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MICRO-ECONOMIC EFFECTS OF TECHNOLOGICAL CHANGE ON SMALLHOLDER AGRICULTURE IN NORTHERN NIGERIA: A LINEAR PROGRAMMING ANALYSIS

presented by

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has been accepted towards fulfillment of the requirements for

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Warren H. Vincent

Major professor

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MICRO-ECONOMIC EFFECTS OF TECHNOLOGICAL CHANGE ON SMALLHOLDER AGRICULTURE IN NORTHERN NIGERIA: A LINEAR PROGRAMMING ANALYSIS

By

Enefiok George Etuk

A DISSERTATION

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ABSTRACT

MICRO-ECONOMIC EFFECTS OF
TECHNOLOGICAL CHANGE ON
SMALLHOLDER AGRICULTURE
IN NORTHERN NIGERIA:
A LINEAR PROGRAMMING ANALYSIS

By

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The primary purpose of this study was to analyze empirically the changes in farm income, enterprise combination, resource use and productivity, and in the elasticities of supply for selected crops that may be associated with the adoption of a new technology (embodied in the use of modern inputs) on a small farm in Northern Nigeria.

Using farm survey data obtained from the Zaria area of Kaduna state, optimum farm plans were generated for a representative small farm with traditional and new technologies. A comparative analysis of these optimum farm plans was used to obtain indications of the direct change in farm income, farm resource use and productivity and in the cropping pattern that could result from the interpolation of the elements of the new technology into the existing farming system. A static linear programming model, formulated to maximize total gross margins subject to

meeting the minimum grain consumption requirements of the farming household, was used as the computational tool in the farm planning exercises.

The results of the analysis showed that the introduction of the new technology would induce significant increases in farm income, resource use and productivity as well as substantial reallocations of the land resource among crop enterprises. Most of the crop enterprises included in the model were in a better competitive position when produced with modern inputs in the rates assumed in the study.

The amount of labor available for work on the farm in peak months was found to be a critically limiting factor in agricultural production with the new technology. The introduction of credit opportunities to permit the availability of operating capital for the hiring of additional labor during the peak months, and/or an increase in the number of manhours devoted to farming by household members, substantially improved the potential for achieving increases in farm income, output, resource use and productivity with the new technology. Since the health and nutrition of small farmers are important factors in determining the amount of work that they can undertake on the farm, it was suggested that programs designed to improve the health and nutrition of these farmers should be made an integral part of agricultural development efforts. Given high and increasing wage rates, the absence of a landless class of laborers, and the problems that have frequently frustrated the administration of credit programs in developing countries (problems such as low repayment rates and the diversion of credit funds for non-farming purposes), it was also suggested that the provision of credit should be considered a short-term solution. The introduction of measures (such as the selective mechanization of farm operations) that significantly improve the efficiency of labor utilization during peak periods was suggested as a long-term solution to the labor bottleneck problem.

With the assumptions made in the study, the optimum level of fertilizer use was found to be relatively insensitive to changes in the prices of chemical fertilizers. The removal of the subsidy on chemical fertilizers did not affect the optimum amounts of fertilizer used.

Parametric programming was used to generate normative supply functions for groundnut and tomatoes (the two most important cash crops in the study area) under traditional and new technologies. These step supply functions were transformed into smooth, continuous functions by means of regression analysis and price elasticities of supply were calculated for the two crops. The elasticity coefficients (which indicate percentage changes in output) were converted into absolute changes in the output of the crops in response to a one percent change in their prices. The results indicated that the introduction of the new technology would increase the supply of groundnut and tomatoes but would reduce their price elasticities of supply within the price range used in the analysis. However, absolute changes in the output of tomatoes in response to a one percent change in its price increased with the introduction of the new technology. Thus the adoption of the new technology would enhance the effectiveness of price increases in inducing absolute increases in the output of tomatoes. This was also found to be true for groundnut, but only when credit was made available with the new technology.

Dedicated to my parents Nette and George Etukudo

for all the sacrifices they have made

for my education in Nigeria and the United States

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CHAPTER I

INTRODUCTION

1.1 The Problem and Its Setting

Before the mid-1960's the agricultural sector was dominant in the Nigerian economy. It provided employment for over seventy percent of the labor force, contributed more than half of the gross Domestic Product, accounted for over eighty percent of all foreign exchange earnings and was a major source of public revenues as well as capital for investment in other sectors (IBRD, 1974:77). In addition, agriculture supplied an overwhelming proportion of the country's food requirements. In 1963, for example, food imports constituted less than 3.8 percent of the domestic agricultural produce and consisted mostly of luxury consumption goods (Wells, 1974).

The performance of the agricultural sector has been deteriorating during the last decade. Between 1966 and 1972, the annual rate of growth of the agricultural sector was 1.5 percent which was lower than the population growth rate of 2.5 percent per annum, and less than those of other sectors such as manufacturing, construction and minerals (Falusi, 1973:2). Food production has not responded adequately to increases in the demand for food. As a result, there have been sharp and frequent rises in food prices.

Robinson (1974:6) has reported that ". . . between 1968 and 1973 wholesale prices of the major food crops (except rice) more than doubled." This situation has necessitated the diversion of scarce foreign exchange to the importation of basic staples which had previously been produced locally and in sufficient quantities to satisfy domestic needs. Nigeria's expenditure on food imports increased from fifty million Naira in 1970 to four hundred million Naira in 1976 (Abdullahi, 1977:1). There are indications that the magnitude of food deficits may increase if the present trend remains unchecked (F.M.A.N.R., 1974). The production of raw materials has also not kept pace with increases in the needs of expanding local industries. For example, Nigeria was a cotton exporter for many years but now she has to import cotton to meet the needs of domestic textile industries because domestic cotton output is sometimes inadequate (Hunter, et al., 1976:33).

A significant constraint on the development of agriculture is the low level of farm investment (Ogunfowora, 1972:74). The result is that land and labor continue to be the main inputs in agricultural production in Nigeria. The use of purchased inputs such as fertilizers, pesticides and herbicides is extremely low. In 1970-71, for example, only 13,000 tons of plant nutrients were used on all crops in all states in the country (Robinson, 1974:1). The average national level of fertilizer consumption is 1.28 Kg per cropped hectare. This is well below the recommended average of 18.18 Kg per hectare (Federal Republic of Nigeria, 1975:63).

The tools used in farming are mostly hoes and cutlasses. Conditions related to climate such as the tse tse fly and the shortage of fodder restrict the use of ox-drawn implements. Power equipment and large agricultural machinery such as farm tractors are virtually absent (IBRD, 1974:78). This low level of agricultural production technology has been cited as one of the causes of the poor performance of the agricultural sector (Falusi, 1973:2). Other factors that may have contributed to the unsatisfactory situation in the agricultural sector include the decrease in the available labor force in the rural areas resulting from rural to urban migration, the shortage of trained agricultural personnel, pest outbreak, poor storage and unorganized marketing systems, and unfavorable weather conditions (AERLS, 1978:1).

The future role of the agricultural sector in Nigeria's economic development is clearly specified in the Third National Development Plan, 1975-80. Not only is most of the population to continue to derive their living from agriculture, but most of the increases in the labor force may have to be absorbed in the agricultural sector since the elasticity of employment with respect to output in the industrial sector is relatively low. In addition, the sector is expected to meet the demand for better staple food which is growing at the rate of 5 percent per annum.

It is also expected to supply sufficient raw materials for expanding local industries, contribute to foreign exchange earnings through increases in exports as well as provide a major market for industrial sector products. The capacity of the agricultural sector to perform these functions may be seriously handicapped by the low level of agricultural production technology. This raises the need for the introduction of new technologies designed to increase the output and income of smallholders through improvements in productivity.

Hopper (1975:10) has identified four types of opportunities for the development of traditional agriculture.[1] These are:

a) an extension of the area of land under cultivation,

b) a reorganization of traditional inputs in an effort to improve efficiency in production,

c) the utilization of more inputs under indigenous technological conditions, e.g., "a larger application of labor and capital to make land improvements such as an extension of irrigation, land terracing and shaping for better water control",

d) ". . . the use of new inputs singly or in combination with traditional production factors in a new technical relationship", i.e., the introduction of a new technology.

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[1] Agricultural development could involve some combination of two or more of these approaches. (Norman, 1974:24).

Increases in the area of land under cultivation has been the major means to higher output and income for Nigerian farmers (Helleiner, 1966; Buntjer, 1973). However, it is likely that increases in acreage may not be an important source of output growth in the future. In some parts of Nigeria, e.g. Kano state, high population densities have brought about scarcity of land. In other areas, increased use of land, under conditions of increasing population pressure, could "upset the arable/fallow balance" and "accelerate the fertility loss in [a] traditional system [that is] characteristically dependent on an arable/fallow sequence to maintain yields per acre" (Collinson, 1972:63).

A number of studies have shown that allocative efficiency is high in traditional agriculture (Tax, 1953; Hopper, 1965; Norman, 1970; Helleiner, 1973; etc.). As a result, Schultz (1964:39) concluded that no appreciable increase in agricultural production could be achieved by reallocating the factors at the disposal of subsistence farmers that are bound by traditional agriculture.[2]

Limited potential also exists for the development of agriculture through the utilization of more inputs under traditional technology. As Hopper (1974:11) has indicated, "the marginal increment to production of additions to either land area, or to traditional forms of capital and labor on

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[2] Some economists argue to the contrary. See Lipton (1968, pp. 327-351).

old lands, will be small. This is partly because of the low productivity per worker and per unit soil area inherent in older technologies, and partly because of diminishing returns to the inputs added to those already used in present production process."

A number of agricultural economists believe that the greatest opportunity for the development of traditional agriculture seems to be in the introduction of improved technology.[3] Johnston and Mellor (1969:362) think that ". . . the most practical and economical approach to achieving sizeable increases in agricultural productivity and output lies in enhancing the efficiency of the existing agricultural economy through the introduction of modern technology." Hopper (1975:6) has noted that "the development problem for most of the world's nations is how best to accomplish a transformation from a stage where a national economic product is derived primarily from the practice of traditional agrarianism to the stage where output is generated from the use of modern science-based technologies." Norman (1974:20) observed that future increases in agricultural production in Northern Nigeria, particularly in the densely populated areas, could only be achieved through substantial increases in land productivity which would

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[3]Technological change is usually defined in relation to changes in the production function. Such changes may come about either through the use of new factors of production or through the adoption of new ways to use previously known factors (Johnson, 1964). Nicholson (1972) refers to the use of new factors as embodied technical change.

require new technology. Considerable support for technological change in traditional agriculture has also been provided by the experiences of Japan, Taiwan and countries in North America and Western Europe that have been successful in increasing agricultural output and productivity (Johnston, 1960). According to Mellor (1973:4) it is the interaction of the rising demand for food and diminishing returns in traditional agriculture that gives new technology such a prominent role in the development of traditional agriculture.

There is a choice of strategy in the improvement of technology in traditional agriculture. The strategy decision is whether to encourage technological improvements that raise yields within the existing small farm structure or to encourage the development of large mechanized farms (F.A.O., 1969:65). Collinson (1972:75) has characterized the former strategy as "improvement" while the latter approach is described as "transformation". The transformation approach involves structural change whereas improvement involves "intensification" which is usually associated with better seed, improved cultural practices and the use of purchased inputs, particularly fertilizers and insecticides.

For most of the colonial period in Nigeria, the emphasis was on improvement. During the 1960's there was a switch to transformation. This took the form of large settlement schemes. These schemes failed.[4] The governments of Nigeria now believe that the introduction of simple technologies in the form of improved seeds, seed dressing, fertilizers and improved cultural practices is one of the quickest ways of improving agricultural production technology and raising the productivity of agricultural resources (Etuk, 1977). The rationale for this belief is probably based on the experiences of the green revolution countries in Asia.[5] Besides it has been indicated that this type of technology could lead to the growth of employment opportunities in agriculture (Johnston and Cownie, 1969).

There are some problems associated with the large scale introduction of the green revolution technology among peasant farmers in developing countries. Some of the conditions required for the successful application of the technology, such as the availability and correct use of physical inputs, well prepared fields, adequate protection from pests and weeds and easy access to technical advice are still beyond the scope of the peasant farmer (Pearse, 1977:135). These "expensively-created" conditions are mostly found on research stations (where the new technology

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[4]See Kreinin (1963), Chambers (1969); Basu, Adegboye and Olatunbosun (1969) for some of the reasons for the failure of the schemes.

[5]This kind of technology formed the basis of the green revolution in India and Latin America. In September 1971, the Federal Military Government sent a team of leading Nigerian agriculturalists to visit seven "green revolution countries to study how these countries have solved their food production problems." (AERLS, 1978:2).

originated) and are probably responsible for the spectacular results obtained from the use of the technology on these stations. The use of the technology on peasant farms is often characterized by the application of inadequate amounts of fertilizer and untimely or delayed use of both fertilizers and pesticides because of poorly organized and overloaded delivery systems or local scarcity resulting in the black marketing of supplies. It has also been noted that change from the traditional to the new technology involves a movement away from an agriculture "whose know-how is passed down by older cultivators and whose inputs are products of local farms and villages" towards one in which the know-how emanates from "scientific centers" and the inputs are obtained from industry (Pearse, 1977:137). As Ishikawa (1970) had observed, such a shift may not be easily achieved.

The rapid spread of the green revolution technology in Asian countries was the result of organized programs designed to facilitate and promote the correct use of the elements of the technology. The main components of these programs included (Pearse, 1977:130):

a) a technological package[6] designed to fit the ecological conditions of the regions in which it is to be applied,

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[6] A technological package is defined here as a set of complementary inputs whose proportions have been predetermined scientifically.

b) arrangements for the communication of the knowledge of the technology to farmers,

c) measures to ensure the availability of physical inputs like improved seeds, fertilizers and pesticides,

d) measures to "favor the prospect of profitable sale sufficiently attractive to compensate for the greatly increased production costs and risks involved",

e) a credit system to facilitate the payment for physical inputs and the financing of additional cultivation expenses such as the hiring of labor.

In Nigeria, a variety of measures aimed at promoting improvement in the technology of agricultural production through the introduction and expansion in the use of fertilizers and other modern inputs have been initiated. A subsidy scheme has been established to encourage the use of chemical fertilizers which is the main improved technological input (Norman, 1974:29). The rate of fertilizer subsidy in Nigeria in the period 1968-69 to 1971-72 was about 50 percent of the state store price (F.A.O., 1974). This was increased to about 75 percent in 1976. In the Third National Development Plan 1975-80, the Federal Government is to supply over 1½ million metric tons of fertilizer to the states at a capital cost of over seventy million Naira. An agricultural bank has also been established to provide farmers with the capital needed for the purchase of the new farm inputs. The Bank has been provided with 150 million Naira in the present plan period to supply credit to farmers. A National Accelerated Food Production Programme (NAFPP) and an "Operation Feed the Nation" (OFN) program have been launched to boost food production through increased use of modern inputs on food crops.

The use of these inputs could significantly alter the relative resource requirements of crop enterprises as well as their relative net revenues. Such changes in the technical and economic circumstances within which peasant farmers make their decisions about resource allocation could substantially affect the pattern of allocation of farm resources. This could have pronounced effects on cropping patterns, farm income, employment and on the productivities of farm resources (Dalrymple, 1969:43). Gotsch and Falcon (1975) have reported that about 20 percent increase in cropped acreage, about 70 percent increase in farm income and substantial reallocation of land resources among crops were associated with the introduction of the green revolution technology on a representative farm in the Pakistan Punjab. In Northern Nigeria, Ogunfowora (1972) has predicted that sole crops are in a better "competitive position" than crop mixtures under improved technological conditions. The results of the same study has also indicated that the introduction of improved technology could result in a higher return per unit of capital. Other studies (Falusi, 1973; Norman, 1976a, b, c; Spencer and Byerlee, 1976) have shown that changes in labor requirements as well as in returns to labor are associated with technological change in smallholder agriculture. Data from the ex post experience of the green revolution countries of Asia have also indicated that the technology has important farm level implications.

More attempts to predict the likely effects of new technology are needed to provide an adequate basis for the assessment of the technology. Zalla et al. (1977:24) have drawn attention to the discrepancies that exist among the results of previous studies. Additional studies could shed more light on such discrepancies and enhance our understanding of the farm level economic effects of technological change. The effects of new technology tend to be location-specific in nature due to differences in the cropping options open to farmers (Gotsch, 1971:9; Collier, 1977:351). The implication is that generalizations of the results of a few studies over wide geographical areas may not be valid. This means that analysis of the consequences of changes in the technology of agricultural production are required in more areas in order to broaden the scope of knowledge concerning the role of new technology in traditional agriculture.

The need for micro studies of the economic implications of new agricultural production technology is particularly acute in Northern Nigeria. Although the use of modern inputs in the area has increased significantly in the last few years, relatively few attempts have been made to collect input-output data on the new technology and to determine the probable effects of the adoption of this technology on the production activities of the small farm. The result is that there is a dearth of basic input-output data on the use of modern inputs under farmers' conditions in Northern Nigeria. There is also paucity of relevant quantitative information on the changes in key farm variables such as income, crop mix and resource productivity that are likely to be associated with the use of these inputs on the small farm. The lack of such micro information could widen the gap between the production unit, particularly smallholders, and policy makers and planners. Upton (1973:268) has observed that the rate of agricultural development depends on the extent to which the changes in the pattern of production on the individual farm units that make up the agricultural sector contribute to the desired development objectives. Since the ultimate objective of government is to raise farm income and resource productivity, policy makers and planners can only anticipate and evaluate fully the effects of current agricultural development policies and strategies if they understand the improvements in resource productivity and the income of the small farm that are likely to be generated by the use of modern inputs. The analysis of the potential effects of the new technology on the optimum pattern of resource allocation could also provide extension workers with "advisory content" as well as with "an understanding of the reorganizational difficulties the farmer is likely to meet." These difficulties could then be discussed with the farmer in order to "alleviate much of the uncertainty felt by the farmer about both the demand the change will make on him and on the know-how of the extension worker" (Collinson, 1972:93).

The decline in the production of major crops such as groundnuts has often been attributed to the comparatively low prices offered to producers of such crops by the marketing agencies. Given that farmers are rational and tend to respond positively to increases in commodity prices, policy makers have sometimes been called upon to raise producer prices in order to increase output. Price increases ranging from 10 to 150 percent have recently been set for major commodities (New Nigerian, April 1, 1975). Decisions on the appropriate increases in prices require a good knowledge of the price elasticity of supply. It is likely that the adoption of a new technology could have a significant effect on the responsiveness of farmers to price incentives. For example, Gotsch and Falcon (1975:35) found that new technology "exerted a profound influence on both the optimal level of output at current prices (shifts in the supply curve) and the elasticity of farmers price responses." This implies that supply elasticities calculated prior to the introduction of the new technology could be misleading and that an understanding of the effect of the new technology on the price elasticity of supply would be a prerequisite for informed price policy making.

1.2 Objectives

The primary aim of this study is to analyze empirically the likely farm-level effects of the use of modern inputs[7] by small farmers in Northern Nigeria. The specific objectives are:

1. To obtain basic input-output data for selected crop enterprises from small farmers who have adopted the new technology.
2. To ascertain the changes in the cropping pattern, farm labor use, farm income and in the productivities of farm resources that are likely to be associated with the use of modern inputs on a small farm in Northern Nigeria.
3. To examine the potential effect of the new technology on the price elasticity of supply for selected crops.
4. To derive from the results of the study some implications for agricultural development policies and strategies.

1.3 The Research Approach

Previous attempts to predict the farm-level economic effects of technological change on smallholder agriculture in Northern Nigeria have been limited to partial budgeting of single crop enterprises or to whole-farm planning

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[7]The new technology examined in this study is embodied in the use of these inputs. The level of application of the new technology is that found in the study area in the survey year.

exercises in which the data on the new technology have been obtained from research station experiments or demonstration plot trials (Norman, 1976a, b, c; Ogunfowora, 1972). As a result, the information obtained from these efforts have been inadequate as a basis for the evaluation of the new technology. The subsistence objectives of the smallholder necessitate diversification, so that farmers are interested not just in a single crop enterprise but in the farm business as a whole (Olayide et al., 1972; Blagburn, 1961). Upton (1973:197) has noted the dangers of not studying the whole farm in situations where more than one crop is of major economic importance. Not only are important supplementary, complementary and competitive relationships among crop enterprises ignored, but it is also difficult to assess the opportunity cost of resources used. The use of research station and demonstration plot data overlooks the marked differences between the conditions at these stations and those within which farmers operate as well as the ability of farmers to adapt the new technology to their own circumstances. Research stations are usually located in the best agricultural areas of the ecological zone in which they are situated, and there is often "considerable control of farmer compliance and limitation on his freedom of adaptation" in demonstration trials on farmers' fields (Palmer-Jones, 1978).

The objectives of this study are achieved by means of a whole-farm planning approach based on farm survey data obtained from Giwa District in the Zaria area of Northern Nigeria. In addition to having a relatively large body of base data on agriculture, significant amounts of modern inputs have recently been distributed in the area.

1.3.1 The Analytical Framework

A linear programming model of the "representative farm" in the study area is used to obtain the optimum farm plan under traditional technology and resource constraints. Activities, constraints, production coefficients and net prices reflecting the use of modern inputs under farmers' conditions are introduced into the model which is then solved to give the optimum farm plan under the new technology. A comparative analysis of these farm plans is used to obtain indications of the direct change in farm income, farm resource productivity and cropping pattern that could result from the interpolation of the elements of the new technology into the existing farming system.

Static, normative supply curves for the production of major crops under both technologies are derived by means of parametric programming. Estimates of the price elasticities of these supply curves are derived from statistical analysis and are compared to obtain indications of the likely effect of new technology on the responsiveness of crop production to changes in product prices.

The use of linear programming as the computational tool in the farm planning exercises is based on the premise that "peasant farmers tend to behave in ways which optimize their objectives given the constraints within which they operate". Low (1974:64) has cited a number of studies of African farmers which support this premise. The technique was first used in the analysis of smallholder production decisions in African agriculture in the late 1950's. Since then, the number of applications of the linear programming approach to African agriculture has increased tremendously.[8]

Mudahar (1974:2) has indicated that the main advantage of the programming approach is that it "allows for several farm commodities as farm activities, seasonal labor and land constraints, more than one production technique, land-labor-capital substitution, and a choice among several farm activities which are subject to different economic, resource and behavioral constraints." Thus linear programming can be used to provide a more adequate analytical description of whole-farm situations than other commonly used calculation techniques of farm planning.

Another important advantage of the linear programming method is that it allows the determination of certain important economic measures of the optimal plan (Hardaker, 1971:64). For example, it is possible to say how stable the optimal plan is, measured in terms of the change in the net revenue of each enterprise needed to bring about a change in the levels of the activities in the optimal

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[8]See Mwangi (1978:58-60); and Ruigu (1978:117-118) for a brief but good review of some of the applications of the linear programming approach to African agriculture.

solution. Similarly, the productivity of the farm resources can be assessed and the importance of the various planning constraints evaluated.

While the linear programming technique provides a versatile tool for planning, it has several limitations. Many of its assumptions are unrealistic. For example, it is often assumed that farmers have no enterprise preferences, they have perfect knowledge of their alternatives and risk and uncertainty do not enter the choice criteria. Upton (1974) has provided an excellent discussion of some of the methodological problems that constitute the most important limitations to the application of linear programming to peasant agriculture. However, the advantages of the technique outweigh these methodological limitations.

1.3.2 Sources of Data

In order to develop farm plans by linear programming, data are typically needed on the production alternatives on the farm, the technical coefficients of production, prices of inputs and outputs, and the resources that are available or can be made available on the farm. These data are obtained from either primary or secondary sources. In deciding on the sources of data to use, it is important to consider both the relevance and the reliability of the information obtained. The use of secondary sources has the advantage of cheapness and the relative speed with which the data can be assembled; but the data so obtained may not provide reliable estimates of the corresponding parameters of the population in question. One of the problems faced by social science researchers in most developing countries is the lack of reliable data from secondary sources. Official sources may not have the data that are needed or the available data may be very inaccurate. This has made the collection of primary data from the field a common need in the execution of social science research in these countries.

The data that are used for the empirical analysis in this study were obtained from both secondary and primary sources. Given the resources available for the study, it was not possible to collect primary data from farmers who had not adopted the new technology. It was hoped that the baseline study conducted at the start of the Guided Change Project (GCP) in 1974 would provide adequate input-output data on the traditional technology. However, data from the baseline study were later found to be incomplete and could therefore not be used. The best available input-output data on traditional technology was obtained from the report of a farm management study conducted in the area in 1966-67 (Norman, 1972). In that study, 124 randomly selected farm families from three villages were interviewed twice weekly throughout the survey year. Thirty-eight of the farmers in the sample were drawn from Hanwa, a village which is only about one kilometer from the one that was surveyed for data on the new technology. The average farm family in Hanwa consisted of seven persons, of which two were male adults. The average size of holding was 2.94 hectares. The average cultivated area was 2.87 hectares fragmented into about seven fields. Table A-1 in Appendix A shows the average hectares that were devoted to different crop enterprises.

About 2,381 manhours of labor, consisting of 2,069 manhours of family labor and 312 manhours of hired labor, were used on the average farm. Since there have not been any major changes in the structure of agricultural production, it is assumed that the data from that study adequately describe the characteristics of traditional technology as presently used on small farms in the area.

A survey of two local markets conducted by Theo DeWit provided data on output prices. The major source of data for determining the production alternatives open to the farmers, the resources available, prices of inputs and input-output coefficients of production with the new technology was a farm survey conducted by the author under the auspices of the Guided Change Project (GCP) of the Department of Agricultural Economics and Rural Sociology, Ahmadu Bello University. This survey covered the period from March 1977 to February 1978. The purpose of the survey was to obtain input-output data that reflect the use of modern inputs under farmers' conditions in the study area.

The heterogeneity of Giwa district in terms of natural conditions, kinds of cash crops grown, urban influence, market opportunities and methods of production led to the use of a two-stage sampling procedure for the selection of respondents.

The first stage consisted of a classification of villages in the district into "homogeneous" farming areas on the basis of the major cash crops grown, distance from Zaria and the levels of modern input use. Three types of farming areas were identified for the district. One of these areas (Area I) lies behind the Kufena Rock to the south of Wusasa. It is about two to four kilometers from Zaria. Groundnuts and vegetables (tomatoes, peppers and okra) are the important cash crops in this area, which has also been reported to have the highest rates of application of modern inputs (DeWit, 1978).

Another farming area (Area II) is situated near Shika, about eight to ten kilometers from Zaria. Root crops (mostly yams and potatoes) are the main cash crops. The third farming area (Area III) consists of villages located about twenty to thirty kilometers southwest of Zaria. The most commonly grown cash crop in this area is rice which is cultivated on "marshland". Cotton is also widely grown in the area. The lowest levels of modern input use have been recorded on fields in this area. Access to this area from Samaru is extremely difficult during the wet season. Cochrane (1963:38) and Collinson (1972:96) have indicated that the division of a heterogeneous population into internally "homogeneous" subpopulations could facilitate data collection procedures by removing natural conditions, urban influence, market opportunities and methods of production as sources of [interfarm] variations.

Given the resources available for the study, only Area I was purposively selected for further investigation. Among the villages in this area, Pan Hauya was chosen for the survey for logistical reasons. This village was assumed to be typical of other villages in the selected area in important attributes influencing the pattern of production.

In the second stage, 80 households were randomly selected from a list of 300 households in the village. From this sample, a subsample of 50 households, including only those that were certain to obtain modern inputs during the 1977-78 cropping season, was drawn for the survey.

The cost route or multiple visit method was used to collect information from the farmers. The researcher and two experienced enumerators from the Guided Change Project interviewed the respondents once a week throughout the cropping season. A number of factors were responsible for the choice of the cost route method. Firstly, most of the farmers interviewed are illiterate, keep no records and had to rely on their memory for the required information. Secondly, the length of memory recall is limited. Thirdly, the information required included "continuous", "nonregistered" data such as daily family and hired labor inputs.

Data were collected on inputs, outputs, production practices, and expenses for each field farmed by each household in the subsample. Information on "gandu" fields was supplied by the gandu head, while "gayauna" operators answered questions concerning gayauna fields.[9]

The problems encountered during the survey are similar to those dicussed by Spencer (1972), Norman (1973), Collinson (1974), Kearl (1976), Ejiga (1977), and Palmer-Jones (1977).

1.3.3 Some Limitations of the Research Design

The design of a study is concerned with the blueprint or scheme for the collection, measurement and analysis of data. It is an important aspect of a study because it affects the validity of the inferences that can be drawn from the results of the study. Ideally, the appropriate research design is determined by the objectives of the study. In practice, however, the design of a study frequently is a compromise dictated by the limitations of the resources available for the study and the availability of data.

The ideal research design for achieving the objectives of the present study would have been the controlled experimental design. Such a design (also known as the "Pretest-Posttest Control Group Design") would have involved

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[9] "Gandu" fields are those farmed by the entire household under the supervision of the head of the household. Fields controlled by household members other than the family head are known as "gayauna" fields.

the collection of data from two equivalent groups of farmers before and after the introduction of the new technology to one of the two groups of farmers (Stouffer, 1950; Campbell and Stanley, 1966:13). Given the natural social setting in which this study was conducted and the resources available for the study, the use of the experimental design was not feasible. Therefore a "quasi-experimental" design involving the use of data from separate samples of farmers in different years was adopted. In this design [described by Campbell and Stanley (1966:53) as the "Separate-Sample Pretest-Posttest Design"] data were collected from one sample before the introduction of the new technology and from another sample after the introduction of the new technology.

Both Stouffer (1950) and Campbell and Stanley (1966:34) have encouraged the use of "quasi-experimental designs" in situations where the controlled experimental design is not feasible. They have also stressed that in such situations it is important to be aware of the limitations or imperfections in the adopted design so as to avoid "overinterpretations" of the results of the study. The purpose of this section is to point out the main threat to the validity of the inferences drawn in this study.

The use of data from different groups of farmers in different years may not provide a firm basis for making inferences about the effect of the new technology, since such a research design does not provide any way of eliminating or discovering the effects of other factors such as differences in management, weather, labor productivity and the physical characteristics of the area. There is always the disturbing possibility that the populations of the two samples were initially different and that the observed effects are the result of these other factors rather than technological adoption. Thus the major limitation of the "quasi-experimental" design adopted in this study is that some of the uncontrolled factors may constitute plausible rival explanations of the observed differences between the two sets of farmers. Seltiz et al. (1959:93) have pointed out that in the social sciences, where there is little knowledge of what factors need to be controlled, and where many of the relevant factors are difficult or impossible to control, there is no way to be completely certain of the validity of inferences that may be drawn. This possibility of invalid inference makes it necessary to evaluate research findings in the context of other knowledge. They argue that "the establishment of confidence in the imputation of any causal relationship between events requires repetition of research and the relating of the findings to other research". In this study, inferences are made on the assumption that the circumstances of the two groups of farmers are comparable and that the effects of factors other than technological change are relatively minor.

1.3.4 Construction of the Representative Farm

The prohibitively high cost of programming every farm unit has led to the use of the representative farm [or more accurately, the representative resource situation (Plaxico and Tweeten, 1963:1458)] as the unit of linear programming analysis. Barnard and Nix (1976:363) have indicated that "in areas where there is reasonable homogeneity in at least some of the major resources -- particularly with respect to natural factors, such as soil type, topography and climate -- linear programming can be used to obtain solutions to 'model' or 'representative' farm situations in order to guide planning on individual farms".[10] The usefulness of the representative farm approach is limited by the manner in which the representative farm is constructed. Collinson (1972:125) has discussed three alternative techniques for deriving representative farms. These are:

a) the identification of a particular farm as the typical farm,

b) the use of an "average farm" (derived from the means of resources, input-output and net price coefficients of a sample of farms) as the representative farm,

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[10] Even in these areas, individual farms are likely to display considerable variation around a particular representative situation (when account is taken of both quantitative and qualitative aspects of farm resources). Thus solutions covering a whole range of situations may be required if differences in factors such as farm size and the number of workers are to be accommodated.

c) the synthesis of a "hypothetical" or composite farm from different components of the population.

The identification of a typical farm unit requires consideration of a wide range of relevant criteria. Not only is the selection of these criteria difficult, but also data on them may be unavailable or difficult to collect. Besides, even when the data are available, it is not easy to find a single farm that could validly be considered typical in all respects.

An important limitation to the use of the "average farm" is that it brings with it the problem of aggregation bias (Collinson, 1972:134). This has been demonstrated by Frick and Andrews (1965), Day (1963), Hartley (1962), and Buckwell and Hazel (1972). While the synthesis of a composite farm reduces the aggregation bias, it involves the stratification of the population on the basis of characteristics of farms and farmers which strongly influence the particular decision under study. Farm economics research has shown that nonphysical variables such as institutional restrictions, motivations, preferences, managerial ability, etc., have a profound impact on farm organization, production efficiency and earnings, and deserve being built into stratification schemes (Plaxico and Tweeten, 1962:1463). One practical weakness of the synthesis procedure is that it is difficult to quantify several of these institutional and human factors and even more difficult to determine their distribution within a population. As Carter (1963:1454) has pointed out, their quantification is necessary to provide a basis for stratification in sampling.

The choice of the method of representative farm construction depends on the purpose for which the results of the study are to be used. If the study is designed to estimate regional or national supply response, which would require that the results for the representative farm be "raised" to give an aggregate estimate, then methods of benchmark farm construction which minimize aggregation bias are needed. However, when the objective, as in this study, is to identify the direction of farm adjustment and estimate the degree of farmer's response to changing prices in a given area, the problems of aggregation bias and their control are not relevant, and the use of the average farm can be justified. Even in the estimation of aggregate supply functions, the benefits of a reduction in aggregation bias, achieved through a rigorous construction of benchmark farms must be balanced against the costs (both in terms of time and money) of reducing aggregation bias (Ogunfowora, 1972:25).

In the present study, the representative farm is based on data obtained from the survey conducted by the author in 1977-78. The farms in the sample were considered to be sufficiently similar with respect to the key variables that affect farm adjustment. The average farm was used as the unit of analysis. Only ten percent of the farms in the sample were more than six hectares in size. These farms were excluded from the derivation of the representative farm in order to reduce the upward bias of the average farm size. Thus, the levels of the initial resources of the representative farm are based on the means of the resources of sample farms that were less than six hectares in size.

Only one representative farm was used for the analysis so as to provide an opportunity for detailed examination of numerous problem situations using parametric techniques. Sharples (1969) has advocated a reduction in the number of representative farms used in supply analysis. He contends that the major economic relationships that researchers have sought to isolate do not differ greatly among representative farms and can be adequately accommodated by parametric programming on fewer representative farms. He also argued that a reduction in the number of representative farms was necessary for timeliness of the results of the study which is vital particularly for short run analysis.

The representative farm approach is used in this study to indicate "average results" for a homogeneous group of farms.[11] No attempt is made to estimate aggregate results. Sharples (1969:359) has stressed the importance of this

[11]Since every farm is unique, it is not possible to eliminate within-group variation entirely (unless each individual farm is treated as a separate group). Therefore, a group is only homogeneous in relation to the whole population (Upton, 1974:120).

type of micro, farm-firm analysis for providing valuable insights that could aid the understanding of short run supply response at the aggregate level. He argues that information on the "Potential economic impact of a change in an instrument variable on a farmer's income and organization must not be ignored just because it cannot be plugged into a neat mathematical aggregation formula."

1.4 Organization of the Study

This chapter was devoted to the definition of the problem and its setting, the statement of the specific objectives of the study and the methodological approach adopted in achieving these objectives. In Chapter II there is a description of the characteristics of farming in the study area as revealed in the analysis of the data obtained in the survey conducted by the author in 1977-78. Chapter III presents the structure of the linear programming models used to represent the planning environment of the representative farm in the study area. Model activities, restrictions, technical coefficients and prices are discussed. In Chapter IV the results of the various applications of the models are reported. The derived effects of the new technology on farm income, cropping patterns and resource use are discussed.

The response of the production of selected crops to changes in their prices is examined in Chapter V. Normative supply curves for the production of the selected crops under traditional and new technologies are presented and the effect of the new technology on estimates of the price elasticity of supply for the crops are discussed. Chapter VI contains the summary, the policy implications of the results of the study, its limitations and some suggestions for future research.

CHAPTER II

CHARACTERISTICS OF AGRICULTURAL PRODUCTION IN THE STUDY AREA

Proper representation of an agricultural situation in a linear programming framework requires a good knowledge of the structure of farming in the area under investigation. This chapter describes some attributes of the farming system in the study area as revealed in the analysis of the data generated in the survey conducted by the author in 1977-78. The description is presented in terms of the characteristics of the representative farm.

2.1 Physical Characteristics of the Study Area

The study area is situated in the Zaria area of Kaduna state which is located in the Northern Guinea Savanna ecological zone. The natural vegetation is savanna woodland. The land is a gently undulating plain at an altitude of 610 to 914 meters. The soils are typically leached ferruginous tropical soils.

There are two distinct seasons -- the dry season and the wet season. The wet season, which usually begins in March or April, can last for about 145 to 185 days. In 1977, the year this study was conducted, the wet season extended from May to October. The annual rainfall was 745.5 mm. Details of the average rainfall distribution in the study area are given in Table 2.1. While the annual rainfall in the study year was higher than that of the drought year of 1973, it was only 67.3 percent of the long term average and considerably lower than those of the three preceding years (1974, 1975, and 1976). The length of the growing season was even shorter than that of the drought year of 1973. Thus 1977 could be considered a "bad" crop year. The implication is that the results of this study would be more typical of a "bad" crop year than either an "average" or "good" crop year.

2.2 Land Use

Farms vary in size from just over one hectare to almost ten hectares. About ninety percent of the farms in the sample were less than six hectares each in size. The size of the representative farm was 2.83 hectares. The farms tended to be fragmented consisting of an average of about six fields. The average size of field was about 0.55 hectares. There are two types of fields -- gandu fields and gayauna fields. Gandu fields are those farmed by the entire household under the supervision of the gandu head. Gayauna fields are controlled by household members other than the family head.

Norman (1973:5) has distinguished between two types of farmland in Northern Nigeria:

a) gona or upland fields which are cultivated only during the wet season with low value, less labor intensive crops such as millet, guinea corn,

TABLE 2.1

RAINFALL DISTRIBUTION BY MONTH IN MM

Month	Year					
	Long Term Average (1928-1969)	1973	1974	1975	1976	1977
January	0.3	0.0	0.0	0.0	0.0	0.0
February	1.5	0.0	0.0	0.0	0.0	0.0
March	7.0	0.0	11.2	0.3	0.0	0.0
April	36.8	17.0	30.0	85.8	86.2	0.0
May	125.2	35.0	33.8	130.1	135.5	78.3
June	165.5	74.0	144.4	135.5	206.9	101.7
July	221.5	91.0	251.9	303.1	226.4	59.0
August	281.5	230.0	328.9	113.4	188.1	302.7
September	230.4	124.0	247.0	212.2	191.0	199.5
October	36.1	24.0	67.6	8.3	162.2	4.3
November	1.3	0.0	0.0	0.0	0.0	0.0
December	0.1	0.0	0.0	0.0	0.0	0.0
Annual	1107.2	595.0	1114.8	988.7	1196.3	745.5
% of Long Term Average	100	53.7	100.7	89.3	108	67.3

SOURCE: Soil Science Section, I.A.R.

cotton and groundnuts; and

b) fadama or lowland fields which are permanently wet and can support high value, labor intensive crops like sugar cane, rice and onions.

Virtually all the farmland in the study area is of the gona or upland type.

2.3 Kinds of Crops and Cropping Pattern

Nineteen different crops were grown in the study area during the survey period. These crops included cereals, legumes, root crops and vegetables. They were grown either as sole stands or as crop mixtures. The practice of growing two or more crops together on the same piece of land and at the same time is referred to as intercropping. Both technical and socioeconomic reasons have been advanced for intercropping (Norman 1973:36). Technical reasons include the mutual benefit derived by the crops in the mixture, soil protection and a reduction in the incidence of disease and pest attack. For example, cowpeas are more susceptible to insect attack when cultivated sole than when cultivated in a mixture. The socioeconomic reasons are the need to maximize returns to the limiting factors, especially land and labor, the need to obtain higher output and the need for security. Intercropping provides a form of crop diversification which is a strategy against risk (Norman, 1973:37).

The 19 crops grown in the study area were grown in a total of 65 crop combinations. These crop combinations and the number of farmers growing each combination are presented in Table B-1, Appendix B. Table 2.2 shows the number of hectares devoted to different crop enterprises on the representative farm in the study area during the survey period. Sole cropping accounted for 32.5 percent of the cultivated hectares while 67.5 percent was planted for different crop mixtures. Millet/guinea corn (ML/GC) mixture accounted for about 32.9 percent of the cultivated hectares and for about 48.7 percent of the area under crop mixtures.

Livestock production was not an important farm activity in the study area during the survey period.

2.4 Farm Labor Force

The family is the major source of the farm labor force. The representative farm family in the study area consisted of seven persons. Table 2.3 shows the composition of the representative farm family in the study area as recorded at the beginning of the survey period.

The total labor input on the representative farm was 2,338 manhours.[1] Fifty-five percent of the total labor input on the representative farm came from family sources. About 90 percent of the total family labor input was male adult labor. There was very little participation of women in farm work because of the practice of partial or complete

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[1]Expressed in man equivalent hours. Female adult hours and children (7-14 years) hours reported were converted to man equivalent by multiplying by 0.75 and 0.5 respectively.

TABLE 2.2

KINDS AND AMOUNTS OF CROP ENTERPRISES
ON THE REPRESENTATIVE FARM

Crop Enterprise	Hectares
Guinea Corn (GC)	0.12
Maize (MZ)	0.08
Groundnut (GN)	0.10
Tomatoes (TM)	0.24
Pepper (PP)	0.20
Okra (OK)	0.17
Other Sole Crops	0.01
Millet/Guinea Corn (ML/GC)	0.93
Maize/Guinea Corn (MZ/GC)	0.05
Other 2-Crop Mixtures	0.44
3-Crop Mixtures	0.38
Mixtures with More than 3 Crops	0.11
TOTAL	2.83

SOURCE: Field survey.

TABLE 2.3

COMPOSITION OF THE REPRESENTATIVE FARM FAMILY IN THE STUDY AREA

Kind	Number in Family
Male Adults (15 years or more)	2
Female Adults (15 years or more)	2
Large Children (7-14 years)	1
Small Children (less than 7 years)	2
TOTAL	7

SOURCE: Field survey.

seclusion of Moslem wives (Smith, 1955). Table 2.4 shows the labor inputs on the representative farm by month.

Family labor is usually augmented by hired labor, especially during peak labor demand. Monthly hired labor inputs on the representative farm are also shown in Table 2.4. The proportion of hired labor used on the representative farm was relatively high. Forty-five percent of the total labor input was hired. This contrasts sharply with 18 percent found by Norman (1972). However, farmers in Mairiga in the World Bank Project in Gusau have been reported to have hired about 37 percent of the total on-farm labor use. Abalu (1978) found that groundnut farmers hired 73 percent of their labor inputs while Hays et al. (1977) have reported that up to 56 percent of total labor inputs employed by cowpea farmers was hired.

Hired labor is obtained under a variety of arrangements, including exchange and contract systems as well as simply hiring on a daily or per hour basis. The average wage rate for hired labor in the study area was 0.257 Naira per manhour during the survey period.

Seasonal fluctuations exist in both the amounts of labor used and in the wage rate for hired labor as shown in Table 2.4. These seasonal variations reflect the effect of climate on agricultural production. The peak months of agricultural production are May to August. About 49 percent of the annual input of manhours on the representative farm occurred during these months. December to March

TABLE 2.4

MONTHLY WAGE RATES AND LABOR INPUTS ON THE REPRESENTATIVE FARM

Month	Family Labor (manhours)	Hired Labor (manhours)	Total Labor (manhours)	Wage Rate (Naira/manhour)
March 1977	50	0	50	---
April 1977	67	73	140	0.264
May 1977	184	64	248	0.266
June 1977	150	189	339	0.280
July 1977	148	140	288	0.269
August 1977	128	135	263	0.298
September 1977	107	96	203	0.230
October 1977	151	99	250	0.220
November 1977	131	122	253	0.221
December 1977	102	98	200	0.243
January 1978	61	43	104	0.274
February 1978	0	0	0	---
Total	1279	1059	2338	
Percent of Total	54.7	45.3	100	

SOURCE: Field survey.

are the slack months in agricultural production and labor inputs during these months represent only 15 percent of the annual labor input on the representative farm. One would not expect any hiring of labor during the slack season when relatively insignificant amounts of family labor inputs are used. However, hired labor inputs are used in the slack months because family members are sometimes engaged in off-farm occupations. Norman (1973:12) has reported that about 47 percent of the average male adults' time in the Zaria area is spent on off-farm occupations.

There is a relatively large seasonal variation in the wage rate for hired labor. One possible explanation for this is that wage rates vary with the activity performed by the hired labor and different activities are performed in different months.

It has been observed that the amount of land a family can handle during the peak period largely determines the level of agricultural activities during the rest of the year (Ogunfowora, 1972). This tends to make labor a more limiting resource than land. The bottleneck in farm labor demand during the peak season is regarded as the major labor management problem in the study area.

2.5 Farm Capital

Capital in farming refers to manmade goods or assets that are produced for the purpose of being used in the process of agricultural production. It includes items such as machines, tools, buildings, roads, land improvements, tree crops, livestock, seeds, fertilizers, etc. These assets are usually classified, according to the length of their productive life, into fixed (or long term) capital and operating (or working or short term) capital. The former consists of items such as machines, tools, land improvements and buildings with a productive life that extends beyond one production cycle, whereas the latter is made up of assets such as fertilizer and seed that are used up in a single production cycle (Upton, 1974:149; Herbst, 1974:8, Barnard and Nix, 1976:50).

The level of fixed capital in the study area is relatively low. Livestock are restricted to backyard poultry and a few sheep and goats, tree crops do not grow well, farm buildings other than grain stores (rumbus) are absent, and farm equipment consists mostly of hand tools. Norman (1973:17) has reported an average inventory value of fixed capital of about 4.2 Naira.

Operating capital items such as fertilizer, seed, pesticides and hired labor are purchased inputs and their use usually entails cash expenditures.[2] Personal savings and credit from local moneylenders are the two main sources of cash for the purchase of operating capital assets. The level of savings is relatively low because of the low level

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[2]Use of hired labor and seed does not always involve cash expenditures since some of the labor hired is paid in kind and some of the seed was saved from the previous year's harvest.

of farm incomes. Institutional credit does not exist in the area. Debt aversion and high rates of interest restrict the use of funds from local moneylenders. Vigo (1965) has reported that farmers in Northern Nigeria sometimes obtain credit from traders who charge interest rates ranging from 50 to 90 percent.

Table 2.5 shows the cash expenditures of the representative farm on purchased inputs by month. These are the amounts extimated to have been spent on hired labor, seeds, pesticides, and fertilizers during the 1977-78 production season. Total cash expenses by the representative farm amounted to 180.39 Naira.

2.6 Technology of Agricultural Production

Two kinds of agricultural production technology are being used in the study area. The traditional technology is indigenous to the area and has been in use for a very long time. Land and labor are virtually the only inputs of this technology, although a few farmers use organic manure to replenish soil fertility.[3] The traditional technology is currently being replaced by a new technology through the activities of the Guided Change Project (GCP). The new technology involves the use of improved seed varieties, the application of chemical fertilizers and pesticides

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[3]Most of the organic manure applied is produced as a result of the cattle owned by the nomadic Fulani being corralled on the field after harvesting has been completed. Often this arrangement is undertaken without monetary cost on either side; the crop residues provide food for the cattle which produce manure.

TABLE 2.5

CASH EXPENSES OF THE REPRESENTATIVE FARM BY MONTH

Month	Cash Expenses (₦)
March 1977	0
April 1977	10.67
May 1977	14.12
June 1977	26.61
July 1977	18.46
August 1977	26.27
September 1977	21.50
October 1977	18.57
November 1977	14.21
December 1977	19.42
January 1978	10.56
February 1978	0
TOTAL	180.39

SOURCE: Field survey.

and the adoption of improved cultural practices such as early planting. This kind of technology originated from research stations, and is consistent with the policy of the government on agricultural modernization which emphasizes small changes in technology rather than highly mechanized practices that are beyond the financial ability and technical competence of most of the farming population. Norman (1974:29) considers chemical fertilizers as the main modern input of the new technology. About 3.7 bags (185 kg) of superphosphate (supa) and 2.6 bags (130 kg) of sulphate of ammonia (sulfa) were used on the representative farm.

Englehard (1978) has noted that farmers in the study area use the new technology in ways that deviate from the recommendations of the research stations. He observed that farmers attempt to adapt the new technology to their own circumstances. Such adaption consisted mostly of the elimination or combination of specific operations in an effort to reduce the labor requirements of the new technology at periods of peak labor demand. For example, farmers have been known to apply superphosphate and sulphate of ammonia as a mixture in one application instead of the recommended two applications of sulphate of ammonia and one application of superphosphate. Farmers believe that one application saves labor and that the extra yield from split application is not sifficient to pay for additional labor costs. Some farmers also plant groundnut 12-15 inches apart on 4-foot ridges rather than 9 inches apart on 3-foot ridges as recommended by the research station. Land preparation and the planting of groundnut take place in the period May to June, which is a peak period in labor use. Farmers contend that they cannot afford the time it takes to make 3-foot ridges.

CHAPTER III

THE STRUCTURE OF THE LINEAR PROGRAMMING MODELS FOR THE STUDY AREA

3.1 Introduction

Linear programming is a technique for maximizing (or minimizing) a linear objective function subject to some linear constraints. The technique is used as a farm planning tool in this study. In such a context, the objective function is usually in the form:

$$Z = \sum_{j=1}^{n} C_j X_j$$

where Z represents the returns to be maximized. The X_j's are decision variables such as the number of hectares of crops to be produced or the amount of labor to be hired. The C_j's measure the marginal contribution of each decision variable such as the returns over variable costs (gross margins) of one hectare of a crop.

The fixed conditions present on the farm are usually stated in the form of linear restrictions such as:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (i = 1, 2, \ldots, m)$$

where the X_j's are as previously defined, and b_i represents the total amount of a resource available. The a_{ij}'s represent how much of a resource is required for each activity unit, such as the amount of labor required to produce one hectare of a crop.

Another restriction on the decision variable takes the form of

$$X_j \geq 0 \text{ for all j's}$$

which specifies that only non-negative levels of each decision variable may be examined. Linear programming then provides a means to find the levels of the decision variables that would maximize the objective function subject to the fixed conditions on the farm and the non-negativity requirement.[1]

The mathematical framework of a linear programming matrix requires a number of important assumptions to be made about the nature of the process being represented. These assumptions include additivity, divisibility, finiteness and linearity (Hardaker, 1971:6).[2] In this study it is also assumed that input-output values, resource supplies and the prices of inputs and outputs are known with certainty. Although for many purposes this assumption may be a useful simplification of reality, Kennedy and Francisco (1974) and Upton and Casey (1974) have contended that risk

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[1]See Heady and Candler (1973:416) for a mathematical formulation of a linear programming model in matrix notation.

[2]Other forms of programming such as parametric programming, separable programming, dynamic linear programming, integer programming, recursive programming, quadratic and stochastic programming are available for use in situations where some of the assumptions may be difficult to justify.

considerations are important in smallholder decision making and that some method of incorporating risk factors into a linear programming framework is therefore desirable.

A number of approaches[3] have been developed to account for risk in linear programming models of the farm-firm, but there is no clear guidance as to which of these approaches is the most descriptive. In the formulation of the linear programming models in this study, the risk factor is only implicitly specified by incorporating restrictions to insure the production of grains to meet minimum family consumption needs. In addition to being easily included in the model, this specification is relatively undemanding in its data requirements about yield and price distributions.

The structure of a linear programming model is determined by three related components (Beneke and Winterboer, 1971:35). The components are: the objective function, the activities in the model and the constraints or restrictions in the model. This chapter describes each of these components for the linear programming model which is used to represent the planning environment of the representative farm in the area.

Hardaker (1971:2) has stressed that the validity of the results obtained from linear programming exercises depends on the reliability of the data employed and on the skill with which the real circumstances of the farm

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[3]The attempts include Boussard and Petit (1967), Markowitz (1959), McInerney (1969), Hazel and How (1970), Hazel (1970, 1971), among others.

are represented in the rather rigid mathematical framework of a linear programming matrix. In the formulation of the models used in this study, every effort was made to reflect as realistically as possible the actual farm conditions in the study area. A detailed survey of a sample of farms in the study area provided most of the data needed for quantifying resources and other restrictions, activities and input-output relationships.

Two kinds of technology are defined in the programming exercises: a traditional technology which does not include the use of modern inputs (fertilizer, improved seed, and pesticides) and a new technology that incorporates these inputs into the existing farming system. The latter has been recently adopted in the area through the activities of the Guided Change Project (GCP). The tableau for the new technology is presented in Tables 3.1 to 3.9. The traditional technology has a similar tableau and so it is not duplicated here. The only difference is that the traditional technology matrix does not include maize (a new crop in the area) and modern input activities and constraints.

Each column of the tableau defines an activity with its respective input-output coefficients. Each row represents a restriction. A negative coefficient signifies addition to the resource while a positive coefficient indicates a demand on the resource.

3.2 The Objective Function

A variety of objectives have been specified for the smallholder in traditional agriculture. Schults (1964) and Hopper (1965) believe that peasant farmers are profit maximizers. Wolf (1966) has indicated that peasant farmers have status objectives. DeWilde (1967) contends that "for many Africans security is a more important consideration than the possibility of increasing income." Lipton (1968) seems to have a similar view. Norman (1973:43) found that although small farmers in the Zaria area in Northern Nigeria used inputs in a manner consistent with a profit maximizing objective, they adopted intercropping and other practices indicative of an insurance or risk minimization strategy. He concluded that both security and profit maximization were relevant goals of farmers in that area. Charlick (1974) has reported that farmers adopted "unprofitable" new technology so as to satisfy their patrons. It has also been suggested that the objectives of the smallholder may include maximization of the flow of consumption, growth maximization and "satisficing" and that the objectives were likely to vary over time, according to the farmers' age and needs, and the external factors that influence his productive capacity (Upton, 1974). Heyer (1971) has stressed the "difficulty of deciding what it is that subsistence farmers aim for." She contends that the objective function is ambiguous and suggests "insuring an adequate food supply in drought years, producing a suitably varied diet, maximizing the number of people fed, maximizing the market value of output" as possible alternatives that could be considered. This complexity in ascertaining the objectives of smallholders makes the definition of a meaningful and operational objective function a difficult problem in application of linear programming to peasant agriculture.

In this study, it is assumed that farmers in the study area are risk averse and seek security (through the production of grain for family consumption and diversification in crop production) as well as the maximization of net farm income. Upton (1974) has indicated that there are two alternative approaches to incorporating more than one objective in a single linear programming model. One approach is to combine the various objectives into a single decision criterion such as expected utility maximization. The other approach (known as the "lexicographic" approach) is to "employ a hierarchy of objectives treating all but one as constraints." The lexicographic approach has been widely used in studies of African farmers (Low, 1974; Ogunfowora, 1972; Mwangi, 1978) and is the approach adopted in this study.

The security objective of producing staple food for the family is specified in the matrix as constraints to force the production of necessary amounts of millet and guinea corn for meeting minimum family consumption levels. These required amounts were derived from the results of a consumption study undertaken in the study area in 1970.[4] Net farm income (expressed as gross margins)[5] is specified in the model as the ultimate objective to be maximized.

3.3 Activities in the Model

Seven groups of activities have been specified in the model. These are:

a) crop production activities

b) labor hiring activities

c) capital borrowing activities

d) fertilizer buying activities

e) grain consumption activities

f) crop selling activities

g) transfer activities

a) Crop production activities

The cropping choices defined for the representative farm in the model are outlined in Table 3.1, columns A1 to A14. They comprise a selection of five sole crops (guinea corn, maize, groundnut, tomatoes, peppers), two 2-crop mixtures (millet/guinea corn, maize/guinea corn) and one 3-crop mixture (millet/guinea corn/cowpea) enterprises. These crop enterprises were identified by the researcher

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[4] Simmons, E. B. (1976). Calorie and protein intakes in three villages of northern Zaria Province, May 1970-July 1971. Samaru Miscellaneous Paper No. 55 (I.A.R.) A.B.U.

[5] The gross margin of an enterprise is defined as the total value of production of the enterprise less variable costs of production. Total gross margin less total fixed cost is equal to net farm income.

TABLE 3.1

CROP PRODUCTION ACTIVITIES[a]

Row No.	Objective Function (C_j) / Resources	Units	A_1 ML/GC (1 HA) -2.34	A_2 ML/GC (MI) (1 HA) -2.90	A_3 ML/GC/CP (1 HA) -7.44	A_4 ML/GC/CP (MI) (1 HA) -8.01	A_5 PGC (1 HA) -2.55	A_6 PGC (MI) (1 HA) -2.80	A_7 MZ/GC (MI) (1 HA) -4.35
			Crop Production Activities						
1	Land	HA	1	1	1	1	1	1	1
2	FL Mar	HRS	6.41	7.30	6.89		5.11		
3	FL Apr	HRS	70.59	58.01	75.14	76.36	17.01	20.91	16.36
4	FL May	HRS	125.38	155.60	187.33	141.82	42.81	19.09	100.25
5	FL Jun	HRS	82.15	74.93	101.19	121.63	57.11	42.42	55.25
6	FL Jul	HRS	63.20	83.50	89.68	96.30	58.17	42.04	80.91
7	FL Aug	HRS	76.47	103.76	97.88	161.50	40.44	40.31	37.27
8	FL Sep	HRS	34.07	24.70	46.67	76.00	8.49	54.24	59.09
9	FL Oct	HRS	7.14	11.23	28.78	18.28		29.09	7.27
10	FL Nov	HRS	84.20	109.18	83.88	107.25	60.29	97.27	54.24
11	FL Dec	HRS	42.96	69.67	11.01	17.23	18.74	54.45	60.45
12	FL Jan	HRS	14.59	25.07	1.46	20.90	2.30	7.58	20.91
13	FL Feb	HRS	3.53						
14	OC Mar	₦							
15	OC Apr	₦	0.81	1.19	0.81	1.19			2.64
16	OC May	₦	1.53	1.71	1.43	1.61	2.55	2.80	1.71
17	OC Jun	₦							
18	OC Jul	₦							
19	OC Aug	₦			5.21	5.21			
20	OC Sep	₦							
21	OC Oct	₦							
22	OC Nov	₦							
23	OC Dec	₦							
24	OC Jan	₦							
25	OC Feb	₦							
26	SUPA	KG		116		106		86	22
27	SULFA	KG		105		95		41	31
28	MLS	KG	-307	-412	-261	-295			
29	GCS	KG	-680	-827	-588	-636	-600	-708	-324
30	CPS	KG			-128	-126			
31	MZS	KG							-297
32	GNS	KG							
33	TMS	KG							
34	PPS	KG							
35	MLC	KG							
36	GCC	KG							

[a]For explanation of abbreviations, see Table C.1, Appendix C.

TABLE 3.1 (continued)

Row No.	Objective Function (C_j) / Resources	Units	A_8 PMZ (MI) (1 HA) -5.28	A_9 PGN (1 HA) -8.96	A_{10} PGN (MI) (1 HA) -9.20	A_{11} PTM (1 HA) -0.30	A_{12} PTM (MI) (1 HA) -0.30	A_{13} PPF (1 HA) -0.25	A_{14} PPP (MI) (1 HA) -0.25	Sign	RHS
			Crop Production Activities								
1	Land	HA	1	1	1	1	1	1	1	≤	2.83
2	FL Mar	HRS		14.32						≤	50
3	FL Apr	HRS		2.25	9.09	35.60	44.55	56.00	54.36	≤	67
4	FL May	HRS	96.67	35.01	29.09	54.32	65.55	43.91	63.64	≤	184
5	FL Jun	HRS	113.18	126.30	167.27	42.56	54.31	78.63	74.55	≤	150
6	FL Jul	HRS	88.78	122.05	89.95	21.73	48.69	52.70	64.82	≤	148
7	FL Aug	HRS	59.40	70.62	51.51	20.05	32.20	65.23	83.95	≤	128
8	FL Sep	HRS	42.13	40.69	40.00	6.45	13.95	91.04	124.55	≤	107
9	FL Oct	HRS	83.64	44.77	5.45	2.36		61.38	50.31	≤	151
10	FL Nov	HRS	16.36	68.35	139.27			20.19	23.04	≤	131
11	FL Dec	HRS		24.96	110.00			16.45	12.13	≤	102
12	FL Jan	HRS		20.89	52.73			2.03		≤	61
13	FL Feb	HRS		28.59						≤	61
14	OC Mar	N								=	0
15	OC Apr	N								≤	10.67
16	OC May	N	5.28			0.30	0.30	0.25	0.25	≤	14.12
17	OC Jun	N		8.96	9.20					≤	26.61
18	OC Jul	N								≤	18.46
19	OC Aug	N								≤	26.27
20	OC Sep	N								≤	21.50
21	OC Oct	N								≤	18.57
22	OC Nov	N								≤	14.21
23	OC Dec	N								≤	19.46
24	OC Jan	N								≤	10.56
25	OC Feb	N								=	0
26	SUPA	KG	48		100		44		58	=	0
27	SULFA	KG	40				43		32	=	0
28	MLS	KG								=	0
29	GCS	KG								=	0
30	CPS	KG								=	0
31	MZS	KG	-394							=	0
32	GNS	KG		-876	-1229					=	0
33	TMS	KG				-253	-365			=	0
34	PPS	KG						-339	-351	=	0
35	MLC	KG									182
36	GCC	KG									877

SOURCE: Computed.

as the enterprises that most adequately depict the important production opportunities available to the smallholder in the study area. They were significant in terms of their contribution to family food requirements and farm income. Their significance was reflected in the relative proportion of total cultivated acreage that was devoted to these crops.

Two activities are specified for each crop enterprise. One of the activities represents production of the crop enterprise using modern inputs while the other represents production without modern inputs. The most common fertilization level for the crop enterprise was specified in the production with modern inputs. Data limitations did not allow the inclusion of more than one fertilization level for each crop enterprise.

When two or more crops were interplanted in a mixture, the production activity was defined in terms of the mixture, rather than the individual crops in the mixture. Input-output relationships were calculated for the field or enterprise as a whole. Crawford (1978) has discussed some of the problems associated with using crop mixtures as production activities in a linear programming model.

The activity unit (i.e., the amount of crop production that each unit of activity represents) is one hectare. The objective function coefficients (C_j) for the crop production activities represent the costs of seed and seed dressing for each unit of activity and are assigned negative signs.

The input-output coefficients for traditional and new

technologies are presented in Table 3.1. These coefficients are the amounts of input required per unit of activity. They specify how the magnitude of a constraint or restriction would be influenced by an increase of one unit of each activity in the model. The coefficients that signify a decrease in the magnitude of a restriction carry positive signs while coefficients indicating an increase in the magnitude of a restriction have negative signs associated with them.

In this study, the technical coefficients of production with traditional technology were obtained from the report of a farm management study conducted by D. W. Norman in the study area in 1966-67. Some of the characteristics of the farmers interviewed in that study were presented in Chapter I. That study was the most relevant and reliable secondary source available for obtaining such coefficients.

The input-output coefficients of production with the new technology were obtained from a farm survey conducted by the author in 1977-78. The elements of the survey design were described in Chapter I. Average input-output coefficients for the activities in the model were determined from fields considered to be similar in rate of fertilizer application, monthly labor use and yields per hectare. It was assumed that such fields were also similar in seeding rate, plant population and level of management. Each coefficient is the mean of a small sample of observations from relatively similar fields.

The differences between the traditional technology

coefficients and the new technology coefficients must be interpreted cautiously given that the two sets of data were generated from separate samples of farmers in different years. If the populations of the two samples were initially different, then not all of the observed differences between the coefficients can be attributed to the introduction of the new technology.

It is assumed in this study that the circumstances of the two groups of farmers were equivalent and that most (if not all) of the observed differences in the coefficients are the <u>result</u> of technological adoption.

Table 3.2 compares the average annual labor requirement under traditional and new technologies for selected crop enterprises. In spite of some of the labor-saving adaptations of farmers indicated in Chapter II, the adoption of the new technology resulted in increased labor requirements in all cases. The increases in labor requirements ranged from 13.1 percent for sole crop pepper to 41.6 percent for sole crop tomatoes. These increases result mostly from additional labor requirements for fertilizer application, better weeding and the harvesting of heavier yields under the new technology. Tomatoes has the highest increase in labor requirement. This is probably due to additional labor requirements for better seedbed preparation and nursery practices. The amount of time allocated to a particular crop enterprise and how well the farming operations are performed may depend upon the relative importance of the

TABLE 3.2

A COMPARISON OF
AVERAGE TOTAL LABOR REQUIREMENT PER HECTARE
FOR SELECTED CROP ENTERPRISES
UNDER TRADITIONAL AND NEW TECHNOLOGIES

Crop Enterprise	Labor Requirement: Traditional Technology	New Technology	Change Percent
ML/GC	610.69	722.95	18.4
ML/GC/CP	729.91	837.27	14.7
GC	310.47	407.40	31.2
MZ/GC	---	492.00	--
MZ	---	500.16	--
GN	598.8	694.36	16.0
TM	183.07	259.25	41.6
PPP	487.56	551.35	13.1

SOURCE: Computed.

crop enterprise in the farming system. Thus the relative labor requirements of different crop enterprises is specific to the farming system under study and may be different for the same enterprise in other farming systems.

Table 3.3 compares the average monthly labor input per hectare for the whole farm under traditional and new technologies. It shows that the adoption of the new technology resulted in increases in the labor input per hectare in all months except February, April and May. The highest increases in the labor input per hectare occurred in June, October, November and December. The increase in June is due to additional labor input for fertilizer application and better weeding. The increases in October, November and December are due to additional labor inputs for harvesting the heavier yields resulting from the introduction of the new technology. The increase in the labor input in the month of December is very high. Since the rains came late in the year that data were collected on the new technology, and planting was delayed, it is likely that part of the increase in the labor input in December is due to the effect of a late harvest. The average annual labor input per hectare increased by 16.6 percent with the introduction of the new technology. Table 3.4 shows that the adoption of the new technology gave rise to increases in the yields of crops. The highest increases in yields occurred in millet/guinea corn, sole crop groundnut and sole crop tomatoes enterprises. These are the most

TABLE 3.3

A COMPARISON OF AVERAGE MONTHLY LABOR INPUT PER HECTARE FOR THE WHOLE-FARM UNDER TRADITIONAL AND NEW TECHNOLOGIES

	Average Labor Input per Hectare		
Month	Traditional Technology	New Technology	Change Percent
March	14.35	17.67	23.1
April	51.31	49.47	-3.6
May	89.03	87.63	-1.6
June	96.17	119.79	24.6
July	91.35	101.77	11.4
August	81.37	92.93	14.2
September	62.82	71.73	14.2
October	61.02	88.34	44.8
November	65.06	89.40	37.4
December	41.70	70.67	69.5
January	31.54	36.75	16.5
February	22.95	---	--
TOTAL	708.67	826.15	16.6

SOURCE: Computed.

TABLE 3.4

A COMPARISON OF AVERAGE YIELDS
OF SELECTED CROP ENTERPRISES
UNDER TRADITIONAL AND NEW TECHNOLOGIES

		Yields per Hectare (KG/HA)		
Crop Enterprise[a]		Traditional Technology	New Technology	Change Percent
ML/GC	ML	307	412	34.2
	GC	680	827	21.6
ML/GC/CP	ML	261	295	13.0
	GC	588	636	8.2
	CP	128	126	1.6
GC		600	708	18.0
GN		876	1229	40.3
TM		253	365	44.3
PPP		339	351	3.5

SOURCE: Computed.

[a]The relative proportions of individual crops in a crop mixture are assumed to be the same under both traditional and new technologies.

important food and cash crop enterprises in the study area. The relatively high increases in yields are probably due to greater use of improved seed varieties, better management practices and the use of seed dressing. The level of fertilizer use on the millet/guinea corn and groundnut enterprises was relatively high as shown in Table 3.5 which compares actual and recommended levels of fertilizer use for selected crop enterprises. The actual levels are much lower than the recommended levels for all crop enterprises except sole crop groundnut. The most common level of fertilizer use on sole crop groundnut fields in the study area was two bags or 100 kg of superphosphate per hectare, which is about the same as the recommended level. This is probably due to increased extension activities on groundnut fields.

b) Labor hiring activities

Farmers in the study area use hired labor to augment the stock of family labor available for work on the family farm. Labor hiring activities are represented in Columns A15 to A26 in Table 3.6. Hired labor is obtained under a variety of arrangements, including exchange and contract systems as well as simply hiring on a daily or per hour basis. Work paid for by the hour was the most common and for simplicity all non-family labor in the model is assumed to be hired on a per hour basis. The activity unit is one manhour.

The prices used are the wage rates per manhour prevailing

TABLE 3.5

A COMPARISON OF ACTUAL RATES OF FERTILIZER USE WITH RECOMMENDED LEVELS FOR SELECTED CROP ENTERPRISES

Crop Enterprise	Levels of Fertilizer Use (KG/HA)			
	Actual[b]		Recommended[a]	
	Supa	Sulfa	Supa	Sulfa
ML/GC	116	105	---	---
ML/GC/CP	106	95	---	---
GC	86	41	125	125
MZ/GC	22	31	---	---
MZ	48	40	220	157
GN	100	0	94	0
TM	44	43	---	---
PPP	58	32	250-500	250

[a]The recommended levels were obtained from Extension guides issued by AERLS. There are no recommendations for crop mixtures.

[b]The actual levels are the most common fertilization levels found in the survey conducted by the author in 1977-78.

TABLE 3.6

LABOR HIRING ACTIVITIES[a]

Row No.	Objective Function (c_j) / Resources	Unit	Labor Hiring Activities: A_{15} HL Mar (1 HR) -0.26	A_{16} HL Apr (1 HR) -0.26	A_{17} HL May (1 HR) -0.27	A_{18} HL Jun (1 HR) -0.28	A_{19} HL Jul (1 HR) -0.27	A_{20} HL Aug (1 HR) -0.30	A_{21} HL Sep (1 HR) -0.23	A_{22} HL Oct (1 HR) -0.22	A_{23} HL Nov (1 HR) -0.22	A_{24} HL Dec (1 HR) -0.24	A_{25} HL Jan (1 HR) -0.27	A_{26} HL Feb (1 HR) -0.27	Sign	RHS
2	FL Mar	HR	-1												≤	50
3	FL Apr	HR		-1											≤	67
4	FL May	HR			-1										≤	184
5	FL Jun	HR				-1									≤	150
6	FL Jul	HR					-1								≤	148
7	FL Aug	HR						-1							≤	128
8	FL Sep	HR							-1						≤	107
9	FL Oct	HR								-1					≤	151
10	FL Nov	HR									-1				≤	131
11	FL Dec	HR										-1			≤	102
12	FL Jan	HR											-1		≤	61
13	FL Feb	HR												-1	≤	61
14	OC Mar	₦	0.26												=	0.00
15	OC Apr	₦		0.26											≤	10.67
16	OC May	₦			0.27										≤	14.12
17	OC Jun	₦				0.28									≤	26.61
18	OC Jul	₦					0.27								≤	18.46
19	OC Aug	₦						0.30							≤	26.27
20	OC Sep	₦							0.23						≤	21.50
21	OC Oct	₦								0.22					≤	18.57
22	OC Nov	₦									0.22				≤	14.21
23	OC Dec	₦										0.24			≤	19.46
24	OC Jan	₦											0.27		≤	10.56
25	OC Feb	₦												0.27	=	0.00

SOURCE: Computed.

[a]For explanation of abbreviations, see Table C.1, Appendix C.

in the study area during the survey period. Hired labor is remunerated either in kind or in cash. Where possible, kind payments were converted to money value by multiplying the product by its average price.

Hired labor and family labor are assumed to be near perfect substitutes. The labor hiring activities have a negative coefficient in the family labor rows, indicating that an increase of one unit of hired labor relaxes the labor constraint by one unit. The wage rate of hired labor is positive in the operating capital row, meaning that an increase of hired labor by one unit will decrease operating capital by its wage rate. Thus the extent to which hired labor can be used to relax the family labor constraint is determined by the operating capital available to the farm firm.

Labor hiring activities have negative C_j values in the objective function since each unit of hired labor reduces the value of the objective function by its wage rate. The average farm in the study area is a net buyer of labor. Hence the selling of family labor in the form of off-farm work is not provided for in the model.

c) Capital borrowing activities

Capital borrowing activities are shown in Table 3.7, Columns A27 to A38. Although there is no formal loan program in the area, these activities were included in the model to evaluate the potential contribution of credit facilities to farm income and enterprise organization. The capital

TABLE 3.7

CAPITAL BORROWING ACTIVITIES[a]

Row No.	Objective Function (c_j) Resources	Unit	Capital Borrowing Activities A_{27} BC Mar (₦1) -0.15	A_{28} BC Apr (₦1) -0.15	A_{29} BC May (₦1) -0.15	A_{30} BC Jun (₦1) -0.15	A_{31} BC Jul (₦1) -0.15	A_{32} BC Aug (₦1) -0.15	A_{33} BC Sep (₦1) -0.15	A_{34} BC Oct (₦1) -0.15	A_{35} BC Nov (₦1) -0.15	A_{36} BC Dec (₦1) -0.15	A_{37} BC Jan (₦1) -0.15	A_{38} BC Feb (₦1) -0.15	Sign	RHS
14	OC Mar	₦	-1												=	0.00
15	OC Apr	₦		-1											<	10.67
16	OC May	₦			-1										≤	14.12
17	OC Jun	₦				-1									≤	26.61
18	OC Jul	₦					-1								≤	18.46
19	OC Aug	₦						-1							≤	26.27
20	OC Sep	₦							-1						≤	21.50
21	OC Oct	₦								-1					≤	18.57
22	OC Nov	₦									-1				≤	14.21
23	OC Dec	₦										-1			≤	19.42
24	OC Jan	₦											-1		≤	10.56
25	OC Feb	₦												-1	=	0.00

SOURCE: Computed.

[a]For explanation of abbreviations, see Table C.1, Appendix C.

borrowing activities are specified on a monthly basis at 15 percent annual interest cost. The activity unit is one Naira.

d) Fertilizer buying activities

Fertilizer is a purchased input. Fertilizer buying activities are included in the model to allow the purchase of fertilizer. Columns A39 and A40 of Table 3.8 represent the fertilizer buying activities. The activity unit is one bag (50 kg).

The price of fertilizer is the subsidized price in Kaduna state in 1977. Fertilizer buying reduces the value of the objective function so that fertilizer buying activities are assigned negative coefficients in the objective function. The fertilizer buying activities also have negative coefficients in the fertilizer rows because fertilizer buying increases the stock of fertilizer.

e) Grain consumption activities

Family food consumption consists mostly of grains. The grain consumption activities are shown in Table 3.8, Columns A41 and A42. They depict the consumption of millet and guinea corn by the family. The activity unit is one kilogram (1 kg). The activity has positive coefficients in the millet and guinea corn rows because it reduces the quantity of these crops.

TABLE 3.8

FERTILIZER BUYING, GRAIN CONSUMPTION AND CROP SELLING ACTIVITIES[a]

	Objective Function (c_j)		Fertilizer Buying, Grain Consumption and Crop Selling Activities												
Row No.	Resources	Unit	A_{39} BSUPA (1BAG) -1.00	A_{40} BSULFA (1BAG) -1.50	A_{41} CML (1 KG) 0.18	A_{42} CGC (1 KG) 0.19	A_{43} SML (1 KG) 0.18	A_{44} SGC (1 KG) 0.19	A_{45} SCP (1 KG) 0.31	A_{46} SMZ (1 KG) 0.25	A_{47} SGN (1 KG) 0.20	A_{48} STM (1 KG) 0.38	A_{49} SPP (1 KG) 0.45	Sign	RHS
17	OC Jun	₦	1.00	1.50										<	26.61
26	SUPA	KG	-50											≤	100
27	SULFA	KG		-50										≤	100
28	MLS	KG			1		1							=	0
29	GCS	KG				1		1						=	0
30	CPS	KG							1					=	0
31	MZS	KG								1				=	0
32	GNS	KG									1			=	0
33	TMS	KG										1		=	0
34	PPS	KG											1	=	0
35	MLC	KG			1									=	182
36	GCC	KG				1								=	877

SOURCE: Computed.

[a]For explanation of abbreviations, see Table C.1 in Appendix C.

f) Crop selling activities

In the formulation of the model all crop products are permitted to be sold. It is assumed that minimum family grain consumption requirements will be satisfied before any selling activities are undertaken. Maize and all non-grain crops are sold without any constraint. It is also assumed that all selling is done at harvest and that no storage except of grain for consumption takes place on the farm. Table 3.8 Columns A43 to A49 indicate the crop selling activities. The activity unit is one kilogram (1 kg). The prices used are those prevailing in the local market during the harvesting period. The objective function coefficients are positive because selling adds to the value of the objective function. The row coefficients are also positive since selling activities reduce the stock of output.

g) Transfer activities

In Table 3.9, Columns A50 to A60 represent transfer activities which are used to pass surplus capital from one month to another during the year. Column A61 represents a "pay-off" activity which is included as a convenient device by means of which any capital surplus to requirements is accumulated at the end of the year. This activity is given a fractional but positive net revenue in the objective function to ensure that the transfer activities pass surplus capital through from month to month, even if it is not required directly to finance operations (Barnard and Nix, 1976:443).

TABLE 3.9

TRANSFER ACTIVITIES[a]

Row No.	Objective Function (c_j) / Resources	A_{50} TCMA 0	A_{51} TCAM 0	A_{52} TCMJ 0	A_{53} TCJJ 0	A_{54} TCJA 0	A_{55} TCAS 0	A_{56} TCSO 0	A_{57} TCON 0	A_{58} TCND 0	A_{59} TCDJ 0	A_{60} TCJF 0	A_{61} PAYOFF 0.001	Sign	RHS
		Transfer Activities													
14	OC Mar	1												=	0.00
15	OC Apr	-1	1											<	10.67
16	OC May		-1	1										$\leq$	14.12
17	OC Jun			-1	1									$\leq$	26.61
18	OC Jul				-1	1								$\leq$	18.46
19	OC Aug					-1	1							$\leq$	26.27
20	OC Sep						-1	1						$\leq$	21.50
21	OC Oct							-1	1					$\leq$	18.57
22	OC Nov								-1	1				$\leq$	14.21
23	OC Dec									-1	1			$\leq$	19.42
24	OC Jan										-1	1		$\leq$	10.56
25	OC Feb											-1	1	=	0.00

SOURCE: Computed.

[a]For explanation of abbreviations, see Table B.1 in Appendix B.

3.4 Restrictions in the Model

Farming in the study area is carried out under a number of constraints or restrictions. These restrictions, which include availability of land, family labor, operating capital, family consumption requirements and non-negativity of activity levels, are outlined as rows in Table 3.1. They are described below.

a) Land restriction

The amount of land available for cultivation by the representative farm was about 2.83 hectares. This consisted mostly of land owned by the household through inheritance. There was little evidence of land selling or renting in the study area. Consequently, no provision is made in the model for any such activities.

Only upland or gona type of farmland is considered in the model. Fadama land is omitted because it was virtually absent in the study area. The land is also assumed to be homogeneous in quality. The row unit is hectares.

b) Labor restrictions

Family labor restrictions are specified on a monthly basis in the model.[6] The row unit is manhours. The amount

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[6]Beneke and Winterboer (1971:65) have indicated that including a single labor restraint implies that labor can be freely substituted among seasons of the year. Labor is likely to have different opportunity costs in different seasons. Realistic planning requires taking account of the seasonality of labor requirements and restraints. Restraints should be formed to focus on those periods of the year in which labor allocation is critical. The remaining, non-critical periods can also be included to provide a complete accounting for labor within the system.

of family labor available for work on the representative farm each month was assumed to be equal to the number of manhours actually spent on the farm by family members during each month. These were estimated from the data obtained in the survey conducted by the author and are presented in Table 2.4 in Chapter II.

Family labor could be augmented with hired labor. However, the amount of labor that can be hired depends on the total labor requirement relative to the amount of family labor available, the amount of hired labor available in relation to its wage rate and on the amount of operating capital available for the hiring of labor.

c) Operating capital restrictions

A major problem in the specification of operating capital constraints in a linear programming matrix is the difficulty in obtaining relevant data on the amount of operating capital available for farming activities. In this study, reported cash expenses of individual households are used as a proxy for the amount of operating capital. The amount of funds available for cash expenses on the representative farm was set equal to the amount estimated to have been spent on hired labor, seeds, pesticides and fertilizers for the crop production activities during the 1977-78 production season. These were estimated from the data obtained in the survey conducted by the author and are presented in Table 2.5 in Chapter II. The row unit is Naira.

The operating capital constraints are also specified

on a monthly basis. Barnard and Nix (1976:439) have specified two main ways of incorporating operating capital into a linear programming matrix. One is to use transfer activities to pass surplus capital from one period to another during the year. The other is to accumulate capital balances in successive periods. In this study, transfer activities are used to pass surplus funds from one month to another during the year.

d) Grain consumption constraints

It is assumed that the representative farm seeks to achieve security by producing its own grain consumption requirements. Constraints are therefore incorporated into the model to force the production of minimum amounts of millet and guinea corn for family consumption. The required amounts were derived from the results of a consumption study undertaken in the study area in 1970.

e) Non-negative restriction

None of the activities included in the model can be operated at negative levels.

3.5 Some Limitations of the Model

The description that has just been presented does not exhaust the list of activities and restrictions that could possibly be included in a linear programming model of peasant agriculture. For example, additional levels of fertilization could be included as separate activities. The number of activities depends on the availability of data and on the objectives of the study. It is important to note that the size and complexity of a planning model may have an important influence on its usefulness. Large and complex models are costly to develop in terms of both time and money, and it is not always certain that the benefits to be derived from using a more sophisticated model (in terms of greater precision of the planning decisions derived from it) are sufficient to justify the costs. Also as one tries to build more realism into the model by increasing the number of activities and restrictions, one risks making the model so complicated that he cannot readily trace the logical connections between a change in an instrument variable and a resulting change in production.

Hardaker (1971:33) has advised that planning models should be kept simple in the first place, but if the results prove to be unsatisfactory in practical terms, more refinements can then be considered. This advice dictated the philosophy underlying the approach to model formulation in this study.

This chapter has presented a detailed description of the components of the linear programming models to be employed in this study. The results of the various applications of the model are discussed in the chapter that follows.

CHAPTER IV

ANALYSIS OF RESULTS FROM APPLICATIONS OF THE LINEAR PROGRAMMING MODELS

The structure of the linear programming models used in this study was described in Chapter III. This chapter presents an analysis of the results of the applications of the linear programming models. The analysis is focused on the changes in farm income, cropping pattern, resource use and productivity and selected economic efficiency measures that are likely to be associated with the introduction of modern inputs and improved cultural practices into the farming system.

The first optimum plan, or base plan, was obtained with traditional technology and existing resource levels. Then activities, constraints and coefficients reflecting the use of modern inputs under farm conditions were introduced into the model and the optimum farm plan under the new technology and existing resource levels was determined. This plan was compared to the base plan to obtain the derived effects of the adoption of the new technology under existing resource levels.

In the next phase of the analysis three alternatives using variants of the new technology model were defined for investigating the effects of changing some of the planning

constraints. In Alternative I the amount of family labor available for work on the family farm was increased with other resources and coefficients remaining unchanged. Alternative II assumed an increase in operating capital without any changes in other resources and coefficients. In Alternative III there was a simultaneous increase in the amount of family labor and operating capital.

The linear programming output in each situation provided information on the value of the objective function, the optimum enterprise combination, the resources used with their respective marginal value products (MVP's), the non-optimal activities with the costs associated with forcing each of them into the solution and the stability limits of the optimum plan. The validity of the optimal solution depends on the realism of the assumptions made concerning prices, technical coefficients and constraints. The optimal solution may differ from the actual practice of farmers because the linear programming model is an abstraction from reality, and some of the factors omitted from the model in the attempt to keep the model manageable may prevent the model from capturing all aspects of the farmers' behavior in the study area.

4.1 Optimum Organization of the Representative Farm with Traditional Technology and Existing Resource Levels

The characteristics of the optimum farm plan under traditional technology and existing resource levels are shown in Table 4.1. The value of the objective function

TABLE 4.1

OPTIMUM ORGANIZATION OF THE REPRESENTATIVE FARM
UNDER TRADITIONAL TECHNOLOGY
AND EXISTING RESOURCE LEVELS

Item	Unit	Activity Level
ML/GC	HA	0.99
ML/GC/CP	HA	0.00
PGC	HA	0.34
PGN	HA	0.18
PTM	HA	0.59
PPP	HA	0.73
Total Gross Margin	₦	362.96
Land	HA	2.83
Family Labor	HR	1081.74
Hired Labor	HR	193.37
Total Labor	HR	1275.11
Operating Capital	₦	74.33
Return to Land and Management		70.55
Return/hectare	₦/HA	24.93
Return to Labor and Management		356.97
Return/manhour	₦/HR	0.33
Return to Capital and Management		81.76
Return/operating capital		1.10

SOURCE: Computed.

or the total gross margin (TGM) is equal to 362.96 Naira. This does not take into account costs considered fixed to the farm such as depreciation on buildings and tools, taxes, etc. Net farm income can be obtained by subtracting the fixed costs from the total gross margin. In general, the fixed costs item is minimal or zero in the study area, so that the total gross margin is equivalent to net farm income. Table 4.1 also contains some measures of economic efficiency with respect to the limiting resources of land, family labor and operating capital. The return to land and management was obtained by deducting the cost of unpaid family labor and the interest on owner's operating capital from the total gross margin. The return to labor and management was obtained by deducting the interest on owner's operating capital from the total gross margin. Total gross margin plus the interest on borrowed capital less the cost of unpaid family labor gave the return to operating capital and management. In all cases, unpaid family labor was valued at the average wage rate for hired labor while the opportunity cost of owner's operating capital was assumed to be the annual interest rate of 15 percent. The average return to a unit of land is 24.93 Naira. The average return to a unit of family labor is 0.33 Naira while the average return to a unit of operating capital is 1.10.

The optimum combination of enterprises is also provided in Table 4.1. The optimal plan included cash crops and food crops, and utilized all of the available land. Millet/guinea

corn crop mixture was cultivated on 0.99 hectares or about 35 percent of the cultivated land area. The remaining 65 percent of the cultivated land area was devoted to sole crop guinea corn, groundnut, tomatoes and peppers. Peppers and tomatoes were the most important cash crops in terms of the proportion of the cultivated farm land on which they were grown. Tomatoes were grown on 0.59 hectares or 21 percent of the farm land, while peppers were grown on 0.73 hectares or 26 percent of the farm land.

Not all the crop enterprises grown by farmers in the study area are included in the optimum plan. For example the millet/guinea corn/cowpea enterprise was not included in the optimum plan even though it is grown by farmers in the study area. Its exclusion from the optimum plan must not be taken to mean that there will be no increase in its production. Rather, it signifies that at given conditions it is not competitive enough to be included in the income maximizing plans.

The total labor use in the optimum farm plan was 1275.11 manhours, made up of 1081.74 manhours of family labor and 193.37 manhours of hired labor. A total of 74.33 Naira of operating capital was used. The marginal value products of the resources are presented in Table 4.2.

The marginal value products of the resource restrictions presented in Table 4.2 are the shadow prices on the disposal activities of the linear programming model. Beneke and Winterboer (1971:21) have argued that the

TABLE 4.2

MARGINAL VALUE PRODUCTS (MVP's)
UNDER TRADITIONAL TECHNOLOGY
AND EXISTING RESOURCE LEVELS

	Resource	Unit	Marginal Value Product (₦)
1	Land	HA	43.06
2	FL Mar	HR	0.00
3	FL Apr	HR	0.36
4	FL May	HR	0.27
5	FL Jun	HR	0.28
6	FL Jul	HR	0.27
7	FL Aug	HR	0.30
8	FL Sep	HR	0.21
9	FL Oct	HR	0.00
10	FL Nov	HR	0.22
11	FL Dec	HR	0.00
12	FL Jan	HR	0.00
13	FL Feb	HR	0.00
14	OC Mar	₦	0.36
15	OC Apr	₦	0.36
16	OC May	₦	0.00
17	OC Jun	₦	0.00
18	OC Jul	₦	0.00
19	OC Aug	₦	0.00
20	OC Sep	₦	0.00
21	OC Oct	₦	0.00
22	OC Nov	₦	0.00
23	OC Dec	₦	0.00
24	OC Jan	₦	0.00
25	OC Feb	₦	0.00

SOURCE: Computed.

interpretation of the shadow prices on the disposal activities as marginal value products is not consistent with the exact definition of the marginal value product. The marginal value product of a resource is defined as the increase in the value of total output that is obtained from the use of an additional unit of the resource with all other inputs held constant. This latter condition is not met in the linear programming framework because production coefficients for the activities are defined in fixed ratio one to another. Thus an increase in the use of one input requires an increase in another. Despite this, the shadow prices of the disposal activities are operationally useful because they provide information concerning the resources that could best be expanded to increase income. The behavior of the marginal value products from linear programming for further additions of the resource may be erratic due to corner solutions in linear programming. That is, the solution holds for a specific range until other resources become limiting, at which point another organization becomes optimal and the marginal value products of the resources change.

The marginal value products indicate the productivity of resources on the farm. They indicate the amount by which the total gross margin of the farm would be increased by utilizing an additional unit of the resource. Thus they represent the gains in income which are possible through the acquisition of scarce resources. The marginal value products are zero for excess (slack) resources and are positive for limiting or constraining resources. A relatively high marginal value product indicates scarcity of the resource. The more limiting the resource, the higher the marginal value product. To be meaningful, the marginal value products have to be considered relative to the marginal factor costs of the resources. It is profitable to acquire a resource if its marginal value product is greater than its marginal factor cost. The high marginal value product of 43.06 Naira for land reflects the scarcity of land. It shows that the total gross margin will be increased by 43.06 Naira if an additional unit of land was made available. Expansion of land beyond the available amount could be profitable if the marginal factor cost of land is less than 43.06 Naira. Data is lacking for rent of land so it is not possible to make a comparison between the MVP and the rent of land.

Family labor was a limiting factor in production in April, May, June, July, August, September and November. These months correspond very closely to the peak periods in farm activities when operations like land preparation, planting, weeding and harvesting are carried out. Additional units of labor during these months would increase the value of the objective function by the amounts indicated by the marginal value products. The marginal value product of labor was highest in April indicating that labor was more constraining in this month. In April the marginal value product was substantially higher than the prevailing wage rate. Assuming that the opportunity cost of family labor is the wage rate, farmers can increase the level of farm income if they were willing to work extra hours during that month or had the funds to hire casual labor. The results also indicate that farmers could afford to pay higher than the prevailing wage rate to attract hired labor to break the bottleneck on labor in the month of April. In the month of September, the marginal value product is less than the marginal factor cost of labor. Hence it would be unprofitable to hire extra labor in this month.

The marginal value product of operating capital was 0.36 in March and 0.36 in April. Thus operating capital is also a constraint on production in March and April. In both months, the marginal value product is higher than the marginal factor cost of operating capital which is the interest rate of 15 percent. Hence farm income could be increased if more operating capital was available. This suggests the need for short term credit to relax the operating capital constraint. It emphasizes the importance of both the amount and distribution of operating capital, which is significant for the implementation of credit programs.

The output of the linear programming routine also provided information on the activities excluded from the optimum plan. The excluded activities are the least profitable enterprises. The cost of forcing an excluded enterprise into the solution indicates how the value of the objective function would be reduced (or how income would be penalized) if a unit of the enterprise were forced into the optimal plan. It reveals the competitive position of the enterprise. The higher the cost, the lower is its competitive position. The only enterprise not included in the programming solution was the millet/guinea corn/ cowpea enterprise (Table 4.1). Forcing a unit of this enterprise into the optimum solution would reduce the total gross margin by 32.29 Naira.

The levels of income, output and resource productivity in traditional farming has not been regarded as satisfactory. This has made the achievement of substantial increases in these key farm variables the ultimate objective of agricultural development efforts in Nigeria. Traditional agricultural production technology is considered the major limiting factor to increased production on small farms. Therefore, the introduction of a new technology is believed to provide the greatest opportunity for the realization of improved conditions in traditional agriculture. Consequently, the adoption of a new technology of the kind described in this study is being actively encouraged in Nigeria to provide a basis for the needed improvements in output, income and resource productivity on small farms. The following sections of the chapter examine the changes in cropping patterns, farm income and resource use and productivity that are likely to be associated with the use of the new technology on a representative farm in the study area.

4.2 Derived Effects of the New Technology with Existing Resource Levels

The effects of the new technology are derived from comparisons of the optimum organization of the representative farm under new technology with the optimum organization of the representative farm under traditional technology. These comparisons are presented in Tables 4.3 and 4.4.

It is important to note that the validity of the inferences drawn concerning the effects of the new technology depends on the extent to which differences in the input-output coefficients reflect differences in the technology of production. With cross-sectional data from different sets of farmers in different years, one cannot always be sure that differences in the technical coefficients are the result of technological adoption. In the comparisons made in this section, it was assumed that most (if not all) of the observed differences were the <u>result</u> of technological change.

The total gross margin of the optimum farm organization with the new technology is 422.02 Naira. This represents an increase of about 16 percent over the total gross margin of the optimum farm plan with traditional technology and indicates that income maximizing farmers could improve their farm income by approximately 16 percent by adopting the new technology with existing levels of resources.

The optimum farm plan with the new technology and existing resource levels included 0.57 hectares of millet/

TABLE 4.3

A COMPARISON OF THE OPTIMUM FARM ORGANIZATIONS OF THE REPRESENTATIVE FARM UNDER TRADITIONAL AND NEW TECHNOLOGIES WITH EXISTING RESOURCE LEVELS

	Item	Unit	Activity Levels		
			Traditional Technology	New Technology	Change Percent
1	ML/GC	HA	0.99	0.00	-42
2	ML/GC (MI)	HA	--	0.57	
3	ML/GC/CP	HA	0.00	0.00	
4	ML/GC/CP (MI)	HA	--	0.00	
5	PGC	HA	0.34	0.00	68
6	PGC (MI)	HA	--	0.57	
7	MZ/GC (MI)	HA	--	0.00	
8	PMZ (MI)	HA	--	0.00	
9	PGN	HA	0.18	0.00	294
10	PGN (MI)	HA	--	0.71	
11	PTM	HA	0.59	0.00	66
12	PTM (MI)	HA	--	0.98	
13	PPP	HA	0.73	0.00	-100
14	PPP (MI)	HA	--	0.00	
	Total Gross Margin	₦	362.96	422.02	16
	Land	HA	2.83	2.83	
	Family Labor	HR	1081.74	1063.50	
	Hired Labor	HR	193.37	307.03	59
	Total Labor	HR	1275.11	1370.53	7
	Operating Capital	₦	74.33	118.53	59
	Return to Land and Management	₦/HR	70.55	127.72	81
	Return/Hectare	₦/HA	24.93	45.13	81
	Return to Labor and Management		356.97	404.13	13
	Return/Manhour	₦/HR	0.33	0.38	15
	Return to Capital and Management		81.76	145.79	78.3
	Return/Operating Capital		1.10	1.23	12

SOURCE: Computed.

guinea corn mixture, 0.57 hectares of sole crop guinea corn, 0.71 hectares of sole crop groundnut and 0.98 hectares of sole crop tomatoes, all of which are grown using the new technology. These crop enterprises were also part of the optimum farm plan with traditional technology, which means that they are the most competitive enterprises under both technologies and given conditions. The optimum farm plan with traditional technology also included peppers while that with the new technology did not. Thus the introduction of the new technology resulted in a less diversified cropping pattern. This occurs because labor is more constraining under the new technology and peppers is a labor intensive crop enterprise.

There was a choice of technology in the new technology model. The fact that all the crop enterprises in the optimum farm plan with the new technology were produced with modern inputs would indicate that the production of those crop enterprises with modern inputs is in a better competitive position than their production with traditional technology. However, an examination of the shadow prices of the excluded activities revealed that millet/guinea corn/cowpea and pepper enterprises produced with traditional technology were in a better competitive position than the same enterprises produced with new technology.

The adoption of the new technology also gave rise to substantial reallocation of the land resource among the crops included in the optimum plans under both technologies. The acreage under tomatoes and groundnut increased by 66 percent and 294 percent respectively with the introduction of the new technology. These increases were achieved at the expense of reductions in the acreages of pepper and millet/guinea corn enterprises. There was a 42 percent reduction in the size of the millet/guinea corn enterprise and a 100 percent decrease in the acreage under peppers. Thus, under existing levels of resources, the new technology made tomatoes the predominant enterprise in the optimum cropping pattern.

The use of the new technology induced increases in the average returns to the limiting resources of land, family labor and operating capital. The average return per hectare with the new technology is 45.13 Naira. The average return per manhour of family labor is 0.38 Naira and the average return per unit of operating capital is 1.23 with the new technology. These represent increases of 81 percent, 15 percent and 12 percent respectively over the returns under traditional technology. This implies that under existing levels of resources, limiting resources are more efficiently utilized with the new technology.

The marginal value products of resources with the new and traditional technologies are compared in Table 4.4. The marginal value product of land under the new technology is 60.05 Naira which represents a 39 percent increase over the marginal value product of land under traditional technology.

TABLE 4.4

A COMPARISON OF MARGINAL VALUE PRODUCTS (MVPs)
UNDER TRADITIONAL AND NEW TECHNOLOGIES
WITH EXISTING RESOURCE LEVELS

	Resource	Unit	Marginal Value Product (₦) Traditional Technology	New Technology
1	Land	HA	43.06	60.05
2	FL Mar	HR	0.00	0.00
3	FL Apr	HR	0.36	0.34
4	FL May	HR	0.27	0.26
5	FL June	HR	0.28	0.38
5	FL July	HR	0.27	0.27
7	FL Aug	HR	0.30	0.30
8	FL Sep	HR	0.21	0.00
9	FL Oct	HR	0.00	0.00
10	FL Nov	HR	0.22	0.22
11	FL Dec	HR	0.00	0.24
12	FL Jan	HR	0.00	0.00
13	FL Feb	HR	0.00	0.00
14	OC Mar		0.36	0.26
15	OC Apr		0.36	0.26
16	OC May		0.00	0.26
17	OC June		0.00	0.26
18	OC July		0.00	0.00
19	OC Aug		0.00	0.00
20	OC Sep		0.00	0.00
21	OC Oct		0.00	0.00
22	OC Nov		0.00	0.00
23	OC Dec		0.00	0.00
24	OC Jan		0.00	0.00
25	OC Feb		0.00	0.00

SOURCE: Computed.

Thus land is more limiting under the new technology. Under the given conditions an additional unit of land would increase the total gross margin by 60.05 Naira with the new technology.

As in the case of traditional technology, family labor is a constraint on production with the new technology in the months of April, June, July, August and November. Family labor is also limiting in the month of December due to increased labor requirements for harvesting under the new technology. The marginal value product of family labor in June was higher under the new technology than under traditional technology. The marginal value product of June labor was 0.38 Naira with the new technology as against 0.28 Naira with traditional technology. This means that family labor is more limiting in June under the new technology than under traditional technology. This is due to increased labor requirements for fertilizer application and weeding under the new technology. The marginal value products of labor in April and June under the new technology are higher than the prevailing wage rates in these months. Farmers can afford to pay higher wage rates to attract hired labor during these two months with the new technology. This emphasizes the need for the availability of funds for hiring labor to break the labor constraint in these months.

Operating capital is limiting in March, April, May and June under the new technology. The marginal value products of operating capital in May and June are higher under the new technology than under traditional technology. The marginal value product of operating capital in May is 0.26 with the new technology as against 0.00 under traditional technology while that in June is 0.26 with the new technology as against 0.00 with traditional technology. Thus operating capital is more limiting in May and June under the new technology than with traditional technology. This is due to increased capital requirements for the purchase of fertilizer and the hiring of additional labor requirements. With the new technology, farmers are in a position to pay higher interest rates for borrowed capital in these months. This stresses the need for provision of short term credit with the new technology to enable farmers to break the capital constraint. There was virtually no change in total family labor use. However, total hired labor use increased by 59 percent with the introduction of the new technology. This occurs because the new technology increased labor demand in peak months when family labor is constraining. There was also about 59 percent increase in total cash expenditures.

4.3 Effects of Varying Family Labor and Operating Capital on the Optimum Organization of the Representative Farm under New Technology

An important feature of the results presented in the previous section is the high marginal value products attached to the family labor and operating capital constraints in some months of the year. These high marginal value products would indicate that increases in the amounts of family labor and operating capital available would be profitable. Accordingly, an attempt is made in this section to analyze the economic effects of increases in the amounts of family labor and operating capital. It is hoped that the results of the analysis would provide insights concerning the extent to which labor and capital are limiting factors in agricultural production under the new technology.

These effects are presented as Alternatives I, II and III. In Alternative I, it is assumed that farmers would be willing to work as hard in any month as they do in the peak labor month. The amount of family labor available for work on the family farm in each month is set equal to the number of hours worked in the peak labor month. Other resources and coefficients remain unchanged.

In Alternative II, the opportunity is given to the farmer to augment operating capital through borrowing activities. This was considered reasonable in view of the increasing positive response by commercial banks to government directive to them to provide loans to farmers. Other resources and coefficients were not changed. There was no constraint imposed on the amount of credit that could be obtained. The advantage of such a formulation is that it allows the model to determine the optimum level and timing of credit. This kind of information is of value in the formulation of an appropriate lending policy. The combined effects of increases in the labor supply and the availability of credit was examined in Alternative III. The results are presented in Tables 4.5 and 4.6.

An increase in the amount of family labor, ceteris paribus, effects an expansion in farm income. Total gross margin is increased by 18 percent. There is a 38 percent increase in family labor use and a 35 percent decrease in hired labor use. Total labor use increased by 22 percent. The increased use of family labor resulted in a 13 percent reduction in the returns to family labor indicating diminishing returns to labor. Family labor still constitutes a constraint in May, June, July, August and September as indicated by the marginal value products in these months. These results would tend to indicate that labor is a critically limiting factor in farming under the new technology.

There is also a 27 percent decrease in the use of operating capital due mainly to the reduction in hired labor use. This led to a 10 percent increase in the returns to capital. The marginal value products of operating capital indicate that capital is limiting in March, April, May and June. The marginal value product of land also increased, indicating that land has become more limiting.

The increase in family labor also gave rise to a marked change in the cropping pattern. This consisted of the appearance of a relatively large acreage under peppers (about 19 percent of total cultivated acreage), about

TABLE 4.5

OPTIMUM ORGANIZATION OF THE REPRESENTATIVE FARM WITH NEW TECHNOLOGY AND VARIABLE RESOURCES

	Item	Unit	Existing Resources	Alternatives[a] I	II	III
1	ML/GC	HA				
2	ML/GC (MI)	HA	0.57	0.76	0.59	1.06
3	ML/GC/CP	HA				
4	ML/GC/CP (MI)	HA				
5	PGC	HA				
6	PGC (MI)	HA	0.57	0.35	0.55	
7	MZ/GC (MI)	HA				
8	PMZ (MI)	HA				
9	PGN	HA				
10	PGN (MI)	HA	0.71	0.94	0.80	1.00
11	PTM	HA				
12	PTM (MI)	HA	0.98	0.24	0.89	0.77
13	PPP	HA		0.54		
14	PPP (MI)	HA				
	Total Gross Margin	₦	422.02	498.01	422.49	502.05
	Land	HA	2.83	2.83	2.83	2.83
	Family Labor	HR	1063.50	1467.36	1070.01	1390.28
	Hired Labor	HR	307.03	200.37	344.56	270.69
	Total Labor	HR	1370.53	1667.73	1414.57	1660.97
	Operating Capital	₦	118.53	86.09	131.51	114.21
	Return/Hectare	₦/HA	45.13	36.60	44.25	46.28
	Return/Manhour	₦/HR	0.38	0.33	0.38	0.35
	Return/Operating Capital		1.23	1.35	1.10	1.30

SOURCE: Computed.

[a]Only the amount of family labor available was increased in Alternative I. Alternative II represents an increase in operating capital through credit. In Alternative III there was a simultaneous increase in family labor and operating capital.

TABLE 4.6

MARGINAL VALUE PRODUCTS (MVPs)
UNDER NEW TECHNOLOGY AND VARIABLE RESOURCES

	Resource	Unit	Existing Resources	Alternatives[a] I	II	III
1	Land	HA	60.05	67.48	63.49	73.51
2	FL Mar	HR	0.00	0.00	0.00	0.00
3	FL Apr	HR	0.34	0.00	0.30	0.00
4	FL May	HR	0.26	0.39	0.27	0.32
5	FL Jun	HR	0.38	0.42	0.34	0.34
6	FL Jul	HR	0.27	0.27	0.27	0.27
7	FL Aug	HR	0.30	0.21	0.30	0.30
8	FL Sep	HR	0.00	0.00	0.00	0.00
9	FL Oct	HR	0.00	0.00	0.00	0.00
10	FL Nov	HR	0.22	0.22	0.22	0.22
11	FL Dec	HR	0.24	0.15	0.24	0.21
12	FL Jan	HR	0.00	0.00	0.10	0.00
13	FL Feb	HR	0.00	0.00	0.00	0.00
14	OC Mar	₦	0.26	0.34	0.15	0.15
15	OC Apr	₦	0.26	0.34	0.15	0.15
16	OC May	₦	0.26	0.34	0.15	0.15
17	OC Jun	₦	0.26	0.34	0.15	0.15
18	OC Jul	₦	0.00	0.00	0.00	0.00
19	OC Aug	₦	0.00	0.00	0.00	0.00
20	OC Sep	₦	0.00	0.00	0.00	0.00
21	OC Oct	₦	0.00	0.00	0.00	0.00
22	OC Nov	₦	0.00	0.00	0.00	0.00
23	OC Dec	₦	0.00	0.00	0.00	0.00
24	OC Jan	₦	0.00	0.00	0.00	0.00
25	OC Feb	₦	0.00	0.00	0.00	0.00

SOURCE: Computed.

[a]Only the amount of family labor available was increased in alternative I. Alternative II represents an increase in operating capital through credit. In Alternative III, there was a simultaneous increase in family labor and credit.

33 percent increase in the area under the millet/guinea corn enterprise and a 32 percent increase in groundnut acreage. These increases were achieved at the expense of 39 percent and 76 percent reductions in the acreages under sole crop guinea corn and tomatoes respectively.

The availability of credit does not induce any appreciable change in total gross margins. The important changes are a 12 percent increase in hired labor use and an 11 percent increase in the use of operating capital which resulted in an 11 percent decrease in the returns to capital, indicating diminishing returns to operating capital. The introduction of credit also gave rise to reallocations of the land resource among crop enterprises. Millet/guinea corn and groundnut enterprises increased by 4 percent and 13 percent respectively, while sole crop guinea corn and tomato enterprises were reduced by 4 percent and 9 percent respectively.

The optimum level of credit was 4.39 Naira which was obtained in the month of May.

The effects of a combined increase in family labor and credit availability were a 19 percent increase in total gross margins, a 31 percent increase in family labor use, a 12 percent decrease in hired labor use and a 4 percent increase in operating capital. These led to a slight increase in returns to land, an 8 percent reduction in returns to labor and a 6 percent increase in returns to capital. It also follows that under increased labor and capital availability, capital and land are used more intensively while labor is less intensively used under the new technology.

The marginal value product of land is very high indicating that land is very limiting. An additional unit of land would add 73.51 Naira to the total gross margin.

The optimum cropping pattern is less diversified consisting of 1.06 hectares of millet/guinea corn, 1.00 hectares of groundnut and 0.77 hectares of tomatoes. Sole crop guinea corn is eliminated from the optimum plan. Early in 1976, at the launching of the "Operation Feed the Nation" (OFN) Program, the level of the subsidy on fertilizer was increased to about 75 percent of the state store price. This resulted in a reduction in fertilizer prices from 4 Naira to 1 Naira for a bag of superphosphate (supa) and from 5 Naira to 1.50 Naira for a bag of sulphate of ammonia (sulfa). This is probably one of the highest subsidy rates in the developing world and imposes heavy budget costs on the government. Given the recent drastic cuts in government budgets, it could become increasingly difficult to finance these subsidies. Under the circumstances, it is reasonable to expect the elimination or reduction in the level of the subsidy. This would result in increased fertilizer prices to farmers. Information on the sensitivity of the optimum farm organization to changes in fertilizer prices was obtained from an examination of the stability limits of the optimum plan.

The optimum farm organization used 4.59 bags of superphosphate and 2.5 bags of sulphate of ammonia. The stability limits indicated that the linear programming solution will remain optimal so long as the price of superphosphate does not exceed 8.7 Naira a bag and the price of a bag of sulphate of ammonia does not exceed 11.45 Naira. The primary purpose of the subsidy is to encourage increased use of fertilizer -- the main modern input of the new technology. The results of the study tend to indicate that the elimination of the subsidy would not reduce the optimum level of fertilizer use.

4.4 Comparison of Optimal and Actual Organizations of the Representative Farm under New Technology and Existing Resource Levels

Table 4.7 compares the optimum plan with the actual or observed plan of the representative farm under the new technology and existing resource levels. The comparison shows that the optimum plan differs significantly from the actual or observed plan. Most of the differences between the two farm plans could probably be attributed to the fact that the new technology has only recently been introduced and farmers have not had sufficient time for making all the adjustments necessary to achieve an optimum organization of the farm. Another possible reason for the differences between the optimum and actual farm plans is that some of the crop enterprises (mostly crop mixtures) grown by the farmers could not be included as production alternatives or activities in the linear programming model because

TABLE 4.7

A COMPARISON OF OPTIMAL AND ACTUAL FARM ORGANIZATIONS UNDER NEW TECHNOLOGY AND EXISTING RESOURCE LEVELS

Item	Unit	Optimal	Actual	Change Percent
ML/GC	HA	0.57	0.93	-39
PGC	HA	0.57	0.12	+375
MZ/GC	HA	0.00	0.05	-100
PMZ	HA	0.00	0.08	-100
PGN	HA	0.71	0.10	+610
PTM	HA	0.98	0.24	+308
PPP	HA	0.00	0.20	-100
Unspecified	HA	0.00	1.11	-100
Total Gross Margin	₦	422.02	367.98	+15
Land	HA	2.83	2.83	0
Family Labor	HR	1063.50	1279.00	-17
Hired Labor	HR	307.03	1059.00	-7
Total Labor	HR	1370.53	2338.00	-41
Operating Capital	₦	118.53	180.39	-34
Return/Hectare	₦/HA	45.13	4.32	+945
Return/Manhour	₦/HR	0.38	0.27	+41
Return/Operating Capital		1.23	0.22	+459

Source: Computed.

of data limitations.

The total gross margin of the optimum farm plan represents a 15 per cent increase over the total gross margin of the actual farm plan. The average return per unit of the limiting resources of land, family labor and capital were also significantly higher in the optimum farm plan than in the actual farm plan. But the amounts of labor and capital used in the optimum farm plan were considerably less than the amounts used in the actual farm plan. Total labor use decreased by 41 percent while the use of operating capital decreased by 34 percent. The cropping pattern was less diversified in the optimum farm plan.

Assuming that the results of the linear programming model are valid, the implication is that there is some potential for achieving increases in farm income and obtaining improvements in the efficiency of factor use (as measured by average returns to land, labor and capital) through reallocations of resources on small farms using the new technology. The adjustment process following the introduction of changes in the technology of production in peasant farming could be very slow given the limited knowledge of peasant farmers. A concentrated extension effort could probably speed up this process.

4.5 Summary

The empirical findings presented in this chapter have indicated that most of the crop enterprises (except sole crop pepper and millet/guinea corn/cowpea enterprises) produced on the optimum farm plan are in a better competitive position under the new technology than under traditional technology. The findings also suggest that the removal of the subsidy on fertilizer will not affect the optimum use of fertilizer.

The results indicate that there is some potential for increasing farm income, resource use and productivity in traditional farming with the introduction of modern inputs even in a relatively "bad" crop year. There is evidence that the potential of the new technology could be substantially improved if, for a given family labor supply, the family members were willing to commit more time to farm production. Also, to increase the availability of credit can be important. Labor in peak periods is a limiting factor in farming with the new technology. While the provision of credit may enable farmers to hire additional labor to break the labor bottleneck in these periods, high wage rates and the absence of a landless class of laborers would severely limit the amount of labor that could be hired in practice. It would seem that the long term solution lies in the introduction of simple power equipment and tools that would increase the efficiency of labor use in these periods. Health and nutrition are two important factors that determine the amount of work that individuals can undertake. Programs designed to improve the health and nutrition of small farmers could increase the number of hours that these farmers can spend on work in the family farm.

There are also indications that improvements in farm income as well as in the efficiency of factor use could result from reallocations of resources on small farms that are using the new technology.

This chapter was concerned with the analysis of optimum organizations of the representative farm under traditional and new technologies. The next chapter discusses normative supply functions and price elasticities of supply for selected crops.

CHAPTER V

NORMATIVE SUPPLY FUNCTIONS FOR SELECTED CROPS UNDER TRADITIONAL AND NEW TECHNOLOGIES

5.1 Introduction

The analysis in the previous chapter dealt with changes in the optimal allocation of farm resources when the input-output coefficients in agriculture have changed significantly from their traditional values largely as a result of the adoption of a new technology. The present chapter examines the relative influence of the new technology on product supply and elasticities on a representative farm in the study area. This is achieved through the analysis of the supply functions for groundnut and tomatoes.

Groundnut and tomatoes are the two most important cash crops in the study area. Groundnut has been a major earner of foreign exchange for Nigeria. Nigeria is still the world's largest exporter of groundnut. Between 1962 and 1972, groundnut exports constituted an average of over 20 percent of the total annual value of Nigerian exports (Abalu, 1974). It is also a raw material for some agro-based industries. Tomatoes are consumed locally in large amounts as a vegetable. A relatively huge amount of foreign exchange is spent on importation of tomato products. It has been reported that Nigeria imports about ₦600,000 worth of tomato puree annually (Quinn, 1974). It is also a raw material for local industries concerned with the processing of the crop.

In recent years, there has been an increasing decline in the production of both groundnut and tomatoes. This has adversely affected the country's foreign exchange reserves as well as the development and expansion of some local industries. For example, the groundnut mills in Zaria have, in recent years, been unable to obtain enough groundnut for their full operations. Total purchases of groundnut in 1976 amounted to only 42,000 tons compared to 454,000 tons and 172,000 tons in 1972 and 1975 respectively (Business Times, February 22, 1977:24). The Cadbury tomato processing factory in Zaria was established with a capacity for processing 60 tons of fresh tomatoes per day. The company has only been able to secure about 10 tons of fresh tomatoes daily (Agbonifo, 1974).

The low prices received by farmers for these products has often been cited as one of the causes of the deterioration of their output. Given that farmers are rational and tend to respond positively to increases in commodity prices, policy makers have sometimes been called upon to raise producer prices in order to increase output. Decisions on the appropriate increases in prices require an accurate knowledge of the price elasticity of supply.

It has been reported that the introduction of a new technology could exert a profound influence on the elasticity of farmer price responses (Gotsch and Falcon, 1974:35). Thus previous estimates of price elasticities are unlikely to be a very good guide to the future in areas experiencing rapid technological change. Olayide (1972) has stressed the need for more refined estimates of supply coefficients and elasticities for Nigeria's major crops in order to provide a basis for meaningful public decisions.

A variety of methods have been used to estimate supply functions. Traditionally, product supply functions have been estimated by a "descriptive"[1] approach usually characterized by econometric analysis of aggregate time series data. This approach embodies the estimation of parameters on the basis of past response of producers to changes in relevant economic variables. The results are useful and meaningful to the extent that the econometric techniques are adequate and that producers' past behavior constitutes a reasonable indication of future behavior. Most studies of agricultural supply response in Nigeria have been based on this approach.

Another approach to estimation of the supply function is based on microeconomic analysis using linear programming techniques. This method explains the nature of supply response on the basis of what farmers "could do" to maximize income under given conditions of production and prices. These conditions of production can be derived from controlled

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[1]The term "descriptive" is used since historical behavior of producers is described in this approach.

experimental data or from farm surveys.

Both approaches have their limitations, since neither seems adequate for all purposes and they are supplements rather than substitutes for each other. However, at a time when there are radical changes in the agricultural sector, there are definite advantages in adopting the programming approach. These advantages have been summarized by Buckwell and Hazell (1972:119) as follows:

a) Microeconomic models provide a wealth of information at the farm level, which makes them extremely useful in the evaluation of the impact of policy on many problems of farm management.

b) A programming model necessarily embodies a complete causal system of the functioning of the individual farm. Therefore it is not so susceptible to the problems which arise when the policies to be evaluated involve extrapolation of explanatory variables beyond the range of past experience.

c) A programming model can also take formal account of the fact that most farms produce many products using many resources (i.e., multiproduct/multi-resource farms), and hence is well suited to the total impact of changes in relative prices on the supply of individual products.

These advantages must be weighed against the enormous data requirements of any comprehensive programming model. A further difficulty is that the supply function obtained is normative[2] in the sense that it indicates what a farmer would plan to produce if he intended to maximize income. It is not predictive in the sense that it would explain what he actually would produce. The degree of correspondence between programming results and actual response depends "on the manner that restraints are built into the model to correspond to real world inflexibilities" and/or how closely the assumptions reflect the actual conditions or circumstances in the study area (Heady, 1961). Normative models are generally more helpful in the formulation of policy than in its evaluation. It has been shown that the normative approach may lead to an upward biased estimate of the supply function and elasticities (Anderson and Heady, 1965; Frick and Andrews, 1965; Sheehy and McAlexander, 1965, Wipf and Bawden, 1969). It is not yet clear to what extent normative quantities should be adjusted to closely approximate the actual supply response. According to Heady (1961), the linking of normative farm supply analysis with farmers actual response might involve the analysis of producer panels in an attempt to develop a basis for discounting normative quantities to conform with actual supply decisions. Krenz et al. (1962) have suggested that the supply function could be made "less normative" and "more realistic" by including in the

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[2]Day (1964:442-451) has argued that rational choice need not necessarily imply normative choice because decisions are bounded by the limited extent of the individual's knowledge. Simulating the decision environment in a programming model only leads to the "best that can be done" under the circumstances and not what "necessarily ought to be done".

linear programming model only the production alternatives that the farmer is likely to consider. To the extent that programming results are normative, this does reduce their usefulness for evaluating current agricultural policies (Buckwell and Hazell, 1972).

The normative supply functions estimated in this chapter for the representative farm are derived from the linear programming models presented earlier in the thesis. Parametric (or variable price) programming is used to derive the optimal output of the relevant commodity as its price is varied over an appropriate range while other prices are held constant. Since the programming model also considers alternative products that compete for limited factors of production, the optimal output is not simply a function of the price of the commodity. Krenz et al. (1962) conceptualized the supply function derived from a programming model as follows:

$$Q_A = f(P_1, P_2, P_A, \ldots, P_n, R_1, R_2, \ldots, R_n, a_1, a_2, \ldots, a_n)$$

where Q_A = quantity of commodity A produced as P_A is varied

$P_1 \ldots P_n$ = the net prices of the enterprises in the model

$R_1 \ldots R_n$ = the levels of fixed resources

$a_1 \ldots a_n$ = the coefficients of production for the enterprises in the model.

The functional relationship between the price and quantity of the commodity is discontinuous and in the form of a "step" function. Burt (1964) has defined a step function as "a function such that the range is divided into a finite number of intervals with the dependent variable constant on a given interval". Graphically, the function appears as a series of steps as shown in Figure 5.1. According to Kottke (1967) the optimum solutions and price ranges for all steps in the supply function can be represented by the following equations:

$$
\begin{aligned}
f(P) &= 0 \text{ for } 0 \leq P \leq MC_a \\
&= Q_a \text{ for } MC_a < P \leq MC_b \\
&= Q_b \text{ for } MC_b < P \leq MC_b \\
&= Q_c \text{ for } MC_c < P
\end{aligned}
$$

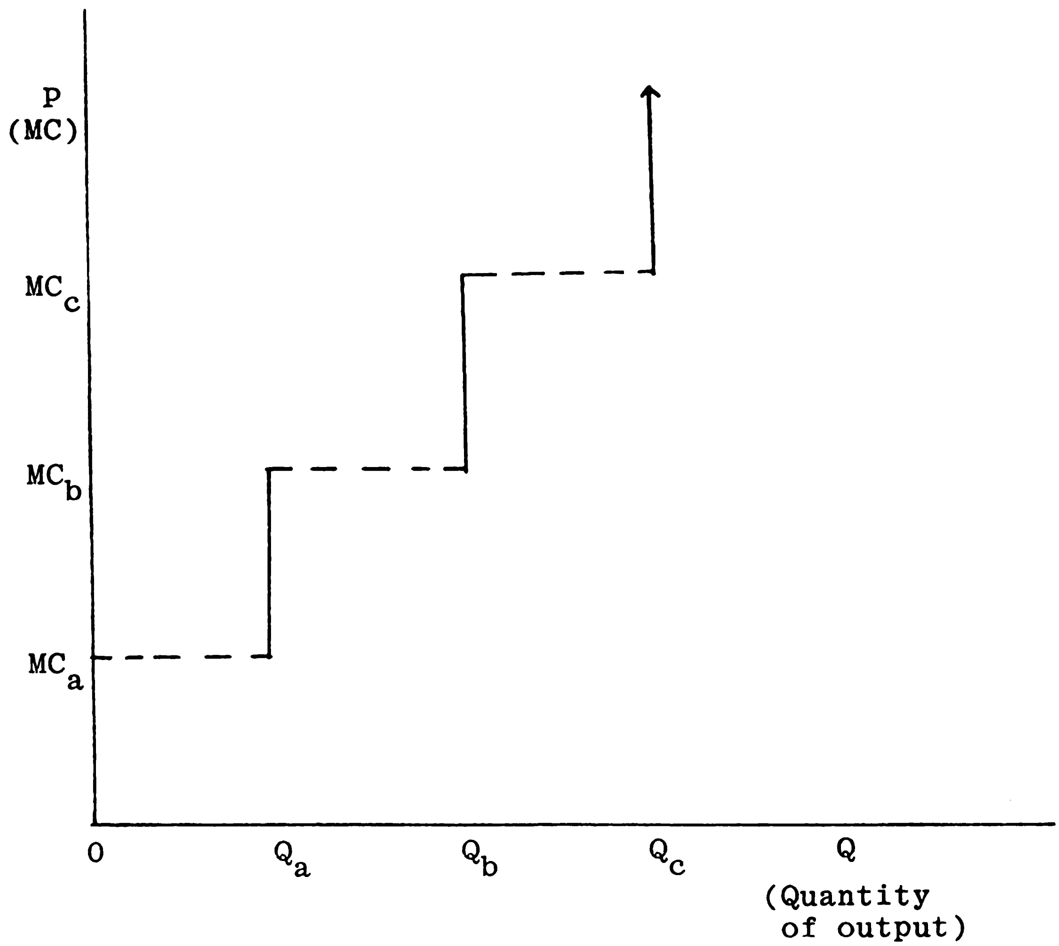
where MC is the marginal cost of producing Q, and P is the price of Q.

The range of the vertical segments of the supply function is based on the profit maximizing criterion P = MR = MC. The optimum cropping pattern, and hence the optimum quantity of the product, holds for all the prices included within the vertical portion of any one step. The "stepped" characteristic of the function results from the finite number of alternatives and rigid resource restrictions used in the programming calculations. The number of "steps and corners" is a function of the number of alternatives and restricting resources. Including more activities and more restrictions may give a normative supply function with more and smaller steps.

Krenz et al. (1962) have argued that the step function more nearly represents the nature of supply functions for

FIGURE 5.1

FARM-FIRM STEP SUPPLY FUNCTION



individual farms than the continuous regression function.[3] They contend that ordinarily farmers change their production patterns only for fairly large changes in expected prices and then in a discrete manner. Few, if any, individuals make adjustments in the continuous manner depicted by a continuous function.

The supply function derived by means of parametric programming is a partial equilibrium, short-run supply function which presupposes that no changes other than the price of the product occur. It is also assumed that farms have achieved an optimum organization before the series of price changes occur. The supply functions are also static in nature since they relate to the present asset structure and technological coefficients of the farm. Supply elasticities associated with normative supply functions are biased upwards when compared with those obtained from time series which represent historical events encompassing all the lags and inflexibilities stemming from uncertainty and resistance to change (Heady, 1961; Wipf and Bawden, 1969).

5.2 Normative Supply Functions for Groundnut and Tomatoes

This section presents the supply functions derived for groundnut and tomatoes from the linear programming models

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[3]A continuous regression function is more typical of an aggregate supply situation, as the steps in the individual supply functions would occur at different prices because of the differences in resources and coefficients of production. Also, the effect of any individual change would be virtually unnoticeable in the typical aggregate supply function found in agriculture.

described in Chapter III. Normative supply functions were derived for the two crops under traditional and new technologies with existing resource levels. The effects of relaxing family labor and credit restrictions on the supply of groundnut and tomatoes under the new technology were also examined. These supply functions must be interpreted cautiously since they were derived from one representative farm based on a purposive sample that was drawn from a limited geographical area.

5.2.1 Groundnut supply functions

In order to obtain the normative supply functions for groundnut, the price of the groundnut selling activity was varied over the range 0.20 Naira per kilogram to 0.40 Naira per kilogram and the corresponding optimum solutions were obtained.[4] The quantities of groundnut produced at each price level were then obtained from the solutions. The relationship between the price of groundnut and the quantity of groundnut produced with traditional technology and existing resources, and with new technology and existing resources are compared in Table 5.1. The comparison reveals the likely effect of the new technology on the supply of groundnut on the representative farm. The introduction of the new technology resulted in a shift in the

[4]The price prevailing in the study area during the survey period was 0.20 Naira per kilogram. The price range used in the supply analysis represents the expected range of price increase.

TABLE 5.1

A COMPARISON OF NORMATIVE SUPPLY FUNCTIONS
FOR GROUNDNUT UNDER TRADITIONAL AND NEW TECHNOLOGIES
WITH EXISTING RESOURCE LEVELS

Traditional Technology		New Technology	
Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)
0.1920-0.2002	159.33	0.1922-0.2552	873.53
0.2002-0.2075	241.96	0.2552-0.2813	972.25
0.2075-0.2127	532.78	0.2813-0.2929	1035.95
0.2127-0.2404	636.44	0.2929-0.3446	1250.50
0.2404-0.3160	854.24	0.3446-0.4019	1266.52
0.3160-0.3463	911.21		
0.3463-0.3805	953.90		
0.3805-1.0484	1000.96		

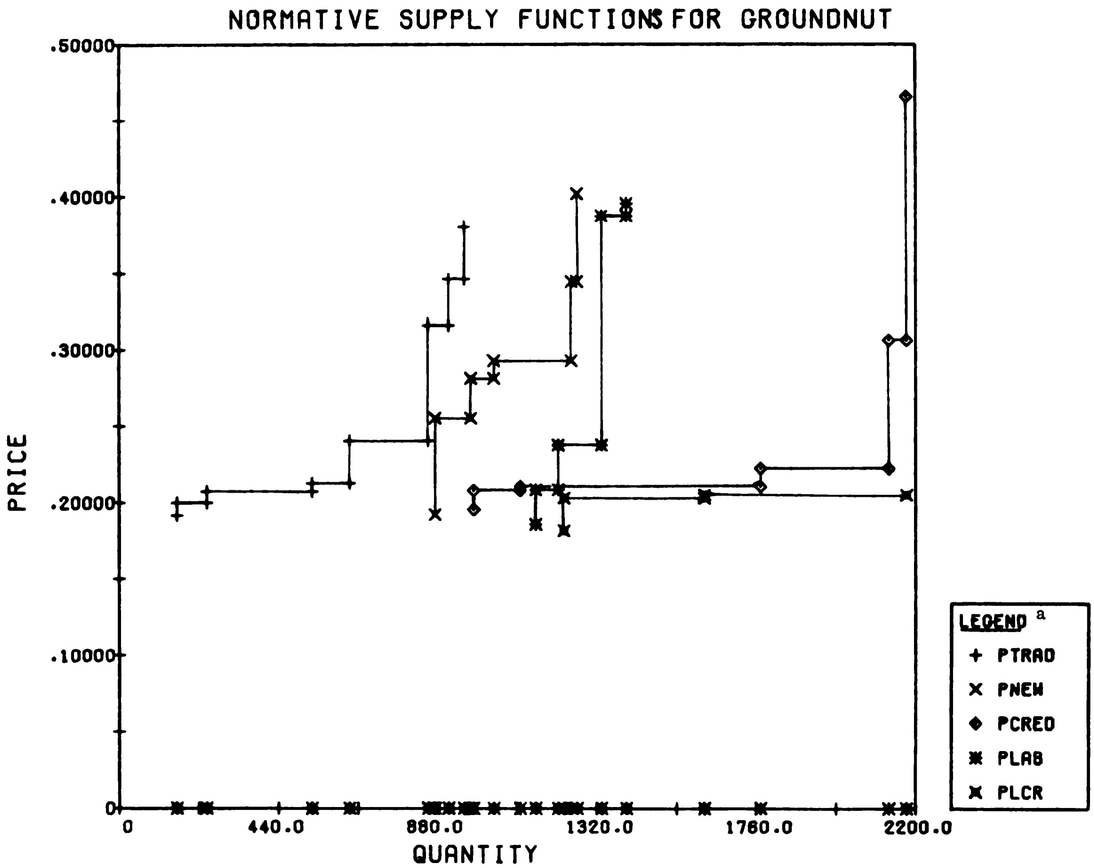
SOURCE: Computed.

supply curve outwards to the right as shown in Figure 5.2. Thus the new technology has the effect of increasing the quantity of groundnut produced at each price. This increase in the quantity of groundnut produced comes from an expansion in the acreage under groundnuts as well as an increase in the yield of groundnut.

Table 5.2 shows the normative supply functions for groundnut with new technology and increased availability of family labor, with new technology and relaxed credit restrictions, and with new technology and a simultaneous increase in the availability of family labor and credit. The table reveals that an increase in family labor or the introduction of credit opportunities or a combination of the two will produce increases in the quantity of groundnut produced at each price under the new technology. Thus the effectiveness of the new technology in achieving increases in the supply of groundnut could be enhanced through an increase in the availability of family labor and/or credit. Normative supply curves under new technology and relaxed family labor and credit restrictions are also shown in Figure 5.2.

At prices above 0.21 Naira per kilogram, the provision of unlimited credit, ceteris paribus, effects a larger increase in the supply of groundnut than would be obtained with the increases in the availability of family labor assumed in this study. The reason for this is that the availability of credit permits the hiring of labor to

FIGURE 5.2



[a]For explanation of abbreviations, see Appendix D.

TABLE 5.2

NORMATIVE SUPPLY FUNCTIONS FOR GROUNDNUT
WITH NEW TECHNOLOGY AND VARIABLE RESOURCES

New Technology and Existing Resources		New Technology and Increased Family Labor		New Technology and Credit		New Technology, Credit and Increased Family Labor	
Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)
0.1922–0.2552	873.53	0.1858–0.2085	1151.93	0.1955–0.2080	980.00	0.1815–0.2030	1230.32
0.2552–0.2813	972.25	0.2085.0.2377	1214.22	0.2080–0.2106	1108.93	0.2030–0.2051	1617.93
0.2813–0.2929	1035.95	0.2377–0.3874	1333.85	0.2106–0.2226	1772.31	0.2051–9000000.39	2174.77
0.2929–0.3446	1250.50	0.3874–0.3954	1402.19	0.2226–0.3063	2126.21		
0.3446–0.4019	1266.52			0.3063–0.4655	2174.77		

SOURCE: Computed.

relax the labor constraint at the peak month which is still restricting under the assumptions made about family labor. The largest increases in the supply of groundnut are obtained with a combined increase in the availability of family labor and credit opportunities. The implication is that the relaxation of both family labor and credit restrictions has the greatest potential for achieving increases in the supply of groundnut under the new technology.

5.2.2 Tomato supply functions

The normative supply functions for tomatoes were also obtained by parametrically varying the price of tomatoes over the range 0.38 Naira per kilogram to 0.76 Naira per kilogram, and obtaining the corresponding optimum solutions.[5] The quantity of tomatoes produced at each price level under traditional and new technologies with existing resources are compared in Table 5.3. As in the case of groundnut, the results indicate that the adoption of the new technology increases the quantity of tomatoes produced at each price. This increase in the supply of tomatoes results from both an expansion in the acreage under tomatoes and an increase in yield.

Table 5.4 shows the normative supply functions for tomatoes with new technology and relaxed family labor and

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[5]The prevailing price in the study area during the survey period was 0.38 Naira per kilogram. The price range used in the supply analysis represents the expected range of price increase.

TABLE 5.3

A COMPARISON OF NORMATIVE SUPPLY FUNCTIONS FOR TOMATOES UNDER TRADITIONAL AND NEW TECHNOLOGIES WITH EXISTING RESOURCE LEVELS

Traditional Technology		New Technology	
Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)
0.3747-0.4331	148.57	0.3390-0.4044	356.23
0.4331-0.4574	192.27	0.4044-0.4707	526.94
0.4574-0.4798	294.59	0.4707-0.4992	551.18
0.4798-0.5927	301.56	0.4992-0.5878	589.50
0.5927-0.6714	352.78	0.5878-1.9300	623.23
0.6714-1312.8334	380.75		

SOURCE: Computed.

TABLE 5.4

NORMATIVE SUPPLY FUNCTIONS FOR TOMATOES
WITH NEW TECHNOLOGY AND VARIABLE RESOURCES

New Technology and Existing Resources		New Technology and Increased Family Labor		New Technology and Credit		New Technology, Credit and Increased Family Labor	
Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)	Price Range (₦)	Quantity (KG)
0.3390-0.4044	356.23	0.3696-0.4054	88.42	0.3521-0.3958	325.96	0.3699-0.4423	280.49
0.4044-0.4707	526.94	0.4054-0.4087	251.43	0.3958-0.4044	356.23	0.4423-0.4582	324.78
0.4707-0.4992	551.18	0.4087-0.4861	466.25	0.4044-0.4594	526.94	0.4582-0.5422	467.09
0.4992-0.5878	589.50	0.4861-0.5591	476.93	0.4594-0.4718	552.58	0.5422-0.5949	563.68
0.5878-1.9300	623.23	0.5591-0.5897	563.68	0.4718-0.4939	600.48	0.5949-0.6817	618.62
		0.5897-0.6342	613.50	0.4939-0.5779	606.00	0.6817-9000000.71	645.88
		0.6342-0.7321	618.04	0.5779-0.6434	645.88		

SOURCE: Computed.

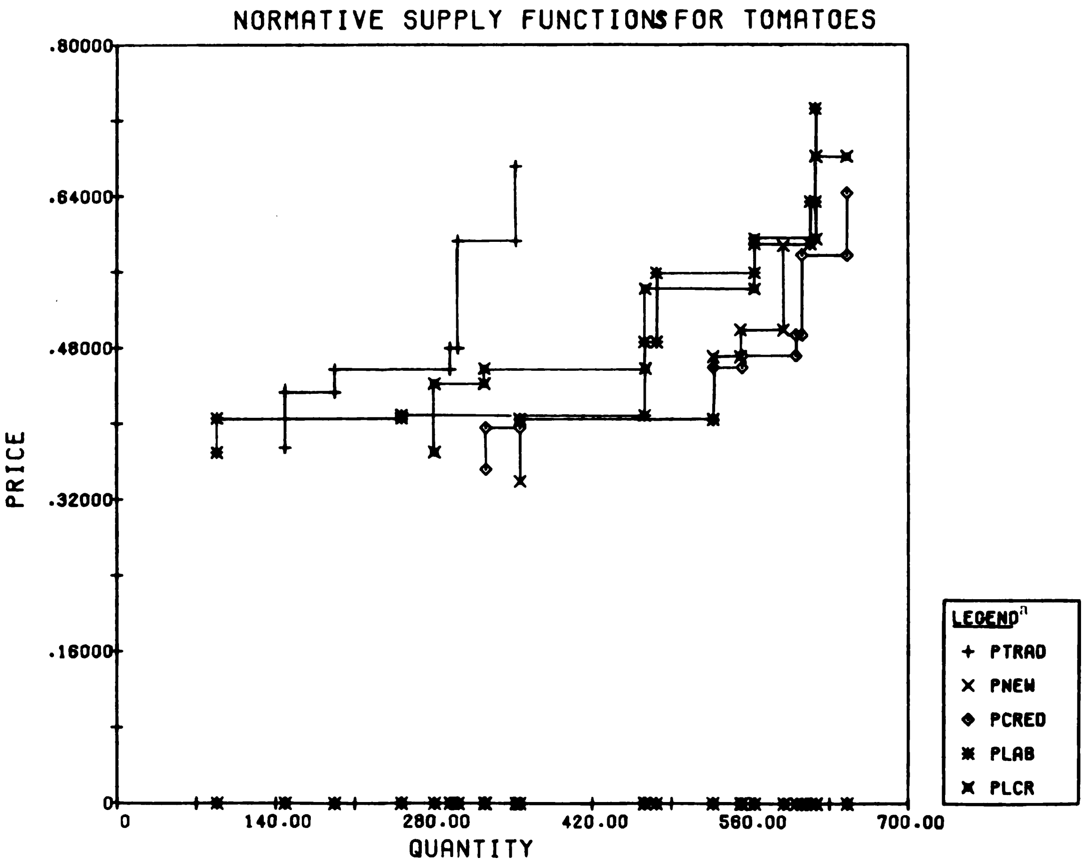
credit restrictions. These supply functions are illustrated in Figure 5.3. An increase in the availability of family labor, ceteris paribus, does not result in an increase in the supply of tomatoes. The introduction of credit induces increases in the supply of tomatoes above the price of 0.46 Naira per kilogram. A combined increase in family labor and credit availability under the new technology results in an increase in the supply of tomatoes above the price of 0.68 Naira per kilogram.

The results in this section show that there is some potential for increasing the supply of groundnut and tomatoes through the introduction of the new technology. The results also indicate that a combined increase in the availability of family labor and credit opportunities will result in larger increases in the supply of groundnut under the new technology than either an increase in family labor alone or the introduction of credit only. This is also true for tomatoes, but only at prices above 0.68 Naira per kilogram.

5.3 The Effect of New Technology on Price Elasticities of Supply for Groundnut and Tomatoes

The derivation of some measure of elasticity is frequently the object of supply analysis. An important limitation of the step supply function, such as those presented in the previous section, is that a meaningful measure of elasticity cannot be obtained as readily as with a smooth, continuous supply function. Although the

FIGURE 5.3



[a]For explanation of abbreviations, see Appendix D.

relative lengths of perfectly inelastic segments and the relative gaps between the vertical segments may reflect the degree of producers' responsiveness, it is difficult to generalize such responsiveness into a single elasticity measure (Kottke, 1967:115). Therefore, step functions are often transformed into smooth, continuous functions in order to facilitate the calculation of valid measures of elasticity. Even though the smoothing process of the step function enables a precise measure of elasticity to be derived, much of the intrinsic behavior of the farmers is obliterated. Accordingly, it would be adviseable to retain the steps for purposes of correct and practical decision-making at the farm level (ibid.).

A number of methods have been employed in obtaining smooth continuous functions from step functions. Ladd and Easley (1959) and Dean et al. (1963) used free hand method. Another method is the use of the optimum quantities and their corresponding prices as the data for a least squares regression analysis to estimate a continuous function. This method has been used by Cesal (1966) and Krenz et al. (1960) and is used in this section to generate price elasticities of supply for groundnut and tomatoes with traditional and new technologies.

A continuous supply function is fitted to the data obtained by parametric programming and presented as step functions in section 5.2. The model used is of the form

$$Q = f(P)$$

where

Q = quantity of the commdity in kilograms per year

P = price of the commodity in Naira per kilogram

Each step of the function is treated as an observation on the dependent variable. It is assumed that the midpoints of the vertical portions of the steps are more stable with respect to price changes and are therefore used as values for the independent variable. However, since such data do not meet the assumptions of normality and independence, statistical inference and probability statements cannot be made.

Different functional forms -- linear, double log, semi-log -- were fitted to the data.[6] The "best" fit was obtained with the semi-log functional form in all cases except for groundnut with new technology and existing resources where the double log gave the "best" fit.[7] The estimated supply equations for groundnut and tomatoes are presented in Tables 5.5 and 5.6, respectively. The $\bar{R}^2$ are high and most of the coefficients would be significant at the 1 percent and 5 percent levels if the required assumptions

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[6]The fitted equations were of the following form:

Linear $\quad Q = \beta_o + \beta_1 P$

Double log $\quad \ln Q = \beta_o + \beta_1 \ln P$

Semi-log $\quad Q = \beta_o + \beta_1 \ln P$

[7]The size of the adjusted R square ($\bar{R}^2$), the sign of the price coefficient and statistically significant F-value for the regression mean square were the criteria of "best" fit.

TABLE 5.5

ESTIMATED SUPPLY EQUATIONS FOR GROUNDNUT

Technology and Resource Level	Functional Form	β_o	β_1	$\bar{R}^2$	$F_{\alpha,\gamma}$
Traditional Technology and Existing Resources	Semi-log	2231.43	1172.81**	.80	24.49 (1,5)
New Technology and Existing Resources	Double log	2890.00	0.81*	.88	30.71 (1,3)
New Technology and Increased Availability of Family Labor[a]	Semi-log	1746.27	360.39**	.99	319.34 (1,2)
New Technology and Credit Availability	Semi-log	3928.42	1645.57	.50	4.96 (1,3)
New Technology and Increased Family Labor and Credit Availability[b]	Linear	-5086.41	32848.305	0	1.00 (1,0)

**Significant at 1 percent if the assumptions for regression were met.

*Significant at 5 percent if the assumptions for regression were met.

SOURCE: Computed.

[a and b]It was assumed that family members would be willing to work as hard each month as they do in the peak labor month. The number of manhours of family labor available each month was set equal to the number of manhours actually worked during the peak month.

TABLE 5.6

ESTIMATED SUPPLY EQUATIONS FOR TOMATOES

Technology and Resource Level	Functional Form	β_o	β_1	$\bar{R}^2$	$F_{\alpha,\gamma}$
Traditional Technology and Existing Resources	Semi-log	573.33	443.53*	.78	15.50 (1,3)
New Technology and Existing Resources	Semi-log	981.90	604.47	.84	17.00 (1,2)
New Technology and Increased Availability of Family Labor[a]	Semi-log	1012.75	848.64**	.80	25.59 (1,5)
New Technology and Credit Availability	Semi-log	1033.66	677.12**	.79	23.58 (1,5)
New Technology and Increased Family Labor and Credit Availability[b]	Semi-log	997.79	802.96**	.96	101.99 (1,3)

**Significant at 1 percent if the assumptions for regression were met.

*Significant at 5 percent if the assumptions for regression were met.

SOURCE: Computed.

a and b It was assumed that family members would be willing to work as hard each month as they do in the peak labor month. The number of manhours of family labor available each month was set equal to the number of manhours actually worked during the peak month.

had been met. Elasticities of supply with respect to own price were calculated for groundnut and tomatoes using the equation

$$e_s = \frac{\delta Q}{\delta P} \cdot \frac{P}{Q}$$

Price elasticities of supply for groundnut under traditional and new technologies were calculated at different price-quantity points within the price range 0.20 Naira per kilogram to 0.40 Naira per kilogram. These price elasticities of supply are shown in Table 5.7. The elasticity coefficients are positive and indicate the percentage increase in the quantity of groundnut produced in response to a 1 percent increase in price. With traditional technology, the price elasticity of supply for groundnut varies from 3.41 at the price of 0.20 Naira per kilogram to 1.17 at the price of 0.35 Naira per kilogram. Since the elasticity coefficients are greater than one, the supply of groundnut over the stated price range is elastic. The price elasticity of supply with the new technology and existing resources is constant at 0.81 within the price range used in the analysis. The elasticity coefficients are less than one so that the supply of groundnut over the stated price range is slightly inelastic under the new technology. Thus the introduction of new technology resulted in a decrease in the price elasticity of supply for groundnut at all prices within the stated price range. This means that the percentage change in the quantity of groundnut produced in response to a 1 percent change in its price, over the price

TABLE 5.7

PRICE ELASTICITIES OF SUPPLY FOR GROUNDNUT

Price (₦/KG)	ELASTICITIES				
	Traditional Technology and Existing Resources	New Technology and Existing Resources	New Technology and Increased Family Labor	New Technology and Credit Availability	New Technology Credit and Increased Family Labor
0.20	3.41	0.81	0.31	1.29	4.43
0.23	2.31	0.81	0.30	1.09	--
0.26	1.80	0.81	0.29	0.96	--
0.29	1.50	0.81	0.28	0.87	--
0.32	1.31	0.81	0.27	0.80	--
0.35	1.17	0.81	0.26	0.75	--

SOURCE: Computed.

range used in the analysis, is higher under traditional technology than with the new technology.

Table 5.7 also shows that the price elasticities of supply for groundnut production under the new technology are influenced by the amount of family labor available and the availability of credit. Supply was very inelastic with an increase in family labor. With the introduction of credit, supply was only slightly inelastic at prices above 0.23 Naira per kilogram.

The effect of the new technology on price elasticities of supply for tomatoes is similar to that of groundnut as shown in Table 5.8 where price elasticities of supply for tomatoes at different price-quantity points within the price range 0.38 Naira per kilogram to 0.76 Naira per kilogram are presented. The introduction of the new technology resulted in a decrease in the elasticity coefficient at each price. With traditional technology the elasticity coefficients varied from 2.66 at the price of 0.40 Naira per kilogram to 1.16 at the price of 0.65 Naira per kilogram. Under new technology and existing resources the price elasticity of supply for tomatoes varied from 1.41 at the price of 0.40 Naira per kilogram to 0.84 at the price of 0.65 Naira per kilogram. Increases in the availability of family labor and the introduction of credit opportunities gave rise to higher price elasticities of supply for tomatoes under the new technology. In all cases, the elasticity coefficients decreased with increases in price within the

TABLE 5.8

PRICE ELASTICITIES OF SUPPLY FOR TOMATOES

	ELASTICITIES				
Price (₦/KG)	Traditional Technology and Existing Resources	New Technology and Existing Resources	New Technology and Increased Family Labor	New Technology and Credit Availability	New Technology Credit and Increased Family Labor
0.40	2.66	1.41	3.61	1.64	3.06
0.45	2.02	1.21	2.53	1.37	2.25
0.50	1.67	1.07	2.00	1.20	1.82
0.55	1.44	0.97	1.68	1.08	1.55
0.60	1.28	0.90	1.47	0.98	1.37
0.65	1.16	0.84	1.31	0.91	1.23

SOURCE: Computed.

price range used in the analysis.

Although the percentage changes in the quantities of groundnut and tomatoes produced in response to a 1 percent change in own price (as indicated by their elasticities) are lower for the new technology than for traditional technology, it does not necessarily mean that a given price increase would be more effective in achieving increases in output under traditional technology than under the new technology. In circumstances where the policy objective is to achieve higher absolute increases in output, the absolute changes in quantity produced in response to a 1 percent change in price constitutes a more relevant indication of the effectiveness of a price increase than the elasticity (which is a measure of the percentage change in quantity in response to a 1 percent change in price). The absolute changes in the quantities of groundnut and tomatoes produced in response to a 1 percent change in own price are shown in Tables 5.9 and 5.10, respectively.

Table 5.9 shows that the absolute changes in the quantity of groundnut produced in response to a 1 percent change in its price are lower under new technology and existing resources than under traditional technology at all prices within the price range used in the analysis. This implies that groundnut price increases, ceteris paribus, would be more effective in inducing increases in the output of groundnuts under traditional technology than with new technology and existing resources. This is probably due to the

TABLE 5.9

ABSOLUTE CHANGES IN OUTPUT OF GROUNDNUT
IN RESPONSE TO A 1 PERCENT CHANGE IN ITS PRICE

Price (₦/KG)	CHANGES IN OUTPUT (KG)				
	Traditional Technology and Existing Resources	New Technology and Existing Resources	New Technology and Increased Family Labor	New Technology and Credit Availability	New Technology Credit and Increased Family Labor
0.20	11.73	6.37	3.62	16.51	65.71
0.23	11.73	7.13	3.65	15.24	--
0.26	11.73	7.88	3.66	16.43	--
0.29	11.69	8.59	3.64	16.46	--
0.32	11.73	9.32	3.61	16.43	--
0.35	11.70	10.04	3.57	16.51	--

SOURCE: Computed.

higher acreage devoted to groundnut in the new technology farm plan at the initial price. Since land is a constraint on production, the response of groundnut production to increases in its price is achieved by substitution of groundnut for other enterprises in the farm organization. A relatively high acreage under groundnut at the initial price would reduce the degree of substitution of groundnut for other crop enterprises as the price of groundnut is increased.

Absolute changes in the quantities of groundnut produced in response to a 1 percent change in its price with the new technology were also influenced by an increase in the availability of family labor and the introduction of credit. The highest absolute changes in the quantity of groundnut produced in response to a 1 percent change in its price were obtained when credit was made available with the new technology, even though price elasticity coefficients were highest under traditional technology (see Table 5.7). The elasticity coefficients were lower under new technology and relaxed credit restrictions than under traditional technology because of the higher base quantities in the former.

Table 5.10 reveals that within the price range used in the analysis higher absolute changes in the output of tomatoes in response to a 1 percent change in its price are obtained under the new technology than with traditional technology, although the new technology had lower price elasticity coefficients. The implication is that, under

TABLE 5.10

ABSOLUTE CHANGES IN OUTPUT OF TOMATOES
IN RESPONSE TO A 1 PERCENT CHANGE IN ITS PRICE

Price (₦/KG)	CHANGES IN OUTPUT (KG)				
	Traditional Technology and Existing Resources	New Technology and Existing Resources	New Technology and Increased Family Labor	New Technology and Credit Availability	New Technology Credit and Increased Family Labor
0.40	4.44	6.04	8.49	6.78	8.02
0.45	4.43	6.04	8.48	6.75	8.02
0.50	4.44	6.02	8.49	6.77	8.03
0.55	4.44	6.02	8.49	6.79	8.03
0.60	4.44	6.06	8.51	6.74	8.05
0.65	4.43	6.06	8.48	6.75	8.02

Source: Computed.

the assumptions made in this study, increases in the price of tomatoes are more effective in inducing increases in the output of tomatoes under the new technology than with traditional technology. One possible explanation for this is that the decreases in the degree of substitution of tomatoes for other crop enterprises (that result from a higher acreage under tomatoes in the new technology farm plan at the initial price) were offset by higher yields under the new technology. The lower price elasticity coefficients obtained under the new technology are due to higher base quantities resulting from a larger acreage and higher yields. Table 5.10 also shows that increases in the price of tomatoes are most effective in increasing the output of tomatoes under the new technology when the amount of family labor available for farm activities is also increased.

The results in this chapter indicate that, under the assumptions made in this study, the introduction of the new technology would increase the optimal level of output of groundnut and tomatoes at current prices (shifts in the supply curves), but would decrease the elasticity of farmer price responses. Within the price range used in the analysis, absolute changes in the quantity of tomatoes produced in response to a given percentage change in its price are higher with the new technology than with traditional technology. This is also true for groundnut when credit is made available with the new technology.

In the next chapter the major empirical findings concerning the effects of the new technology on key farm variables are summarized and the policy implications of these findings are discussed. The limitations of the study are also presented and some suggestions are made for further research.

CHAPTER VI

SUMMARY, POLICY IMPLICATIONS, LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER RESEARCH

6.1 Summary

Neither the present position of Nigerian agriculture nor its recent performance can be regarded as satisfactory. Agricultural output is inadequate and producer incomes and resource productivities are relatively low. Not only have these problems handicapped the capacity of the agricultural sector to contribute significantly to general economic development, but they also constitute impediments to the potential growth of other sectors especially that section of the industrial sector which relies on agriculture for its raw materials.

Technological stagnation has been identified as the primary cause of the poor performance of the agricultural sector. In order to improve the conditions in the sector and enhance its capacity to perform the roles expected of it in the Third National Development Plan 1975-80, the governments of Nigeria have embarked on a series of programs aimed at raising the level of agricultural production technology on small farms. A major strategy in this technological improvement crusade has been the introduction of modern inputs such as chemical fertilizers, improved seed varieties, pesticides and improved cultural practices into the traditional farming system.

The use of these inputs could significantly alter the relative resource requirements of crop enterprises as well as their relative net revenues. Such changes in the technical and economic circumstances within which peasant farmers make their decisions about resource allocation could substantially affect the pattern of allocation of farm resources. This could have pronounced effects on key farm variables such as cropping pattern, income, employment and resource productivity.

There is paucity of <u>relevant</u> quantitative information on the changes in farm income, cropping patterns and resource productivity that are likely to be associated with the use of these inputs on the small farm. Since the ultimate objective of government is to raise farm income, output and resource productivity, this information is needed to provide an adequate basis for the evaluation of current agricultural policies and strategies.

The purpose of this study was to analyze empirically the changes in farm income, enterprise combination, resource use and productivity and the elasticity of supply for selected crops that may be associated with the adoption of a new technology (embodied in the use of modern inputs) on a small farm in Northern Nigeria.

Static linear programming provided the framework for analyzing the economics of resource use under traditional and new technologies. The structure of the linear programming model is described in Chapter III. The model was formulated to maximize total gross margins subject to meeting the minimum grain consumption requirements of the household. The activities in the model included crop production and selling activities, labor hiring activities, capital borrowing activities, fertilizer buying and grain consumption activities. Transfer activities were also included to transfer surplus capital from one month to another. The model was used to generate optimum farm plans under traditional and new technologies. A comparative analysis of these farm plans was used to obtain indications of the direct change in farm income, farm resource productivity and cropping pattern that could result from the interpolation of the elements of the new technology into the existing farming system.

The data that provided the empirical base for the study were obtained from both secondary and primary sources. Data on the traditional technology had to be assembled from secondary sources consisting of published reports of farm management surveys undertaken in the area by researchers at the Institute for Agricultural Research (IAR) Samaru. The major source of data for determining the resource base and the production information on the new technology was a farm survey conducted by the author under the auspices of the Guided Change Project (GCP) of the Department of Agricultural Economics. In that survey, a purposive sample of 50 farming households from Pan Hauya Village in Giwa

District were interviewed once a week during the 1977-78 cropping season.

The unit of analysis was a representative farm based on an average farm derived from farms in the sample that were less than six hectares in size. The representative farm was 2.83 hectares in size, used 1279 manhours of family labor, 1059 manhours of hired labor, 180.39 Naira of operating capital, 3.7 bags of superphosphate and 2.6 bags of sulphate of ammonia.

The results of the study indicate that the new technology has some potential for achieving increases in farm income, resource use and productivity. Under the assumptions made in this study, the adoption of the new technology increased total gross margins on the representative farm by 16 percent. Efficiency of factor use, measured by average returns, was also increased with the introduction of the new technology. There were increases of 81 percent, 15 percent and 12 percent in returns per unit of land, returns per unit of labor and returns per unit of operating capital, respectively.

The cropping pattern was less diversified under the new technology. Pepper was not included in the optimum farm plan of the new technology. All the crop enterprises included in the model, except pepper and millet/guinea corn/ cowpea enterprises, were in a better competitive position when produced with modern inputs. Pepper and millet/guinea corn/cowpea enterprises were relatively more labor intensive and were probably eliminated from the optimum farm plan because labor is more constraining in peak months with the new technology. With existing levels of resources, the marginal value products associated with land, with family labor in June and December, and with operating capital in May and June significantly increased, indicating that these resources became more constraining as the new technology was introduced. The adoption of the new technology induced a 7.5 percent increase in total labor use. This was due mainly to a 59 percent increase in hired labor use. The increase in hired labor led to a 59 percent increase in the use of operating capital under the new technology.

The stability limits of the optimum solution indicated that the optimum level of fertilizer use was not very sensitive to changes in fertilizer price. An increase in fertilizer prices by the amount of the subsidy did not affect the optimum quantity of fertilizers used on the representative farm. The implication is that under existing conditions, the removal of the subsidy, ceteris paribus, may not affect the amounts of fertilizer used.

Three alternatives using variants of the new technology model were defined for investigating the extent to which labor and operating capital are limiting factors in farming with the new technology. In Alternative I, it was assumed that farmers would be willing to work as hard in any month as they do in the peak labor month. Therefore the amount of family labor available for work on the family farm in each month was set equal to the number of hours worked in the peak labor month. In Alternative II, the opportunity was given to the farmer to augment operating capital through borrowing activities. The combined effects of an increase in the amount of family labor available each month and the introduction of credit was examined in Alternative III. In each case, other resources and coefficients remained unchanged. The results indicate that labor in peak months is a critically limiting factor in agricultural production with the new technology. An increase in the amount of family labor available for work on the family farm each month resulted in an 18 percent increase in total gross margins, a 22 percent increase in total labor use and a 27 percent decrease in cash expenses due mainly to a 35 percent decrease in hired labor use. The introduction of credit opportunities at 15 percent annual interest rate did not significantly increase income but it effected substantial reallocations of the land resource, a three percent increase in total labor use due primarily to a 12 percent increase in the use of hired labor. The use of operating capital increased by 11 percent. With a simultaneous increase in family labor and credit availability, total gross margins increased by 19 percent, total labor use increased by 21 percent but the use of operating capital decreased by four percent because of a 12 percent decrease in hired labor use.

Parametric programming was used to generate normative supply functions for groundnut and tomatoes (the two most

important cash crops in the study area) under traditional and new technologies. These step supply functions were transformed into smooth, continuous functions by means of regression analysis and price elasticities of supply were calculated for the two crops. Since agricultural policy may sometimes be concerned with absolute changes in the level of output, the elasticity coefficients were converted into absolute changes in output in response to a one percent change in price in order to provide some indication of the effectiveness of price increases in achieving increases in the absolute level of output of groundnut and tomatoes. The effects of relaxing family labor and credit restrictions on the supply and price elasticities of supply for the two crops under the new technology were also investigated. The results show that for the assumptions made in this study the introduction of the new technology on a representative small farm would give rise to expansion in the output of the crops at each price (shifts in the supply curves). Further increases in the supply of groundnut would be obtained if increases in family labor, or credit, or both were made available with the new technology. This would also be true for tomatoes but only at prices above 0.68 Naira per kilogram. Within the price range used in the analysis, the introduction of the new technology resulted in decreases in the price elasticities of supply at each price for the two crops. However, the absolute changes in the quantity of tomatoes produced in response to a given percentage change in its

price were higher under the new technology than with traditional technology. This was also true for groundnut when credit was made available with the new technology.

6.2 Policy Implications

Some policy implications of the results of the study are presented in this section on the assumption that the data, the analytical framework, and the unit of analysis all have reasonable degree of validity. The quantitative estimates obtained may not be the exact magnitudes but they could provide relevant insights and guidelines that would aid the understanding of the role of new technology in the development of traditional agriculture.

The results of the study indicate that there is some potential for achieving significant increases in farm income, output, resource use and productivity through the adoption of the new technology. Therefore, planning for agricultural development should continue to focus on the design and implementation of programs aimed at facilitating expansion in the use of the technology among small farmers. Specifically programs concerned with making the inputs or elements of the technology available to small farmers at the right time, programs aimed at improving profitable marketing of output and extension programs designed to improve the farmer's familiarity with and competence in the use of the technology need to be expanded.

The results of the study have also indicated that labor in peak months is a critically limiting factor in agricultural production with the new technology. The potential for achieving increases in farm income, output and resource use and productivity is substantially improved when measures are taken to break the labor bottleneck in peak periods. One such measure would be the provision of credit opportunities for small farmers to enable them to hire the additional labor required during such periods. The capacity of credit availability to enhance the potential of the new technology for achieving improvements in output is demonstrated by the results of the study. The introduction of credit opportunities with the new technology substantially increased the output at each price as well as the effectiveness of price increases in inducing absolute increases in output. This emphasizes the complementarity of credit services and the new technology, and suggests that credit should be made an important component of the new technology package. The current policies of the Nigerian Agricultural Bank make it impossible for small farmers to benefit from the services of the Bank. These restrictive policies should be reviewed and necessary changes introduced to enable small farmers to utilize the credit services provided by the Bank. However, given high and increasing wage rates, the absence of a landless class of laborers, and the problems that have frequently frustrated the administration of credit programs in developing countries (problems such as low repayment rates and the diversion of credit funds for non-farming purposes), the provision of credit could only be a short-term solution to the labor bottleneck problem.

Another means of increasing the amount of labor available for farming at peak periods would be for farmers to work longer hours. The results of this study have indicated that increases in the amount of family labor available for work on the farm would significantly increase farm income, resource use and productivity under the new technology. Within the price range used in the analysis, relaxation of family labor restrictions also resulted in an increase in the supply of groundnut and improved the effectiveness of price increases in inducing increases in the output of tomatoes. Increases in the amount of family labor available for work on the farm is considered feasible because of the relatively low average daily family labor inputs in the study area. While the availability of off-farm employment opportunities may partly explain this situation, it is believed that poor health and nutrition severely limit the physical ability of peasant farmers to work for long hours on the farm. Programs designed to improve the health and nutrition of small farmers could increase the amount of work that these farmers can undertake. Such programs have so far not been a major component of the agricultural development strategy. It may be necessary to make nutrition and health improvement programs an integral part of the efforts aimed at improving the conditions in the agricultural sector.

The long-term solution to the labor problem in farming with the new technology is likely to consist of measures, such as selective mechanization of farm operations, that significantly improve the efficiency of labor utilization during the peak periods. Analysis of the impact of alternative forms and levels of mechanizations on desired cropping patterns, production and resource use, as well as their financial returns, would be required.

6.3 Limitations and Suggestions for Further Studies

The effects of technological change are location and time specific. The response to fertilizer is influenced by climatic conditions and may vary from year to year in the same location. There are also fluctuations in fertilizer supplies. An important limitation of this study has been the reliance on one year's data and failure to analyze the consequences of variations in input-output coefficients. This limits the scope of the application of the results of the study. The results of the study need to be complemented with the results of similar studies in other areas and in different years in order to obtain a comprehensive picture that permits broad generalizations to be made concerning the effects of technological change. Therefore there is the need for studies of the effects of the new technology in other farming systems.

Another limitation of the study has been the static nature of the analysis. Static models are useful for a comparative analysis of equilibrium situations and even then when these situations are sufficiently far apart in time to allow equilibrium to be attained. Farmers operate in a dynamic world. Unlike dynamic models, static models cannot provide detailed information about the adjustment path of supply response in proceeding from one set of policy variables to another. Such information is likely to be of greater use for policy evaluation than simple knowledge of the supplies forthcoming under equilibrium situations.

Besides, the approach adopted in the study provides only partial equilibrium solutions. To expect the prices of other products to remain constant while the price of one product changes is strictly a short-run phenomenon; it assumes complete independence between products, a situation that is not common in agriculture. In practice, many products have competitive, supplementary and complementary relationships in the production process. For example, increases in, say, groundnut prices and production would cause shifts to groundnut from competing crops, resulting in reduced supplies and, other things being equal, increased prices for the competitive crops. The converse would accompany falling groundnut prices and production. Hence, competitive product prices tend to be positively correlated: A rise or fall in groundnut price tends to pull competing product prices in the same direction. This condition has obviously been violated in the analysis in this study, in which competing crop prices were held fixed as the price of groundnut was varied.

The usefulness of the study is also limited by its failure to provide any insights concerning the distributive effects of the new technology. This is an important area for study given the governments' concern with equity considerations. Research is thus required to shed some light on the income distribution effects of the new technology.

Most of these limitations are not restricted to the farm planning and supply estimation tools used in this study. The same limitations would also be associated with other commonly used techniques of farm planning and supply estimation. Despite the limitations, the results of the study provide useful insights about the likely microeconomic effects of technological change on small farms in Giwa District of Northern Nigeria, and broaden the scope of knowledge concerning the role of new technology in peasant agriculture.

APPENDICES

APPENDIX A

AVERAGE HECTARES DEVOTED TO DIFFERENT CROP ENTERPRISES UNDER TRADITIONAL TECHNOLOGY

APPENDIX A

TABLE A.1

AVERAGE HECTARES DEVOTED TO DIFFERENT CROP ENTERPRISES UNDER TRADITIONAL TECHNOLOGY

Crop Enterprise	Average Hectares
Guinea corn (GC)	0.050
Groundnut (GN)	0.030
Okra (OK)	0.005
Pepper (PP)	0.002
Tomatoes (TM)	0.002
Other sole crops	0.321
Millet/Guinea corn (ML/GC)	0.940
Other 2-crop mixtures	0.410
Millet/Guinea corn/Cowpeas (ML/GC/CP)	0.130
Other 3-crop mixtures	0.490
Mixtures with more than 3 crops	0.490
TOTAL	2.87

SOURCE: Col. 5, Table A-1, page A1, Appendix A. D. W. Norman: An Economic Survey of Three Villages in Zaria Province: Input-Output Study. Vol. 1 Text. Samaru Miscellaneous Paper No. 37. I.A.R. Samaru. 1972.

APPENDIX B

NUMBER OF SAMPLE FARMERS
GROWING DIFFERENT CROP ENTERPRISES

APPENDIX B

TABLE B.1

NUMBER OF SAMPLE FARMERS GROWING DIFFERENT CROP ENTERPRISES

	Crop Enterprise	Number of Farmers Growing Crop Enterprise
1	Millet	1
2	Guinea corn	13
3	Maize	10
4	Groundnut	12
5	Tomatoes	19
6	Peppers	15
7	Okra	6
8	Sugar cane	1
9	Millet/Guinea corn	40
10	Maize/Guinea corn	8
11	Millet/Okra	1
12	Tomatoes/Guinea corn	2
13	Rice/Peppers	1
14	Cassava/Yams	1
15	Tomatoes/Peppers	5
16	Groundnut/Cowpeas	2
17	Groundnut/Millet	1
18	Maize/Pepper	1
19	Maize/Okra	2
20	Guinea corn/Sweet potatoes	1
21	Peppers/Sweet potatoes	2
22	Okra/Peppers	2
23	Millet/Rice	1
24	Peppers/Guinea corn	1
25	Groundnut/Rice	1
26	Rice/Guinea corn	1
27	Tomatoes/Sweet potatoes	1
28	Groundnut/Guinea corn	2
29	Okra/Guinea corn	2
30	Maize/Cowpeas	1
31	Millet/Sugar cane	1
32	Guinea corn/Cocoyam	1
33	Onion/Rice	1
34	Cotton/Sweet potatoes	1
35	Bambara nuts/Cowpeas	1
36	Okra/Groundnut	2
37	Groundnut/Sugar cane	1
38	Okra/Rice	1
39	Millet/Guinea corn/Maize	1
40	Groundnut/Sweet potatoes/Cowpeas	1
41	Groundnut/Sweet potatoes/Peppers	1
42	Peppers/Tomatoes/Guinea corn	1

TABLE B.1 (continued)

	Crop Enterprise	Number of Farmers Growing Crop Enterprise
43	Yams/Maize/Rice	1
44	Rice/Groundnut/Maize	1
45	Millet/Guinea corn/Okra	2
46	Millet/Guinea corn/Pumpkin	1
47	Tomatoes/Okra/Cowpeas	2
48	Tomatoes/Guinea corn/Cocoyams	1
49	Millet/Guinea corn/Cowpeas	4
50	Groundnut/Guinea corn/Cowpeas	1
51	Tomatoes/Peppers/Sweet potatoes	1
52	Millet/Guinea corn/Peppers	2
53	Tomatoes/Pepper/Okra	1
54	Tomatoes/Pepper/Maize	2
55	Maize/Okra/Pepper	1
56	Millet/Guinea corn/Okra/Pepper	1
57	Onions/Peppers/Tomatoes/Cowpeas	1
58	Tomatoes/Cassava/Yams/Rice	1
59	Tomatoes/Peppers/Bambara nuts/ Sweet potatoes	1
60	Groundnut/Guinea corn/Cotton/ Sweet potatoes	1
61	Maize/Tomatoes/Okra/Rice	1
62	Tomatoes/Peppers/Rice/Guinea corn	1
63	Millet/Guinea corn/Tomatoes/Okra/Rice	1
64	Millet/Guinea corn/Okra/Pepper/ Sweet potatoes	1
65	Millet/Guinea corn/Peppers/Rice/Sweet potatoes/Cowpeas	1
66	Groundnut/Tomatoes/Okra/Peppers/Rice/ Sweet potatoes	1

APPENDIX C

EXPLANATION OF ABBREVIATIONS USED IN THE LINEAR PROGRAMMING MATRIX

APPENDIX C

TABLE C.1

EXPLANATION OF ABBREVIATIONS USED IN THE LINEAR PROGRAMMING MATRIX

Row No./ Column No.	Abbreviations	Complete Heading
RESTRICTIONS		
2	FL Mar	Family labor in March
3	FL Apr	Family labor in April
4	FL May	Family labor in May
5	FL Jun	Family labor in June
6	FL Jul	Family labor in July
7	FL Aug	Family labor in August
8	FL Sep	Family labor in September
9	FL Oct	Family labor in October
10	FL Nov	Family labor in November
11	FL Dec	Family labor in December
12	FL Jan	Family labor in January
13	FL Feb	Family labor in February
14	OC Mar	Operating capital in March
15	OC Apr	Operating capital in April
16	OC May	Operating capital in May
17	OC Jun	Operating capital in June
18	OC Jul	Operating capital in July
19	OC Aug	Operating capital in August
20	OC Sep	Operating capital in September
21	OC Oct	Operating capital in October
22	OC Nov	Operating capital in November
23	OC Dec	Operating capital in December
24	OC Jan	Operating capital in January
25	OC Feb	Operating capital in February

TABLE C.1 (continued)

Row No./ Column No.	Abbreviations	Complete Heading
26	SUPA	Quantity of superphosphate
27	SULFA	Quantity of sulphate of ammonia
28	MLS	Quantity of millet
29	GCS	Quantity of guinea corn
30	CPS	Quantity of cowpeas
31	MZS	Quantity of maize
32	GNS	Quantity of groundnut
33	TMS	Quantity of tomatoes
34	PPS	Quantity of peppers
35	MLC	Millet for consumption
36	GCC	Guinea corn for consumption
ACTIVITIES		
1	ML/GC	Produce millet/guinea corn mixture
2	ML/GC (MI)	Produce millet/guinea corn mixture with modern inputs
3	ML/GC/CP	Produce millet/guinea corn/cowpeas mixture
4	ML/GC/CP (MI)	Produce millet/guinea corn/cowpeas mixture with modern inputs
5	PGC	Produce guinea corn as sole crop
6	PGC (MI)	Produce guinea corn as sole crop with modern inputs
7	MZ/GC (MI)	Produce maize/guinea corn mixture with modern inputs
8	PMZ (MI)	Produce maize as sole crop with modern inputs
9	PGN	Produce groundnut as sole crop
10	PGN (MI)	Produce groundnut as sole crop with modern inputs
11	PTM	Produce tomatoes as sole crop
12	PTM (MI)	Produce tomatoes as sole crop with modern inputs
13	PPP	Produce peppers as sole crop
14	PPP (MI)	Produce peppers as sole crop with modern inputs
15	HL Mar	Hire labor in March

TABLE C.1 (continued)

Row No./ Column No.	Abbreviations	Complete Heading
16	HL Apr	Hire labor in April
17	HL May	Hire labor in May
18	HL Jun	Hire labor in June
19	HL Jul	Hire labor in July
20	HL Aug	Hire labor in August
21	HL Sep	Hire labor in September
22	HL Oct	Hire labor in October
23	HL Nov	Hire labor in November
24	HL Dec	Hire labor in December
25	HL Jan	Hire labor in January
26	HL Feb	Hire labor in February
27	BC Mar	Borrow capital in March
28	BC Apr	Borrow capital in April
29	BC May	Borrow capital in May
30	BC Jun	Borrow capital in June
31	BC Jul	Borrow capital in July
32	BC Aug	Borrow capital in August
33	BC Sep	Borrow capital in September
34	BC Oct	Borrow capital in October
35	BC Nov	Borrow capital in November
36	BC Dec	Borrow capital in December
37	BC Jan	Borrow capital in January
38	BC Feb	Borrow capital in February
39	BSUPA	Buy superphosphate
40	BSULFA	Buy sulphate of ammonia
41	CML	Consume millet
42	CGC	Consume guinea corn
43	SML	Sell millet
44	SGC	Sell guinea corn
45	SCP	Sell cowpeas

TABLE C.1 (continued)

Row No./ Column No.	Abbreviations	Complete Heading
46	SMZ	Sell maize
47	SGN	Sell groundnut
48	STM	Sell tomatoes
49	SPP	Sell peppers
50	TCMA	Transfer capital from March to April
51	TCAM	Transfer capital from April to May
52	TCMJ	Transfer capital from May to June
53	TCJJ	Transfer capital from June to July
54	TCJA	Transfer capital from July to August
55	TCAS	Transfer capital from August to September
56	TCSO	Transfer capital from September to October
57	TCON	Transfer capital from October to November
58	TCND	Transfer capital from November to December
59	TCDJ	Transfer capital from December to January
60	TCJF	Transfer capital from January to February
61	PAYOFF	Pay off activities

APPENDIX D

EXPLANATION OF ABBREVIATIONS USED IN FIGURES 5.2 AND 5.3

APPENDIX D

TABLE D.1

EXPLANATION OF ABBREVIATIONS USED IN FIGURES 5.2 AND 5.3

Abbreviation	Explanation
PTRAD	Traditional technology and existing resources.
PNEW	New technology and existing resources.
PCRED	New technology and credit availability.
PLAB	New technology and an increase in the amount of family labor available.
PLCR	New technology, credit and an increase in the amount of family labor available.

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