at University College, Dar-es-Salaam, to study Education, Linguistics (with French) and Economics after teaching elementary school for several years. He obtained a Bachelor of Arts degree in 1970 and joined the staff of the Institute of Adult Education, University College, Dar-es-Salaam (now the University of Dar-es-Salaam) as an Assistant Resident Tutor.

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