THE ALLOCATION OF RESOURCES IN THE NONMECHANIZED SMALL FARM HOUSEHOLD OF DUMILA, MKUNDI AND MAGOLE VILLAGES AND THE KILOSA DISTRICT, TANZANIA: A NUTRITION BASED APPROACH

BY

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THE ALLOCATION OF RESOURCES IN THE NONMECHANIZED SMALL FARM HOUSEHOLD OF DUMILA, MKUNDI AND MAGOLE VILLAGES AND THE KILOSA DISTRICT, TANZANIA: A NUTRITION BASED APPROACH

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The benchmark farm household and associated farming systems of three villages and two district aggregates in Tanzania are described and then modelled using nutrition and focus loss constrained linear programs. Objective functions, which maximize the production of utilizable protein, are used to simulate production choices of the farm households.

The villages of Dumila, Mkundi and Magole are located in the Kilosa district of the Morogoro region in Tanzania, East Africa. Primary data was collected from small farm heads of household residing in the villages.

The utilizable protein objective function was chosen for three reasons: 1) Over 90% of the respondents stated their first goal in farming was the provision of food, 2) The quantity and quality of protein consumed varies on the basis food supply and dietary composition, and 3) An ongoing debate as to the most crucial nutritional component, the calorie or protein, provides little guidance for a choice of a nutrient to be maximized. This research suggests that the maximization of the production of utilizable protein results in similar

production patterns as those found in the villages and the Kilosa district.

Major crops produced in the villages supply protein, calories, minerals, vitamins and amino acids. A series of minimum level constraints insure adequate nutrients consumption. Utilizable protein quality is allowed to vary through the use of a linear approximation of a nonlinear quantity/quality tradeoff constraint.

Focus loss constraints are included to insure against a disastrous loss of utilizable protein. Focus loss elements are developed on the basis of production patterns and utilizable protein yield.

The linear programming model for each location is optimized: a) with nutrition and focus loss constraints absent, b) with focus loss constraints absent, and c) as a complete model which includes production, nutrition and focus loss constraints. Optimal results from each successive run provide more "rational" farm production patterns.

Land, labor, vitamins and one amino acid tend to be scarce under different criteria. The marginal value product of the scarce resources decrease rapidly as the constraints are relaxed.

The maximization of utilizable protein, devoid of pricing information, is shown to simulate the patterns of production reported.

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CHAPTER 1

INTRODUCTION

The agricultural heritage of Tanzania and the villages of Dumila, Mkundi and Magole is one of limited resources. The farming systems (FS) peculiar to the villages and the farm households (FH) have been adaptive in their response to the exogenous factors acting upon them. The indigenous resources have been combined in a manner which has allowed a population growth rate of over 2.5 percent (%) per annum in recent years.

This chapter reviews some of these developments in Tanzania's past which have resulted in the present FS and associated FHs in the villages. Following, the objectives of the research are defined and the manner for presentation of results documented.

1.1 Historical Background

Approximately five-hundred years ago the areas of what are now Dumila, Mkundi and Magole villages of the Kilosa district in the Morogoro region of Tanzania appear to have been sparsely populated (Wiedner, 1962). The earliest discernable inhabitants were food gatherers. These were Cushites who had migrated from the Ethiopian region. Archaelogical records show they introduced both domestic livestock and cereal crops into the East African area of which Tanzania is part.

A second group of migrants pushed down from the Northern regions to settle in Northern Tanzania. These were the southern Nilotic-speaking people. They were the ancestors of the Dodog and Kalenjin-speaking groups which had previously lived to the north of present day Tanzania. Apparently, the southern Nilotes and Cushites maintained a close and in many cases an intimate relationship which led to intermingling of the blood lines.

During the period A.D. 100 to A.D. 400 peoples of Bantu linguistic origin who had been migrating from a region near the Cameroun-Nigerian border appear to have entered Tanzania (Murphy, 1972). The Cushites were slowly absorbed by the groups which had settled in the lake area. The next major group to enter the region reaching as far down as Central Tanzania (according to oral tradition) were the "Plains Nilotes," "Eastern Nilotes," or the "Paranilotes." These were the predecessors of the nomadic Masai. A last major migratory influx occurred when the Lwoo, Nilotic-speakers from the north pushed into Uganda replacing the Abatembuzi. Elsewhere, the Lwoo established smaller and less centralized city-states owing their allegiance to the Ugandan leaders.

By the ninth or tenth century splinter groups of Bantu migrants were settling in the western part of what today is

Tanzania. The Bantu farmers by this time had domesticated crops including several cereals, okra, certain forms of yams and groundnuts as well as melons and sesame (sim sim) (Wiedner, 1962). Later with the introduction of maize, beans, peas, rice and certain vegetables the basic cropping systems of the Kilosa district appear to have taken hold. This FS was to be upset later due to incursions by ivory and slave traders who caused labor imbalances to occur. Later yet came the colonial rulers who introduced plantation style agriculture which exacerbated an already serious malallocation of resources from the FH perspective.

As the Bantu-speaking migrants moved closer to the coastal areas they came in contact with many different cultures. This helped to create the Swahili civilization which is characteristic of East Africa today. The new language incorporated many different languages into one. As mentioned earlier, the Bantu encountered the Cushitic culture around the great lake region. Further toward the coast they encountered the Nilotic groups. Both these groups were absorbed to a great extent while the Bantu migration continued. Near the coast the migrants encountered the Arab settlers in such great numbers that the process of absorption was one resulting in a linguistic marriage of the two languages. Thus the new Swahili (Kiswahili) civilization was born (Murphy, 1972).

The slave and ivory trade had been carried on for centuries along the East African Coast when sometime after 1000 A.D. the Islamic coastal settlements from Mombasa to Kilwa began to grow in size and economic importance (Martin, 1977). The next four hundred years were characterized by a coastal trade among these city-states. This trade spurred on by the new trade language, which was firmly established by the 1700's, spread inland by the late 19th century. It carried with it a mixture of Arab, African, Indian, Portuguese and English words.

Prior to this time and as early as the 18th century Mombasa, Pemba, the Mafia Island and Kilwa were all governed by Arab governors. They, in turn, were often ruled by Omanis who had regained control of the coast from the Portuguese in the 17th century. The Omani ruler, Seyyid Said, moved his capital to Zanzibar in 1840, which hastened the entry of the British into the East African arena and subsequent British colonialization (Miller, 1971). Indian financers funded Arab caravans which pushed inland looking for slaves and ivory. The slave and ivory trading continued unabated until the arrival of European colonial rule in the 1880's and 90's. The disruption of African societies was considerable prior to the colonial rule due to the trade in human beings. The effects that the slave trade had on the farming systems in the Kilosa district are undocumented. Clearly, the effects associated with this type of depopulation were serious. Kamarck points out that:

> Unfortunately, the slave trade, in addition to being an inhuman and, in a real sense, immoral activity, was a particularly destructive type of commerce. It drew off from the continent human beings at most productive ages. Worse still, it encouraged tribe to fight tribe and encouraged conflict within tribes. Finally, and perhaps most important, any advantages that Africa derived from contact with the rest of the world-learning of some skills, the introduction of new foods such as maize and manioc-were more than offset by the slave trade's plunging vast stretches of Africa into anarchy. (Kamarck, 1971)

This was subsequently to give way to the exploitation of other resources which the FHs in the Kilosa district and other areas depended upon for their livelihood.

Agricultural activities which were highly labor intensive were disrupted by the removal of both women and children for the slave trade. The males were forced to devote additional time to protection of the community. While statistics are not reliable on the amount of disruption caused to the agricultural sector it must have been enormous. Obvious effects would be the reduction of food supplies and associated famine, illness and in many cases death. Furthermore, the accumulated "knowledge" capital may have been lost through the removal of the "teachers". Many societies disintegrated under the pressure of continued loss of members. This disruption of African societies resulted in the disruption of FS in many regions of East Africa including

Tanzania and the Kilosa district. The interrelationships between the FS and the FH were strained in two ways: (1) The forced migration into different physical environments resulted in known farming techniques becoming obsolete, and (2) the typically smaller amount of labor resources available after a series of slave raids.

Colonialization was based on autocratic rule and the partitioning of Africa along geopolitical boundaries between European countries. 1885 is a useful date to begin the chronicle of the colonial era and its effects on the agricultural sector of Tanzania (Gellar, 1977). 1885 marks the year in which the "Scramble for Africa" was inaugurated through the Berlin Conference of 1884-1885. The effects of colonialization in Tanzania and subsequent effects on the FSs in the villages of the Kilosa district were far reaching. The most obvious being the introduction of the plantation system of farming and government taxation. It must be remembered that for nearly 25 years German traders had been setting the stage for their government's declaration of a protectorate in 1885. Between 1914 and 1918, the German protectorate came under British control. Taxation took the form of direct taxes such as the poll tax and indirect taxation such as price controls placed on cash crops to skim profits with only marginal returns to the producer. Again, the effects were the disruption of the human element of the FS due to the reallocation of labor toward the production of cash crops for export to Germany, Britain and other countries demanding the commodities of Tanzania. This reorganization and prioritizing of farming activities, initially by the government and later by private companies and concessionaires given monopoly power, eventually led to the evolution of the division of labor in the FH. Additionally, the introduction of disease had significant impact on the livestock producing areas along the East African coastal regions. For example, rinderpest may have been introduced by draft animals used in the Italian invasion of Ethiopia in the late 1890's (Kamarck, 1971). Over the next few years millions of cattle were killed by the disease resulting in a livestock depopulation of large areas of East Africa. With this reduction in livestock numbers came an associated return to the bush, wild animals as well as Tsetse fly. Some regions have had difficulty in reintroducing domesticated livestock since that time.

The British East African Company, which had been set up in the 1880's, eventually failed and was succeeded by territorial governments with the mandate that they should be self-supporting. Thus the territorial governments were obliged to earn revenues from whatever sources they could. This policy explains some of the rapid expansion of cash crops such as cotton. The introduction of agricultural and mineral products into the European markets also increased the demand within Tanzania for better transportation infrastructure. Even though a conflict existed between the self-sufficiency goals of British territorial governments and borrowing foreign exchange they began to borrow for the development of transportation linkages. This resulted in some peripheral benefits to African FHs which were fortunate to be located along the roads. However, the majority were not so lucky. Prices paid for cash crops from areas where transportation was good, incorporated the lower transportation cost. Since this was a flat rate for all of the commodity the transportation costs for those not along a road made them less competitive.

By the 1930's the traditional FH had come to depend on a small amount of cash crop production as a source of revenue to pay taxes and provide a little disposable income. However, as more resources were allocated to large scale agriculture the small FH became less competitive resulting in lower incomes. This continued reduction in disposable income associated with greater demand by the governments for additional revenues caused a retrenchment of the FH by the 1950's which has continued to the present time.

Throughout the colonial period, beginning with the Germans in the 1800's and culminating with independence from the British in 1961, there were periodic uprisings. These inevitably resulted in loss of crops and income. This led to food production shortfalls and associated illness and disease.

By 1950 it had become clear to many Tanzanians that formal British presence must be withdrawn. This conclusion evolved as a result of colonial practices, one of which dealt with education. Colonial education was intended to train workers skilled enough to implement policy both physically and intellectually. What actually occurred was the development of an educated elite whose advancement beyond a certain level was blocked by the colonial powers. Through education they became aware of rights which were felt to be unalienable and thus the seed of independence was planted by ninety years of repression.

The political forum through which independence was to be gained was the Tanganyikan African National Union (TANU). TANU was born from the 1954 Tanganyikan African Association (TAA) meetings. The 1954 conference dealt with the general themes of education for Africans, taxation policies on agricultural commodities as well as others (Kaniki, 1980). The conference objected to proposed taxation of crops and livestock which led to unreasonably reduced profits for the producer. A tax on cotton was intended to be attached to prices which were already set near cost of production by the colonial governors. This would result in lower net incomes accruing to FH in areas like the Kilosa district. Julius Kambsrage Nyerere was elected Territorial President of the TAA and within a year had proposed a constitution which was accepted and formed the foundation for the TANU orgnization. TANU's first objective was to prepare the Tanganyika African for self-rule and to gain the country's freedom. Independence came six years later on the 9th of December, 1961.

Following independence concern grew over the state of the economy including the agricultural and service sectors and the fledgling industrial sector. In 1967, during his presentation to the party Congress at Arusha, President Nyerere stated that the expectations for development of the country could only be realized through agriculture and the people of Tanzania. The Arusha Declaration emphasizes self reliance, hard work, intelligent use of limited resources, as well as a reduced emphasis on the industrial sector as the foundation for economic development. Since the Arusha Declaration, President Nyerere has paraphrased the intended meaning as follows:

> Inherent in the Arusha Declaration is a rejection of the concept of national grandeur as distinct from the well being of its citizens and a rejection too of material for its own sake. It is a commitment to the belief that there are more important things in life than the amassing of riches, and that if the pursuit of wealth clashes with things like human dignity and social equality, then the latter will be given priority. (Nyerere, 1971)

This interpretation was evident in the development of the Ujamaa "brotherhood" villagization program which reportably affected approximately 75% of Tanzania's agricultural population by mid-1976. The program was undertaken to discourage the development of rural capitalism. While drought has exacerbated problems faced by the agricultural sector in Tanzania so has the misallocation of resources and resultant food shortages, resulting perhaps, from human misjudgment.

Today between 80% and 90% of the population of Tanzania are part of the FHs. The agricultural sector must support an urban sector which is growing and will continue to grow relative to numbers in agriculture. A population growth rate of over 2.5% per annum means that the absolute numbers in both agricultural and urban sectors will continue to grow well into the twenty-first century. Kilosa district, as an agricultural center, must produce a surplus for the growing urban population. This will have to come from villages like Dumila, Mkundi and Magole.

More equity may exist among FHs now than previously; however, costs have been incurred. For example, between 1964 and 1978 approximately 100 metric tons of food crops were imported per year to Tanzania and the trend has been toward larger imports (Gerrard and Roe, 1981). At the same time, World Bank statistics show that food production per capita has fallen from approximately 100% in the 1969-1971 base period to 94% in the period 1977-1979 (World Bank, 1981). This implies that in the short run the possibility of adequate nutrition for the limited resource FH may be deteriorating. Aggregate statistics appear to support this contention. In 1977 the average daily calorie supply was estimated to be 2,063 calories for Tanzania. This is approximately 89% of what the typical Tanzanian would require on a daily basis. This shortage is exacerbated by substitution of "prestige" crops such as cabbage for crops of higher nutritional value such as wild spinach (Kreysler and Schlage, 1969).

The FS in the Kilosa district has been affected by both man-made as well as environmental factors. The human element has adjusted each time to these shocks. The FSs in the villages of Dumila, Mkundi and Magole are a product of the interaction of these factors. Clearly, agricultural policy may be implemented more quickly today than it could years ago. Whether the policies implemented result in the expected improvement of the FS and the ability of the FH to provide improved living conditions is a question more easily answered in retrospect. This dissertation will consider these problems from the perspective of the farm household and its interaction with the FS. It is hoped that results will help the FHs meet their perceived needs.

1.2 Objectives

The central objective of this study is the estimation of alternative allocations, based on nutrition, of scarce resources in the nonmechanized small farm household of the villages of Dumila, Mkundi and Magole in Tanzania. A single period model of the farming systems in the villages acts as the basis for the estimation. Justification for a single period model comes from the assumption that the FH of the district makes enterprise decisions on the basis of minimum subsistence requirements. Increased income is derived from additional marketable surpluses in the short run. Increased food security is derived from consumption of products of higher quality in larger quantities.

The specific objectives of this dissertation are:

1. Examine the major economic determinants of agricultural commodity supply at the FH level in Dumila, Mkundi and Magole in the Kilosa district of Tanzania.
2. Estimate the current nutritional intake level of FHs in the villages.
3. Estimate the economic effects of changing selected input supplies and corresponding adjustments in agricultural output.
4. Identify the greatest constraints to increased agricultural production by the FH in the villages.
5. Suggest policy alternatives for agricultural planning within the district.

1.3 Sources of Information

Information dealing with objective one and two was gathered from sources at the University of Dar es Salaam at

Morogoro in Tanzania. The Faculty of Agriculture, Forestry and Veterinary Science at Morogoro has been involved with data collection describing the farming systems in Kilosa and is continuing to do so. While much of the effort has been directed toward research on increasing the productivity of beans many ancillary projects have been carried out by others at the Faculty. The 1980 Bean/Cowpea Survey (1980 B/CS) was carried out under funding from the Bean Cowpea Collaborative Research Program (B/C CRSP) and the direction of Dr. Jean Due from the University of Illinois. From these data the sufficient information is available to focus on the major economic determinants affecting the FHs in the Kilosa district.

Additional information has been gathered from both private and public sources. These sources include consulting agencies, international centers, libraries and correspondence with other groups.

Objective two is approached through the use of information on the nutritional value of food consumed. Much of this information is available from the 1980 B/CS. Supplemental information is drawn from United Nations Food and Agriculture Organization (FAO) publications. Objective two is an important component of objective three.

Objective three is estimated through the development of a mathematical program using linear programming (LP). Data to develop the LP are supplied from previously mentioned sources.

The program incorporates information on nutritional levels which exist in the district. This is done in a fashion similar to that of Victor E. Smith of Michigan State University (Smith, 1975). Smith has made allowances for both protein quality and quantity in his model.

A risk protection technique called the "focus of loss" analysis proposed by G.L.S. Schackle and expanded upon by Jean-Marc Boussard and Michel Petit is used (Schackle, 1955, 1961; Boussard and Petit, 1967). The approach assumes that farmers diversify so that only a very small possibility for ruin exists. Ruin is defined in terms of the minimum level of income needed for consumptive purposes or by some other criteria. Boussard and Petit assume that the focal loss of one crop is only a fraction of the total permitted loss. The focal loss concept is introduced into the LP through the inclusion of a vector of loss coefficients associated with cropping activities.

The capacity to handle a linear program of this complexity exists at the University of Illinois in the form of computer hardware and staff. The Control Data Corporation APEX-111 Out of Core System 1 linear programming system (APEX) is on line at the University of Illinois (Control Data Corporation, 1979). This program was used to run the linear program.

Objectives four and five are met through analysis of the output generated by the LP.

1.4 Organization of the Dissertation

Chapter one dealt with three themes. First, past historical activities that affected the FH and consequently the FS were reviewed. Secondly, the demand for villages such as Dumila, Mkundi and Magole to supply a surplus of agricultural commodities was considered. Thirdly, the interaction of the FS and FH in meeting the demands placed upon non-mechanized producers of agricultural commodities in the Kilosa district were examined.

Chapter two consists of a description of the FSs modelled. Specific attention is paid to data collection techniques, the villages sampled and inter-village comparisons. The concepts associated with FSs and the FH are delineated and expanded upon.

The focus of chapter three is a review of pertinent literature. Sources of information dealing with theoretical and applied aspects of linear programming (LP), focus of loss risk constraints and nutritional requirements are surveyed. The information is consolidated and used to direct the research undertaken in chapter four.

Chapters four and five describe model specification. The discussion centers on the interaction of a nutritional oriented LP model with production and risk aspects inherent in the FS. All three aspects are combined in the LP model using data gathered, from a subsample of FHs, in Dumila, Mkundi and Magole.

The results generated from the LP are analyzed in chapter six. A series of model specifications produce results from: 1) a land and labor constrained LP, 2) a land, labor and nutritionally constrained LP and 3) a land, labor, nutritionally and risk constrained LP. Comparison of the results of different model specifications supply insights into constraints affecting the FSs.

Chapter seven offers conclusions drawn from the research. Areas which need further study are suggested and useful methods to accomplish this are outlined. Alternative policy decisions which emphasize nutritional sufficiency, surplus production and reasonable risk are considered.

CHAPTER 2

CHARACTERISTICS OF STUDY AREA

2.1 Farming Systems in Dumila, Mkundi and Magole

Norman and Gilbert have stated that the Farming System (FS) as a unit of production and the farming household (FH) as a unit of consumption are inextricably linked (Norman and Gilbert, 1982). This being the case it is necessary to deal with the interaction which results from this symbiotic relationship. The FS which is adopted is a function of the allocation of resources of the FH which in turn is a function of environmental elements restraining the FS.

The environmental elements may be divided into technical and human elements. As Norman and Gilbert point out: "The technical element reflects what the potential of the FS could be. The technical element reflects physical and biological factors, some of which can be modified to affect performance of the FS" (Norman and Gilbert, 1982).

The human element can be divided into: (1) exogenous variables, those dealing with societal influences which are largely outside the control of the individual, and (2) endogenous factors, those dealing with variables falling at least partially within the domain of personal control (land, capital, labor and management).

These concepts provide a general boundary for the system at work in the villages of Dumila, Mkundi and Magole in the Kilosa district of Tanzania. When looking at the FH and FS many similarities are evident. To the extent that the environmental amenities are similar between villages it might be hypothesized that similarities would exist among villages. Furthermore, if similarities do exist and are positively correlated in response to stimuli then progress may be made in improving the well being of individual farm families. In a system which is relatively homogeneous welfare increases for the individual may very well be transmitted to the village and district aggregates. In turn it must be assured that long term effects be taken into consideration to ensure appropriate resource management for society as a whole.

The objectives of this research are tailored to incorporate secondary sources of data with the primary survey research results. The survey results give quantified information on certain aspects of the FS in the villages. However, the information is incomplete and therefore needs to be tested internally as to plausibility. This is done through the incorporation of nutritional requirements with the production aspects of the model. This creates a link between two important aspects of agriculture in less developed countries (LDC's), the FS and FH. It also incorporates implicitly the human factors mentioned previously. The physical need for sustenance is the major agricultural stimulus in Dumila, Mkundi and Magole.

The internal check on the production aspects of the model is increased through the use of focus loss risk constraints. These not only act as a precaution against improper decision choices on the part of the FH but also maintains diversification of the FS through minimum levels of production of major crops. A mix of foodstuffs is insured which provide important nutrients in the diet. If the latter is true and important nutrients are undervalued the focus loss constraints will be active. This is a very important concept given the level of knowledge, not only about the FS but also the FH. In other words, if every factor in the FH were known there would be no reason to include focus loss constraints. Nor, for that matter, would there be a need for any type of risk activity. However, they are not. Therefore, the focus loss constraints will be included with the expectation they will be active in modifying production behavior.

This research picks up at the stage described as the descriptive process (Harwood, 1982). While this may be an inappropriate stage with which to begin it does have offsetting benefits. Harwood and this author would prefer that the research at hand be the focus of original objectives which had been targeted according to environmental realities. Prior to the descriptive stage the objectives of the research should be identified and subsequently the descriptive work tailored to the data needs of meeting those objectives. The lot of the graduate student is not one which often allows this luxury, thus the offsetting benefit of fitting a problem to data. The data must be supplemented. In this case the supplementation takes the form of nutritional activities which strengthen the model.

This leads to the descriptive and methodological stage of the research undertaken. The descriptive aspects of the FS and FH will be dealt with from the perspective of the needs of the FH. Therefore, both the production and consumption activities will be described separately and later integrated along with risk parameters to develop the system.

2.2 Primary Data Sources

Original data for the research was provided through a survey carried out in the Kilosa district by faculty and students from the University of Illinois and the University of Dar es Salaam at Morogoro. Two primary concerns for the planners were the selection of sites which included bean production and year-round accessibility. The villages chosen on this basis were Dumila, Mkundi and Magole in the Kilosa district.

Fifty-eight FHs were selected from the villages. They were chosen randomly from a registration list with the names of all families in the villages. Every jth name was chosen from the list on which the names were assumed to have been randomly placed. The resulting FHs were subsequently enumerated on a one time basis and the information coded and analyzed. The results are found in the publication "Two Contrasting Farming Systems in Morogoro Region, Tanzania" (Due and Anandajayasekeram, 1982).

The objectives of this research differ from those of the work listed above. All FHs which reported the use of mechanized equipment, such as tractors, were deleted for the purpose of this study. The sample size was reduced to forty-six FHs. Thirteen FHs were located in both Dumila and Magole. The remaining twenty FHs were located in Mkundi. These FHs were used as the data source for this research.

The dissertation titled "An Analysis of Resource Use in a Maize-Legume Farming System in the Kilosa District: Tanzania" was referenced frequently (Manday, 1982). Data for that work came from a survey conducted at an earlier time. The survey dealt with the Kilosa district as a single unit. While this information is not as site specific as that from the villages it has been very useful. Where data from this source has been used it has been properly referenced.

2.3 Location

Kilosa district is located in the Morogoro Region of Tanzania, East Africa. The villages of Dumila, Mkundi and Magole lie in the northern half of the Kilosa district. Dumila and Magole are located along the Dodoma-Morogoro town road (Due and Anandajayasekeram, 1982). Magole is located at the coordinates 6 degrees 24 minutes South latitude and 37 degrees 25 minutes East longitude. Mkundi is located at 6 degrees 19 minutes South latitude and 37 degrees 23 minutes East longitude (Department of Interior, 1965). The map in Figure 1 shows the location of Magole, Mkundi and the Kilosa district.

2.4 Rainfall

Over much of Tanzania including the Kilosa district, rains begin in late November and may continue into April, thereafter the dry season occurs lasting about five months (Kenworthy, 1966). The rainfall period between November and April may be characterized by two seasons, the longer and more pronounced starting in March with its peak in April. The long rains are a major determinant of the quality and quantity of the crop production for that year. The average annual rainfall at Morogoro Meteorological Station is between 760 millimeters (mm) and 1600 mm (Anandajayasekeram et al., 1981). Rainfall data from the Ilonga Research Station, the Kilosa Agricultural office and the Berege Mission is presented in Table 1. Figure 2 gives a graphical presentation of the rainfall data from the three areas.

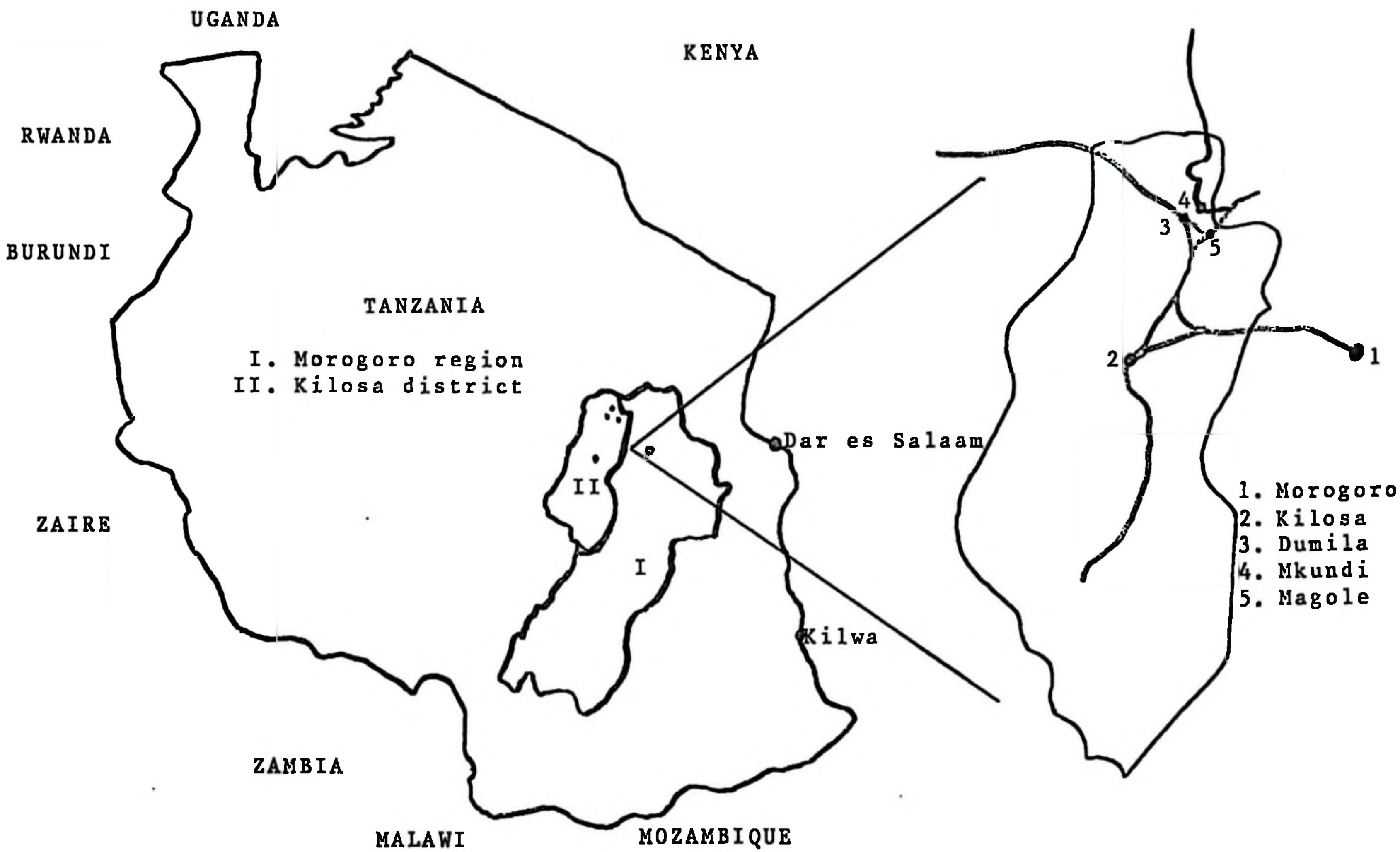

Figure 1. Map showing location of Kilosa district and Dumila, Mkundi and Magole villages, Morogoro region, Tanzania.

Source: 1980 B/CS.

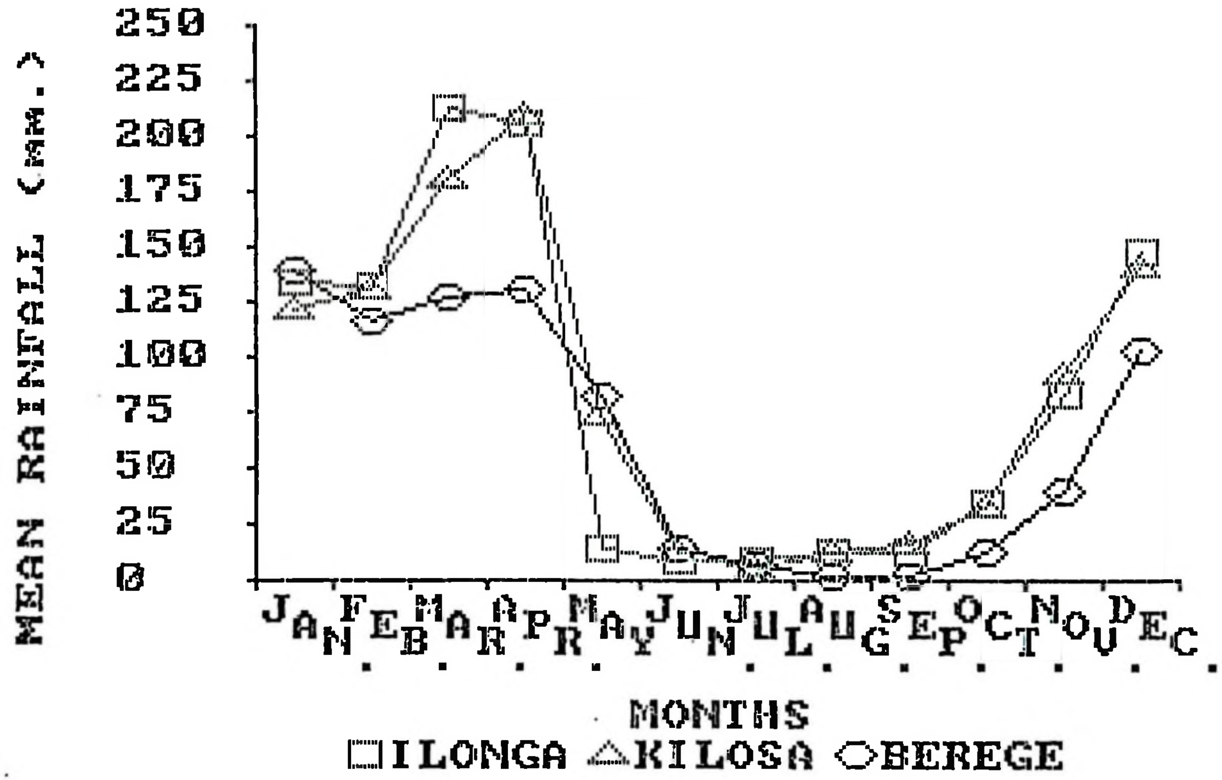

Figure 2. Mean historical rainfall patterns for three locations in Tanzania, 1919-1969.

Source: Manday, Emmanuel, Unpublished Ph.D. Dissertation.

Table 1. Mean historical rainfall patterns for the Ilonga Research Station, Kilosa Agricultural Office and Berege Mission, Tanzania, 1919-1969.

	Ilonga Res. Station	Kilosa Agric. Office	Berege Mission
Month	1919-1969	1919-1969	1919-1969
	(mm)	(mm)	(mm)
January	135.4	123.2	140.7
February	132.8	131.1	116.6
March	213.1	180.6	127.5
April	206.5	209.3	131.1
May	16.0	73.7	82.8
June	9.7	14.0	16.0
July	9.7	6.1	8.6
August	12.7	13.0	2.8
September	13.7	17.8	2.8
October	35.6	32.3	13.0
November	82.8	92.5	39.4
December	147.6	141.0	102.1
Total Millimeters	1015.6	1034.6	783.4

1" = 25.4 MM

Source: Manday, Emmanuel, Unpublished Ph.D. Dissertation

2.5 Land Tenure

The intensity of agricultural production is also affected by the land tenure systems which are prevalent in the Kilosa district. All land is publicly owned and will continue to be in the eyes of the government (Ministry of Agriculture, 1983).

There are four types of tenure arrangements prevalent in Tanzania. These are: (1) customary, (2) communal, (3) leasehold and, (4) rights of occupancy. According to Manday, up to 90% of the land in the Kilosa district is held according to customary land tenure arrangements (Manday, 1982).

It appears that the customary land tenure system in the Kilosa district was one associated with the Kaguru tribe. The Kaguru were closely related to the Luguru which have a well documented tenure arrangement. The basis was a lineage membership which implied the right to live and cultivate on lineage land. This seems to have been incorporated in the present government land policy if the land is not given up voluntarily (Young and Fosbrooke, 1960).

Other aspects of importance also exist. One is the "ngoto" system of payment by "outsiders". A payment for the use of land by a FH which had migrated to the area of the Luguru. This was generally a share of the crop produced on the land. The share going to the controller of the land could not be sold.

Both female and male possess lineage rights but children born on the father's land are no longer full lineage members. These children maintain a defined right to land but in an inferior status. If one of these children marries a person of similar status they will be of still lower status. This lower status results in that FH being forced to pay "ngoto" as they would if they were from some other area. This system may have resulted in cross-cousin marriages among the Luguru to avoid the loss of status and the associated dissipation of lineage wealth.

The customary land tenure system allows the opening of new lands outside the designated village area, while borrowing and renting of land is also possible. Table 2 presents the methods used in the acquisition of additional land by those responding. Only in Magole were there reports of land purchases. It is interesting to find that fifteen respondents in Mkundi said they would clear additional land while two reported no land available. Apparently the land was unavailable for the two due to circumstances outside their control. Overall, it is apparent that additional land is available for the majority of FHs. It would be useful to understand why land was unavailable for 11% of the respondents. Unfortunately, the answer is not deducible from the survey findings.

Clearly the tenure system is difficult to modify when government policy sets property rights. The government of Tanzania in an attempt to restrict the growth of rural capitalism restrains the tenure system by applying the following principles:

1. Villages will have land allocated on a basis of 999 year leases.

2. The land will be sub-allocated by the village to any household for the entire period or any shorter period.

3. This will be done in consultation with government agencies. A land tenure arrangement emphasizing conservation, utilization and improvement of the land will be implemented with consideration for traditional practices and beliefs.

4. Each FH will be restricted from the free sale of the land leased to them. The lease may be surrendered to the village and compensation paid for any improvements and or permanent crops given up (Ministry of Agriculture, 1983).

2.6 Size of Holdings

The FHs enumerated and used in this research are distributed within the one hectare (ha.) to six ha. range. As seen from Table 3 almost half of these fell within the two ha. to three ha. size classification. Seventy-five percent fell within the two ha. to four ha. range. The hectarage in-

Table 2. Methods of acquiring additional land.

Method	Dumila	Mkundi	Magole	All Villages
	No.	No.	No.	%
Clear additional land	7	15	4	59.1
Rent additional land	2	-	-	4.5
Borrow additional land	2	3	4	20.5
Purchase additional land	-	-	2	4.5
No land available	-	2	3	11.4
				100%

Source: 1980 B/CS

Table 3. Distribution of plots (*shambas*), by size.

Size	Dumila	Mkundi	Magole	All Villages
(Ha)	No.	No.	No.	%
Less 1.0	0	0	0	0
>1.0-2.0	0	2	4	13
>2.0-3.0	6	11	4	46
>3.0-4.0	4	4	5	29
>4.0-5.0	1	2	0	7
>5.0-6.0	1	1	0	4
	12	20	13	99%*

*Percent responding is less than 100% due to rounding.

Source: 1980 B/CS.

cludes all plots (shambas) which were either cropped or fallowed by the FH.

2.7 Ages of Farm Household Members

The age distribution of FHs was used as a basis for deriving the consumer units (CU). The CUs are an important aspect of the nutritional requirements used extensively in the model specification. Table 4 presents this information on the basis of aggregate village responses. It is believed by the author that age composition by FH is a more useful figure than the age of farmers interviewed. This is especially useful when dealing with nutrition of the FH in any manner.

2.8 Goals of Farm Households

Each head of the FH was asked their family's primary objective in farming. Table 5 shows that of those reporting over 90% in each village said their foremost objective (goal) in farming was the provision of food for the family. This is not surprising due to the economic and human element within which the FH exists. It is imperative that yearly consumption be maintained above minimum nutritional levels. Income was listed as the second most important objective (goal) by over 90% of all FH. No other objective was reported. This clearly indicates that these farm households view the supply of adequate food as their most important goal.

Table 4. Age composition of the FHs, by sex and maturity groups.

Maturity:	Dumila	Mkundi	Magole	All Villages
	No.	No.	No.	Average No. per age grouping
Adult:				
Male	20	27	15	1.35
Female	18	23	17	1.26
Adolescent:				
Male	9	9	10	0.61
Female	11	10	5	0.57
> 7-9	2	7	6	0.33
> 4-7	5	3	4	0.26
> 1-3	0	3	0	0.07
< 1	0	0	0	0
	n=13	n=20	n=13	
Average Members/FH				4.45

Source = 1980 B/CS

Table 5. Ranking of objectives obtained through farming.

	Dumila	Mkundi	Magole	All Villages
	No.	No.	No.	%
Objective No. 1				
a) Food	13	18	12	95.6
b) Income	0	1	1	4.4
Objective No. 2				
a) Income	13	18	12	95.6
b) Food	0	1	1	4.4
	13	19	13	45

Source: 1980 Bean/Cowpea Collaborative Research Support Program Survey (1980 B/CS).

2.9 Crop Choice Determinants

Table 6 emphasizes the importance of food supplies and the choice of crops. Deleting those individuals who responded ambiguously, 75% or more said food value was the main crop choice determinant. This is assumed to mean the nutritive value and palatability of foods when consumed in combinations with one another. It is interesting that only in Dumila was price mentioned as a choice determinant and then only by three farm households. Contrary to what might be expected, ease of marketing was mentioned as a choice determinant by only one person. This suggests that there is little problem with marketing or that the concept behind the question was

Table 6. Crop choice criteria.

Criteria	Dumila	Mkundi	Magole	All Villages
	No.	No.	No.	%
Food Value	9	12	5	62
Ease of Marketing	-	3	1	5
Availability of Seed	-	3	-	2
Price if Sold	3	-	-	7
Ambiguous	-	-	6	24
	12	18	12	42

Source: 1980 B/CS

not clearly explained. One explanation of the lower prices received by Mkundi farmers is that little information is disseminated to the FH about price differentials in other nearby villages. This might also shed light on the differences in land utilization patterns in Mkundi relative to the other villages. It was also reported by one person that seed availability in Mkundi affected crop choice. While it is not clear whether this is representative of the village it also would affect land utilization.

2.10 Cropping Systems Represented in the Villages

Table 7 presents the different intercropping and interculture systems reported in the villages. None of the systems were reported being used by more than 38% of the respondents. Intercropping is important as an insurance technique. Both resistance to pest damage and drought motivate the use of intercropping techniques. Intensification of agricultural production acts as the catalyst for interculture of crops (the planting of arable crops below perennial crops). The interest of the FH in the insurance and intensification aspects of these activities are present implicitly in their enterprise choices. It is clear from Table 7 that the FHs in the three villages actively participate in these types of activities but do not rely on them exclusively for meeting their consumption requirements. As such, they are not specifically identified as separate activities in the modelling of the villages.

2.11 Marketing of Agricultural Output

Food supply was the primary objective of farming; however, a substantial marketing of produce occurred, resulting in the majority of income accruing to the farm household. One can see from Table 8 that food crops were sold in each of the villages. For example, in Dumila over 75% of the FHs sold maize accounting for 36% of their total maize output. While not as high a percentage of households sold other "sub-

Table 7. Dominant intercropping and interculture patterns of FHs in the Dumila, Mkundi and Magole villages.

	Number of Respondents Reporting Intercrop-Interculture*		
	Dumila	Mkundi	Magole
	No.	No.	No.
Intercrop:			
Cereal/Cereal	0	1	1
Cereal/Tuber	1	0	3
Cereal/Legume	4	8	10
Cereal/Fruit	1	0	1
Cereal/Oil Seed	1	0	1
Tuber/Legume	1	0	0
Cotton/Oil Seed	1	0	0
Oil Seed/Legume	1	2	0
Interculture:			
Tuber/Fruit Tree	2	0	1
Cane/Fruit Tree	1	1	2
Cereal/Fruit Tree	0	4	3

*Information for intercrop and interculture is drawn from the original sample of 58 respondents. Intercrops and intercultures may consist of more than one system. Therefore, double counting exists in the table.

Source: 1980 B/CS.

Table 8. Median value per FH of output and sales of major crops when all crops are produced by all FHs.[a]

	Maize (T.Sh.)	Sorghum (T.Sh.)	Rice (T.Sh.)	Beans (T.Sh.)	Cotton (T.Sh.)	Sunflower (T.Sh.)	TVP (T.Sh.)
Average Value Product:							
Dumila	2017	1276	1530	942	722	267	6752
Mkundi	1884	1541	582	904	1253	257	6421
Magole	1504	2067	989	956	654	720	6890
All Villages	1792	1628	1136	931	924	371	6782
Agricultural Sales:							
Dumila	897	769	823	710	722	267	
Mkundi	859	1003	212	140	1253	254	
Magole	667	1400	346	462	654	544	
All Villages	837	1033	522	522	924	328	
Percent Output Sold:	(%)	(%)	(%)	(%)	(%)	(%)	
Dumila	44.5	62.4	53.8	75.4	100.0	100.0	
Mkundi	45.6	65.1	36.4	15.5	100.0	98.8	
Magole	44.3	67.7	35.0	48.3	100.0	75.6	
All Villages	46.7	63.5	46.0	56.1	100.0	88.4	
Percent of Farms Selling Product:							
Dumila	76.9	53.8	38.5	23.1	38.5	61.5	
Mkundi	60.0	60.0	10.0	5.0	40.0	40.0	
Magole	38.5	46.1	38.5	23.1	46.1	23.1	
All Villages	58.7	54.3	26.1	15.2	41.3	45.7	

[a]Assumes all crops are produced by all FHs.

Source: 1980 B/CS.

sistence-cash" (S-C) crops on as large a scale, the FHs still received substantial revenue from the sale of S-C crops. Sunflower which was not consumed in Dumila was consumed in Mkundi and Magole. It is not obvious why this apparent inconsistency exists. Sunflower seed is a good source of protein as are beans. Of the major crops produced beans and sunflower have the highest percentage of protein. The question of nutritional adequacy is dependent on many other aspects of the FSs in the Kilosa district. These will be addressed in greater detail in chapters four and five.

2.12 Land Resources of the Farm Household

The median plot (*shamba*) size in the villages ranged from 0.6 hectares in Magole to 0.8 hectares in Mkundi. Table 9 presents this information and also provides information on the number of shambas operated by the FH as well as distances to plots. There is a considerable difference which exists in the distance variable. FHs in both Dumila and Magole maintained shambas over two miles away from the homestead. In Mkundi the average distance was less than one mile. Also, the number of shambas operated in Mkundi was one less than in the other villages and less than the median for all the villages. On the other hand, the reported size of the shambas were larger in Mkundi. This difference in size may answer the question of why fewer shambas are operated in Mkundi. One might expect farming intensity to be greater on the shambas

Table 9. Shamba (farm plot) information.

	Average Size of Shamba	Average no of Shambas*	Average Distance of Farthest Shamba
	(Ha)	(No.)	(Miles)
Dumila	0.7	4	2.4
Mkundi	0.8	3	0.9
Magole	0.6	4	2.8
All Villages	0.7	4	2.4

Source: Survey Results.

*Rounded to nearest whole plot.

close to the homestead. As land is brought into production further from the homestead, it may be more marginal land with respect to the additional inputs necessary to farm it. This land may be allocated less of the scarce labor resources available due to travel time and quality of the land. Assuming this to be the case, the further the plot is away from the homestead the more marginal it becomes. As travel time to and from the work site becomes greater the costs associated with producing on the distant shamba increases. This assumes that a value is placed upon a person's time as an active participant in the FH of the FS. Of course, in the situation of decreased production and resultant food shortages land may take on a value much greater than that associated with travel time. However, a margin exists such that added production gained from the farthest parcel will not be equated with the production foregone on other plots which can be cropped more intensively. Unfortunately it is impossible to determine the types of crops produced on the distant shambas due to information gaps. However, the concepts can be used as a guideline in looking at land uses.

The median size of each shamba is 0.7 hectares with four shambas per FH. This suggests that the median size of the farm holdings for all villages is approximately 2.8 hectares. This corresponds to a reported median hectarage of 2.79 hectares for the aggregate of all villages.

2.13 Labor Resource Availability

Figure 3 represents the cropping calendar for the villages of Dumila, Mkundi and Magole in the aggregate. All of the villages have similar periods during which specific agricultural activities are undertaken. The blocked out areas on the cropping calendar represent maximum overlap of labor consuming activities for different crops. Furthermore, among activities there is overlap between periods. Both of these combined provide a general idea of what type of labor requirements might be anticipated. One would expect, correctly, that the time period February-April would require maximum labor availability. This associated with the land preparation,

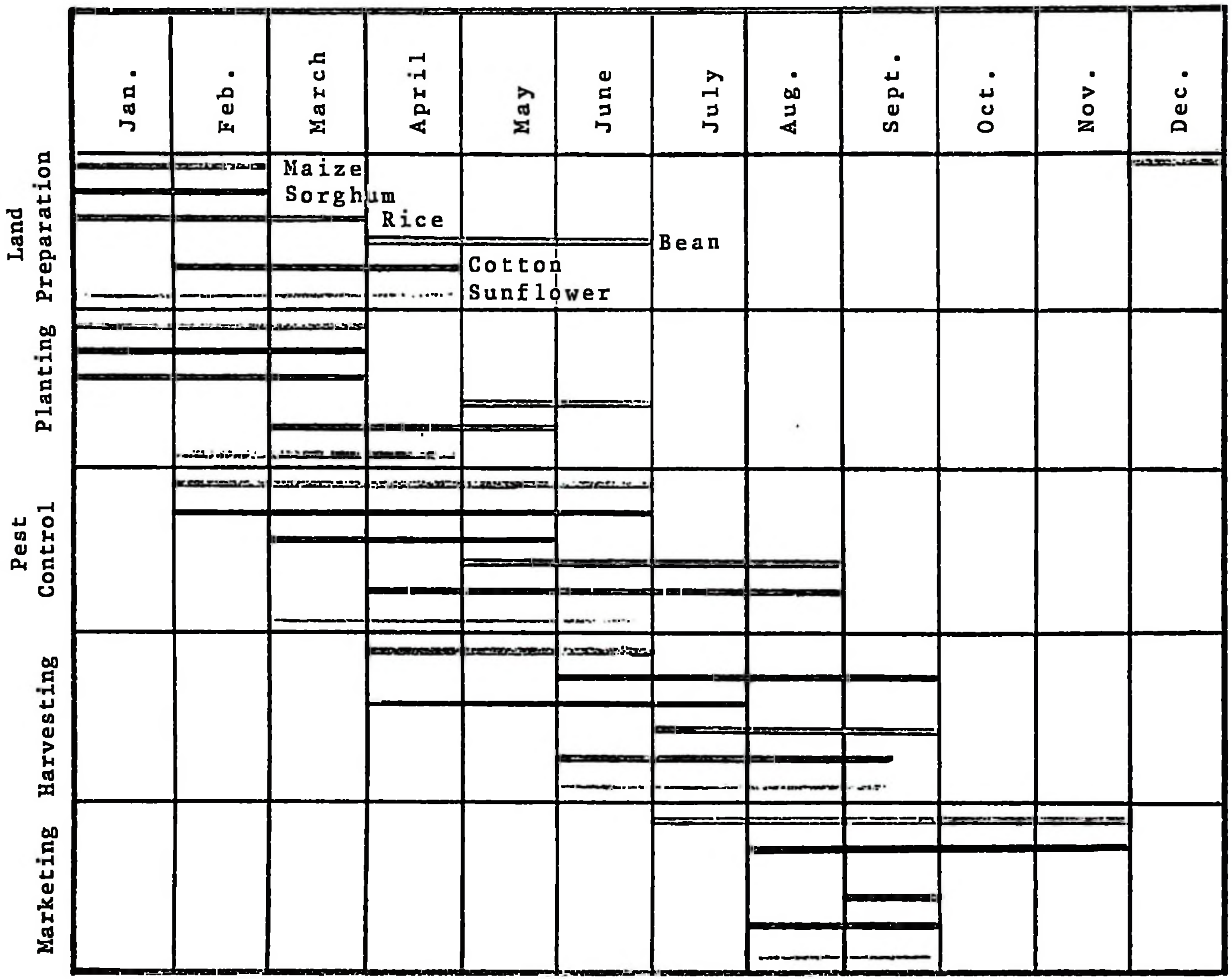

Figure 3. Cropping calendar for the Dumila, Mkundi and Magole villages.

Source: Personal Communication with P. Anandajayasekeram and 1980 B/CS.

planting and weeding and pest removal activities converging upon one another creates a labor bottleneck. It is specifically this type of constraint which may be amenable to increased flexibility. Also, the harvesting-marketing period of May through August represents another potential labor bottleneck. The crop calendar represents the periods where labor must be allocated to these activities. It does not represent the actual amount of labor which is available during these periods.

Table 10 shows the amount of labor which is available to the benchmark FH on a monthly basis and that which is required for the production of the major crops. The labor available is based upon a 304 day work year. The sixty-one days excluded are allocated to religious holidays, sickness, other social activities and days of rest. The normal working day is assumed to be eight hours.

The labor availability of individual FHs aggregated by villages is used as the constraint level for labor. The labor equivalents in male equivalent days (MED), are presented in Table 11. These coefficients are used and applied to all villages. All labor is not performed solely on the production of the major crops. Furthermore, many different activities are undertaken during the day which decrease the actual amount of labor available for crop production activities. No information is available for these other

Table 10. Average FH labor requirements and supplies by month.[a]

MONTH:	Jan (MED)	Feb (MED)	Mar (MED)	Apr (MED)	May (MED)	June (MED)	July (MED)	Aug (MED)	Sept (MED)	Oct (MED)	Nov (MED)	Dec (MED)
Dumila:												
Maize	7.7	13.7	7.3	6.0	7.1	1.1	0.4	0.4	0.4	0.4	0.4	6.4
Sorghum	16.5	23.8	9.6	7.3	7.3	5.3	5.3	7.9	2.4	2.4	2.4	2.4
Rice	13.2	13.2	13.7	13.7	18.0	4.3	4.3	--	--	--	--	6.5
Beans	--	--	--	15.4	20.9	24.1	4.6	4.6	7.8	--	--	--
Cotton	13.8	13.8	22.6	35.8	13.2	13.2	16.6	8.6	8.6	--	--	--
Sunflower	2.6	5.8	5.8	9.6	3.8	5.6	1.8	2.6	0.8	--	--	--
Total Labor:												
Required	54	70	59	88	70	54	33	24	24	3	3	15
Available	72	65	72	70	72	70	72	72	70	72	70	72
Mkundi:												
Maize	6.9	12.0	6.9	5.3	8.6	3.3	0.4	0.4	0.4	0.4	0.4	5.3
Sorghum	14.7	19.0	7.4	4.3	4.3	3.3	3.3	4.0	0.7	0.7	0.7	0.7
Rice	11.0	11.0	6.0	6.0	12.0	6.0	6.0	--	--	--	--	5.0
Beans	--	--	--	10.0	19.0	20.3	11.3	5.3	10.9	--	--	--
Cotton	--	10.7	17.7	26.8	9.1	9.1	11.1	14.2	5.1	--	--	--
Sunflower	3.0	4.5	4.5	8.6	4.1	6.5	2.4	3.0	0.6	--	--	--
Total Labor:												
Required	36	57	43	61	60	49	35	27	18	1	1	11
Available	69	62	69	67	69	67	69	69	67	69	69	67
Magole:												
Maize	10.4	16.3	8.1	5.9	8.8	2.9	0.8	0.8	0.8	0.8	0.8	8.2
Sorghum	13.5	20.5	10.8	7.0	7.0	4.3	4.3	6.3	2.0	2.0	2.0	2.0
Rice	18.5	18.5	9.9	9.9	16.3	6.4	6.4	--	--	--	--	12.5
Beans	--	--	--	11.4	17.3	15.8	9.9	5.5	8.5	--	--	--
Cotton	--	11.2	24.1	34.1	10.0	10.0	13.8	18.7	8.7	--	--	--
Sunflower	4.4	6.3	6.3	14.2	7.9	11.5	3.6	4.6	1.0	--	--	--
Total Labor:												
Required	47	73	59	83	67	51	39	36	21	3	3	23
Available	73	66	73	71	73	71	73	73	71	73	71	73

[a]Assumes all FHs produce all crops.
Source: 1980 B/CS and personal communication with P. Anandajayasekeram.

Table 11. Female and male equivalencies used in the estimation of male equivalent days (MED) of available labor.[a]

	Age of FH Members			
	(Yrs) 4-7	(Yrs) >7-15	(Yrs) >15-19	(Yrs) >19
Sex:				
Male	.25	.50	.67	1.0
Female	.25	.50	.67	1.0

[a]MEDs are derived from information found in Due and Anandajayasekeram (1982) and standardized to ages operative in estimating values for consumer units (CU).

activities from survey results. Therefore, the figure developed by Heyer for a small sample of sixteen families which was 81% of a 48 hour week is used as a basis for adjustment (Heyer, 1966). The figure of 81% of work time allocated to the production of major crops is adjusted because it is likely that at peak labor demand periods other jobs which compete for labor are foregone. Therefore, it is assumed that 95% is a maximum amount of labor that can be supplied to these major crop enterprises at peak labor periods. There are other functions which must be continued even during peak labor periods.

To summarize, a number of reasons exist which support the use of 304 days of labor availability and 95% of this being allocated to major crops. 304 days were used because:

1. The cropping calendar which presents major cropping activities shows activity over a ten month period.

2. Holidays, sick days, rest days and other social activities approximate this figure.

3. Activities other than those directly related to the major crop enterprises are often undertaken.

2.14 Capital Resources Available

The physical capital of the FHs in the villages is very limited. It consisted almost exclusively of tools used in crop production. Most of the value tied up in capital is associated with the hoe. Hoes and pangas (machete) would be used during weeding and harvesting respectively. The panga would also be useful in clearing new land or bringing fallowed land back into production. From Table 12 it is seen that the median FH owned capital equipment valued at approximately 120 Tanzanian Shillings (T.Sh. - One T.Sh. at the time equalled U.S. $0.125).

2.15 Major and Minor Crops Produced in the Villages

The hectarage in the villages were divided among six major crops and two minor crops. Table 13 exhibits the different allocations of land among crops by hectarage and

Table 12. Capital equipment owned per FH by location.

Type of Tool	Dumila No.	Dumila T.Sh./Unit[b]	Mkundi No.	Mkundi T.Sh./Unit	Magole No.	Magole T.Sh./Unit	All Villages[a] No.	All Villages[a] T.Sh./Unit	All Villages n
Hoe	3	30	3	28	4	30	3	26	46
Panga	2	13	1	10	1	9	1	10	45
Axe	1	18	1	17	1	20	1	18	36
Bush Knife	1	21	1	20	2	20	1	18	46

[a]Differences between individual villages and the village category results from the use of the median.

[b]T.Sh. = Tanzanian Shillings; 1 T.Sh. = U.S. $0.125 at the time.

Source: 1980 B/CS

percentage. It is obvious from the results that the agriculture is highly diversified. The "other" category contains a variety of different vegetables, fruits and grain crops which are produced but on such a small scale that survey results did not differentiate among them. The villages were not located in an area where a great deal of vegetables, fruit or livestock production occurs (Due and Anandajayasekeram, 1982). The combination of the six major crops account for approximately 77% of all the land allocated to crop pro-

Table 13. Median allocation of land by crop and percent.[a]

	Dumila (Ha.)	Dumila %	Mkundi (Ha.)	Mkundi %	Magole (Ha.)	Magole %	All Villages (Ha.)	All Villages %
Crop:								
Major:								
Maize	0.44	15.9	0.51	21.5	0.44	15.5	0.51	18.3
Sorghum	0.44	15.9	0.44	18.2	0.48	17.1	0.49	17.6
Rice	0.41	14.5	0.20	8.5	0.36	12.9	0.38	13.5
Beans	0.44	15.7	0.23	9.4	0.30	10.5	0.26	9.4
Sunflower	0.24	8.6	0.17	7.3	0.30	10.8	0.26	9.1
Cotton	0.25	8.8	0.28	11.6	0.45	16.1	0.27	9.6
Minor:								
Cassava	0.24	8.6	0.17	7.1	0.09	3.2	0.25	8.9
Pigeon Peas	0.17	6.1	0.10	4.2	0.16	5.8	0.13	4.6
Others	0.16	5.9	0.29	12.3	0.23	8.2	0.26	9.1
	2.79	100.0	2.39	100.1	2.81	100.1	2.81	100.1

[a]Assumes all crops are produced by all FHs.

Source: 1980 B/CS

duction. Not all farms produced the minor crops nor did all FHs produce each major crop. Of the six major crops, five are S-C crops. Two of the major crops, sunflower and cotton, are produced for their income generating power in Dumila. As was seen in Table 8, part of the sunflowers produced are not sold. The FHs in Magole consumed almost 25% of the sunflower produced. This is quite a deviation from what was reported in both Dumila and Mkundi. A few other noticeable differences appear in Table 13. Mkundi's FHs allocated 22% and 12% of their land to production of maize and cotton respectively. 12.3% of the land was allocated to crops falling in the "other" category. These activities are higher percentages than in either of the other two villages. Mkundi FHs emphasized the importance on the production of maize and sorghum. This may be due to the smaller size of plots in the Mkundi village. The difference is approximately 15% or one half hectare. There also exists sizable differences in the quantity of land allocated to rice in both Dumila (14.5%) and Magole (13.5%). The FHs in Mkundi allocate 8.5% of their land to rice. This has interesting nutritional implications to be discussed later in the text.

2.16 Soil Requirements and Resources

Information of a limited nature was available on FHs which looked for special soils for their crops. Indirectly this may shed light on land allocations for different agriduction. Not all farms produced the minor crops nor did all FHs produce each major crop. Of the six major crops, five are S-C crops. Two of the major crops, sunflower and cotton, are produced for their income generating power in Dumila. As was seen in Table 8, part of the sunflowers produced are not sold. The FHs in Magole consumed almost 25% of the sunflower produced. This is quite a deviation from what was reported in both Dumila and Mkundi. A few other noticeable differences appear in Table 13. Mkundi's FHs allocated 22% and 12% of their land to production of maize and cotton respectively. 12.3% of the land was allocated to crops falling in the "other" category. These activities are higher percentages than in either of the other two villages. Mkundi FHs emphasized the importance on the production of maize and sorghum. This may be due to the smaller size of plots in the Mkundi village. The difference is approximately 15% or one half hectare. There also exists sizable differences in the quantity of land allocated to rice in both Dumila (14.5%) and Magole (13.5%). The FHs in Mkundi allocate 8.5% of their land to rice. This has interesting nutritional implications to be discussed later in the text.

2.16 <u>Soil Requirements and Resources</u>

Information of a limited nature was available on FHs which looked for special soils for their crops. Indirectly this may shed light on land allocations for different agricultural uses. In Dumila 50% of the FHs looked for special land for rice while in Mkundi 57% tried to identify special soils for rice production. This is contrasted in Mkundi where only 20% looked for special soils. Mkundi FHs felt that special soils should be used for bean and sorghum production. These results must be viewed with care due to the small number of respondents. The results of this question can be inspected in Table 14. If the results are representative of the communities there may be striking differences among villages in the types of land available for cultivation or other uses. The emphasis on soils for paddy in both Dumila and Magole is much stronger than in Mkundi. Over 25% of those responding in Magole suggested that maize land was in great demand. Those in Mkundi were inclined to search for sorghum and bean land. What is suggested by these findings is that four of the major crops require "special" land for production to meet the expectations of the FHs.

It may be inferred from Table 15 that the most desired type of land is sandy lowland. This is interesting due to the low water holding capacity and nutrient leaching of sandy soils as well as scarce water at certain times of the year. While this soil classification leaves something to be desired it is useful to have information on the preferences of the FHs. It is particularly important to be aware of the im-

Table 14. FHs searching for special soils.

	Dumila No.	Mkundi No.	Magole No.	All Villages No.
Crop:				
Maize	-	-	2	2
Sorghum	-	2	1	3
Beans	1	2	-	3
Cotton	1	-	-	1
Paddy	3	1	4	8
Cassava	1	-	-	1

Source: 1980 B/CS

Table 15. Soil and land type preferred by FHs responding.

	Dumila No.	Mkundi No.	Magole No.	All Villages No.
Type of Soil:				
Sandy	2	1	2	5
Black	1	-	1	2
Deep Soil	1	-	-	1
Black-Sandy	-	-	1	1
Type of Land:				
Lowland	3	1	1	5

Source: 1980 B/CS

portance placed upon lowland holdings and the different potentials for the types of soils described.

Another method of gaining insight about soils is to view it from the ecological perspective. For example, the various species of Acacia, a genus of trees common to grasslands, is closely associated to habitat conditions. One species, *A. clavigera*, forms woodlands characteristic of Tanzania as far inland as Kilosa town (Lind and Morrison, 1974). Lind and Morrison (1974) suggest the black soils are clays which have been transported downslope by creep and erosion to build up the black clays of the valley floors. The vegetation is characterized by grasslands interspersed with a few trees and shrubs. Termite mounds are normally found in these areas also. The types of clays in these soils are predominantly montmorillonite or illite which exaggerate the effects of drought due to their swelling and subsequent imperviousness to rain water, thus a reason for preferring sandy soils emerges. Perhaps the water holding capacity for the sandy-clay soils is greater than that for the clays mentioned above. When dry, the black soils are exceedingly hard. Overall, the black clay soils are difficult to cultivate but are suitable for production of maize and sorghum. Furthermore, the structure may improve as cultivation continues into the third or fourth year.

A more pragmatic approach in dealing with soils is to suggest functional relationships which impede or promote crop production. Collinson (1983) does this by identifying gross characteristics of soils and relating them to topography. Collinson states that in the Sukumuland area of Tanzania, located Southwest of the Morogoro Region, black to dark gray clays are found which have impeded drainage. The sandy soils in this area and probably in the Kilosa district range from sandy clay loams to loamy sands with a lateritic horizon. These types of soils are characteristic of the Oxisols, which in the former classification system, were approximately Lateritic and Latasolic soils.

The soils characteristic of the Kilosa district support vegetation such that open woodland (Miombo) cover it (Manday, 1982). This type of cover offers adequate protection for the Tsetse fly which precludes intensive livestock production in the district. It is clear that unless a resistant breed of draft animal is developed the hand labor prevalent in the district will continue to be the predominant form of tillage practice.

CHAPTER 3

THEORETICAL ASPECTS AND REVIEW OF LITERATURE

The research undertaken is comprised of three major components. These may be described as a modelling component consisting of the mathematical linear programming (LP) model and two additional components which are the nutrition and risk aspects incorporated within the model. A literature review focusing on each of these components will provide the background necessary for the further development of the study.

The general model format will be presented followed by a discussion of the uses of LP models in the African agricultural sector. A discussion of nutritional and risk components and their usefulness in meeting the objectives of this study will follow in chapters four and five.

3.1 Mathematical Formulation of the Linear Program

The one period LP model used in this study is represented in its general format. The maximand, or objective function, consists of a linear equation containing six crop enterprises. Maximize:

$$S = \sum_{j=1}^{n} N_j X_j \quad (j = 1,2,...,n) \qquad (3.1)$$

where:

N_j = the grams per kilogram of utilizable protein (UP) from the jth major crop.

X_j = the quantity, in kilograms, of the jth major crop produced.

The objective function is maximized subject to a set of thirty-eight linear constraints. These consist of a land constraint, a labor constraint for each of the twelve months, seven protein constraints, one calorie constraint, five mineral and vitamin constraints, five amino acid constraints and seven focus loss constraints. The land constraint is written:

$$L_j X_j \leq M \qquad (3.2)$$

where:

L_j = the quantity of land planted to the jth crop necessary to produce one unit of output of the jth crop in hectares per kilogram.

M = the total hectarage of land available for crop production.

The labor constraints are represented by:

$$\sum_{i=1}^{o} \sum_{j=1}^{n} La_{ij} X_j \leq 0_j \qquad \begin{matrix}(i=1,2,...,o)\\(j=1,2,...,n)\end{matrix} \qquad (3.3)$$

where:

La_{ij} = the number of adult equivalent days (MED) required by the ith crop enterprise in the jth month, in order to produce one kilogram of UP, in MED per kilogram.

O_j = the total MEDs available in the jth month.

The prctein constraints allow the inclusion in the model of an important nutrient component. The protein constraints are developed in a manner which allows both protein quantity and quality considerations to enter the modelling effort. This is a major difference between this model and many others which have been developed. It allows protein quality to be determined within the model rather than fixing the quality "a priori". The seven protein constraints and the calorie constraint are discussed in chapter five. Likewise the constraints dealing with minerals and vitamins and those dealing with amino acid composition are discussed in chapter five.

The final set of constraints deal with risk aspects of the model. The focus loss constraints and their derivation are discussed at length in chapter four. These constraints are incorporated to insure adequate nutrition and reasonable diversification of cropping enterprises. Further specification of the model will be taken up in subsequent chapters and the discussion here will now be directed toward application of LP and some theoretical underpinnings.

3.2 Basic Assumptions of Linear Programming

The basic assumptions of LP specify proportionality, additivity, divisibility and certainty (Hillier and Lieberman, 1980). Proportionality implies that no additional cost is associated with the start up of the operation and that proportionality holds over the entire range of levels of the activity. Additivity assumes that there are no interactions of activities which might affect the total measure of effectiveness or resource usage. Divisibility implies that the units of an activity can be divided into fractional levels. Certainty assumes that all parameters of the model are known constants.

3.3 Application of Linear Programming to Small Scale African Agriculture

Linear programming models have been used widely in agriculture since World War II. Applications to agriculture have been made by agricultural economists

> to specify the optimum organization of resources and enterprises on farms, to suggest desirable farm adjustments, to specify profit maximizing mixes of commodities produced by marketing firms, to specify cost minimizing methods of processing products such as fertilizer or mixed feeds, to specify spatial equilibrium patterns in the flow of agricultural products, to indicate optimum interregional patterns of resource use and products specialization in agriculture, and to solve related types of problems. (Heady and Chandler, 1973)

Clayton (1961) was the first to apply LP to a problem dealing with African agriculture (Clayton, 1961). His study looks at the effect of limited resources on the profitability of the typical farms in a province of Kenya. C.K. Eicher and D.C. Baker have classified the major uses of LP in African small farming as to the type of application as follows (Eicher and Baker, 1982):

(1) identification of constraints facing the small FH and inherent in the FSs.

(2) the development of functions for normative supply and input demand.

(3) estimation of frontier production functions based on cross sectional data.

(4) evaluation of the profitability of new technologies.

(5) development of management strategies and the evaluation of those strategies.

Noticeably lacking from these works are any dealing with nutrition except in a cursory fashion.

Delgado, in work on Upper Volta, found that labor was such a binding constraint that without smoothing of the peaks there was little incentive for the on-farm production of cattle enterprises (Delgado, 1979). This finding, that labor was a serious constraint, was first suggested by Heyer in her analysis of FHs in Kenya (Heyer, 1966). She was perhaps the first to quantify the absorption of labor by noncrop activities. Heyer further observed that a number of goals were perceived by the FHs, one of which was the provision of food for subsistence. Manday used data collected in the Kilosa district to compare traditional agricultural practices with practices under improved technology (Manday, 1982). He found, as had others, that labor was scarce during peak labor periods. A major hypothesis of the study, that farm plans could improve the farm income situation, appear to be substantiated for both indigenous technology and improved practices.

The prominence of the labor shortage during peak labor demand periods associated with the goal of providing minimum subsistence requirements may provide an insight into the disincentive which exists for FHs where marketing and commercialization of their products are limited. Furthermore, it seems to support the general hypothesis set forth by T.W. Schultz that this type of FH is more efficient rather than less efficient in its allocation of FH resources (Schultz, 1964).

Metson applied a LP to a FS in the Nandi District of Kenya (Metson, 1978). The author justified her use of LP on the basis that a normative supply analysis best focused on technical production possibilities and resources available. She identified problems perceived by the FHs including marketing, transportation, capital and labor shortages. Metson worked with representative farms in her research which caused concern over problems associated with aggregation bias. Studies other than Metson's have been undertaken to derive normative supply and input demand functions but these have, in general, not addressed adequately the problems of aggregation bias (Ogunfowora and Norman, 1973; Mwangi, 1978). Metson discusses at length the problem of aggregation bias (Metson, 1978). She defines the bias as

> the difference between the area supply function as developed from the summation of the linear programming solutions for each individual farm in the area, and the summation of the weighted results obtained from a small number of representative or benchmark farms.

The absence of aggregation bias suggests that the optimal LP results will be proportional for the representative farm of a region and for a regional LP when all resources have been summed across all FHs in the region. This goal is very difficult to attain. One way of minimizing the aggregation bias is to choose study areas which are more homogeneous. This was not possible since the data had been collected previously. This research addresses the problem of aggregation bias through use of nonmechanized FHs thus increasing homogeneity between villages and among households. Furthermore, the maximization of nutrient production based upon minimum nutritional requirements provides a basis for homogeniety superior to revenue or cost concepts incorporated in a typical objective function. The requirements for nutrients are based on a common index which is introduced in chapter five and presented in Appendix C. The nutrient requirements for one FH are the same as that for another except that the number, age and sex of individuals will vary from one FH to the next. The demand for nutrients would appear to be more homogeneous among subsistence-cash FHs in the villages than is the demand for income. This is meant to suggest only that aggregation bias may be minimized relative to LP models maximizing a monetary goal. Collinson suggests that: 1) the quantity of food, 2) nutritional quality, 3) reliability of supply and 4) taste are motivational factors dominating the decision making process in traditional African FHs (Collinson, 1983). If this is true, the previous consideration contains enough plausibility to justify further investigation.

The nutritional basis of this work relies heavily on previous work undertaken by V.E. Smith. Smith's mathematical programming model is the only programming model that the author can locate which focuses on the economics of nutrition in Africa (Smith, 1975). Smith undertook a comprehensive study of the economics of nutrition in Nigeria. The research was a macro-economic approach which has been adopted in this work for application to a microeconomic analysis of the FSs in Dumila, Mkundi, Magole villages and the northern area of the Kilosa district as an entity.

One other piece of research focusing on nutrition and using linear programming was carried out by Calkins working with Nepalese farmers (Calkins, 1981). Calkins modelled a number of different production scenarios. He concluded that it was possible to clearly identify the most nutritious and profitable production patterns using linear programming. His incorporation of nutritional requirements is similar to that of Smith except that protein is not dealt with extensively. Calkins' work is the most intensive use of nutritional information in a micro-economic analysis found at the time of this writing.

The focus loss constraints are incorporated in this study to allow risk to enter the model via crop production activities while meeting minimum nutritional requirements. Focus loss constraints have not been applied to African subsistence-cash cropping agriculture to the knowledge of the author.

The concept of focus loss was proposed by Schackle in 1955 (Schackle, 1955). In 1961 he furthered his hypothesis with the development of a model incorporating his previous work (Schackle, 1961). A major hypothesis of Schackle's is paraphrased in his own words: "When many different things are all equally and perfectly possible, it is the brilliant and the black extremes which hold our thoughts" (Schackle, 1961). Schackle's conceptual efforts were directed toward the problem of maximization of expected gain while insuring against disastrous loss.

Boussard and Petit operationalized Schackle's work when they applied the focus concept to the problem of uncertainty in a group of French farmers' production decisions (Boussard and Petit, 1967). They attempted to incorporate a set of linear constraints designed to limit the possibility of ruin while constraining the contribution to total loss by each activity. The model focused on the risk taken, rather than on expected gain. The addition of the focus loss constraints in the study improved the prediction of the farmers' behavior, but the major improvement was a result of the addition of a credit constraint.

Kennedy and Francisco described a method for obtaining indifference schedules for expected income and focus loss income (Kennedy and Francisco, 1974). One of the objectives of the work pertained to practical and theoretical difficulties in specifying F (minimum level of income) at some constant. The authors felt it was more practical and theoretically plausible that their indifference curves provide trade-off information for determining this level F. This is less of a problem when identifying minimum nutritional requirements. S.H. Johnson incorporated focus loss constraints in his study of San Luis Valley farmers faced by waterlogging and salt accumulation on their properties (Johnson, 1981). The focus loss elements constrained the amount of income which could be lost through cropping activities and affected the choice among water supply activities.

The application of nutritional and focus loss constraints to a micro-economic analysis of subsistence-cash FHs presents some intriguing possibilities. Furthermore, the defining of the objective function in terms of nutrient production allows the goal of nutritional sufficiency to be of paramount importance in the research. Further specification of the focus loss constraints and the nutritional constraints are undertaken in chapters four and five.

CHAPTER 4

DESCRIPTION OF RISK CONSTRAINTS

The LP model is unconventional in that the FH is assumed to choose crop combinations which yield the largest gross margin of utilizable protein (UP) subject to land and labor constraints. UP is that amount of protein which is completely used by the body in the formation of tissue. This concept is taken up in chapter five. Capital is not included as a constraint due to the small amount available as was documented in Table 12.

4.1 Background

The focus loss-focus gain constraints as described by Boussard and Petit (1967) have been adopted. In the original formulation, which Boussard and Petit operationalized from the work of G.L.S. Schackle, the authors introduce a method which considers uncertainty in the farmer's production decision process. The authors suggested that farmers maximize profit, equated in the study with gross margin, given a negligible possibility of ruin. Ruin is defined in terms of income. It is suggested that ruin occurs at a point below some minimum level of income necessary for consumption and fixed charges associated with the farming operation. This study treats the concept of ruin as a point below which a nutrient required by the FH is supplied in inadequate amounts. This implies a debilitating state of health associated with both inadequate income and inadequate production or an inadequate supply of nutrients even though adequate income may be available. The latter case will not often exist. The former case is more plausible for the area of the Kilosa district including the FHs responding in the survey.

4.2 Modelling the Focus Loss Constraints

The incorporation of a focus loss-focus gain risk aspect into the LP model maximizing UP is much the same as a conventional LP. The model is an expanded version of the general LP formulation in equation 4.1.

$$\text{Maximize } Z = \sum_{j=1}^{n} N_j X_j \quad (j=1,2,...,n) \qquad (4.1)$$

s.t. a series of production, nutritional and risk constraints

Focus gain is simply the return in UP from the normal production practices in the villages and is represented by equation 4.1 with focus constraints included. The focus of gain is not as critical to this analysis as is the focus of loss (FL).

The FL constraints are derived from data on the normal level of consumption of major crops and imputed values for cash crops. The cash crops may be sold for purchase of UP or other goods and services. Loss is defined in the study as the difference between normal consumption of UP and the amount required on a yearly basis to meet the nutritional requirements of the FHs. Loss is estimated on the basis of equation 4.2.

$$\text{Loss} = \sum_{j=1}^{6} N_j X_j - \text{MINI} \tag{4.2}$$

where N_j = UP from the jth crop in grams per kilogram

X_j = quantity of the jth crop in kilograms

MINI = the minimum nutritional requirements for the F.H. in grams of UP

A vector for Loss is introduced to express the constraint in equation 4.2. This is done on a crop by crop basis. The inclusion of this vector allows restrictions associated with individual crops to be expressed. In this analysis both cropping proportions and proportions associated with the median yield of utilizable protein (UP) per kilogram of commodity produced are considered. This is introduced through focal loss coefficients (FCL) which represent the FL which may accrue to any crop on a kilogram basis. However, no crop may incur a loss greater than 1/K of the total loss where K equals the number of activities. This insures the diversification of the cropping activities which are representative of all three FSs. Given this description the restraint may be written such that for each major crop:

$$(FCL_j)(X_j) - 1/K \text{ Loss} \leq 0 \qquad (4.3)$$

where FCL_j = the focal loss of the jth crop, in grams of UP per kilogram.

X_j = the quantity of the jth crop, in kilograms.

$K = 6$

Equation 4.3 represents a group of six constraints which can be considered security constraints. These protect against a loss which would endanger food security, while at the same time incorporating the riskiness of the activity. K has been assigned a value in a similar way to previous works incorporating focus loss activities. Boussard and Petit suggest that "variations of riskiness among crops are expresssed in the Pi's. Thus there is no reason to assume that K varies from one crop to another" (Boussard and Petit, 1967). Johnson has defined K=n where n equals the number of crops considered in the model (Johnson, 1981). Kennedy and Francisco propose using a value of K greater than or equal to $(n)^{1/2}$ where n equals the number of the activities in the solution (Kennedy and Francisco, 1974).

4.3 Assignment of Coefficients

Assignment of coefficients to be used in the model was dependent upon: 1) the type of crop being considered, cash or subsistence-cash (S-C) crop, 2) the cropping proportions and 3) the yield of UP per kilogram of major crop. The type of crop produced determined whether a value for UP was imputed on the basis of sales or consumption. The level of consumption of the crop, if consumed, was assumed to be the normal level of consumption of that crop. Therefore, consumption was used as a basis for expected production of UP with respect to S-C crops. In the case of the cash crops, quantity of sales acted as the basis for imputed consumption values.

4.4 Cash Crops

In Dumila, cotton and sunflower were produced only for sale by the respondents. This means that they were not consumed directly by the FHs as were the S-C crops. However, the sale of cotton and sunflower produced income which was then spent, in part, on food. The imputed value in UP of cotton and sunflower production and sales is that value associated with the income generating potential of a basket of major food crop commodities most often purchased in the market place.

Assumptions maintained are: 1) As food supplies decrease money spent on other consumer goods is diverted to food purchases at the marginal rate of decrease in the consumption of cotton and sunflower (shadow values for cotton and sunflower when both are cash crops). In other words, the marginal value associated with cotton or sunflower sales should decrease as demand for nutrition becomes a more pervasive influence on the allocation of resources in response to a food shortage; 2) Supplies of additional nutrients are not available in the short run, and 3) The time period under consideration is a normal period relative to environment, production and political activities. Therefore, the quantity of UP consumed during the period under question is assumed to be the normal quantity consumed by the FHs.

Respondents in both Mkundi and Magole reported consumption of sunflower. For this reason only cotton is considered a cash crop in these two villages. Both Mkundi and Magole produce one cash crop and five S-C crops, all of which are considered to be major crops.

4.5 Subsistence-Cash Crops (S-C)

S-C crop coefficients are treated in a similar manner to those of cash crops in developing the focus loss coefficients. An obvious difference which exists is that no values are imputed to S-C crops for UP. Rather the UP values for each crop are used as a basis. The resulting coefficients are adjusted on the basis of yield proportions on a whole farm basis and yield in UP on a kilogram basis from a unit of each crop.

4.6 Development of the Coefficients

Once the conceptual framework was developed the focus loss coefficients in the FL restraints were derived. A basket of commodities consisting of maize, rice and beans acted as a foundation from which UP for the cash crops was imputed. This assumes that income spent on food in the marketplace was partially derived from income accruing to the FH from the sale of cash crops. The derivation consisted of estimating the number of kilograms of each food source that was apt to be purchased in the market given the amount of income spent on food during the year. This information was drawn from the 1969 Household Budget Survey (Bureau of Statistics, 1972). The household survey and the B/CS were not standardized with respect to income ranges. Therefore, information from the Household Budget Survey for the 1,000 - 1,999 T.Sh. range is assumed to be representative of the FHs in the villages. The information from the Budget Survey was adjusted for the amount of income spent for food in the respective villages. The total amount of these sources of food purchased in the market were converted on the basis of UP per kilogram of food. This allowed an estimate of UP provided by the purchases of the food sources to be made. This figure was divided by the total kilogram amount of all foods purchased resulting in a weighted average of UP/kilogram for the basket of foods. Next, a price for a weighted basket of

Table 16. Grams of utilizable protein imputed to cotton and sunflower.

Step I. Quantities of foods purchased in the villages per annum.

	Maize (kg)	Rice (kg)	Beans (kg)	Total kg Purchased
Dumila	49	15	5	69
Mkundi	53	15	5	73
Magole	57	23	5	85
TOTAL	157	53	15	227
x	53	18	5	76

Step II. Grams of utilizable protein per kilogram of commodity basket.

	1) Maize kg purchased x GUP/kg	2) Rice kg purchased x GUP/kg	3) Beans kg purchased x GUP/kg	$\sum_{j=1}^{3}$	Weighted Average GUP/kg
Dumila	(49x45.6)+	(15x45.5)+	(5x162.7)=	(3731 ÷ 69)=	54.1
Mkundi	(53x45.6)+	(15x45.5)+	(5x162.7)=	(3914 ÷ 73)=	53.6
Magole	(57x45.6)+	(15x45.5)+	(5x162.7)=	(4460 ÷ 85)=	52.5

Table 16. (continued)

Step III. Weighted price of commodity basket.

	Maize (Grain)	Maize (Flour)	Rice (Husked)	Beans	Total
Dumila:					
1) kg purchased	20.51	28.12	15.13	5.08	68.8
2) T.Sh./kg	1.81	2.17	2.52	3.00	--
3) Total T.Sh.	37.1	61.0	38.1	15.2	151.4
4) T.Sh./kg of basket	(151.4 T.Sh.)/(68.8 kg) = 2.20 T.Sh./kg				
Mkundi:					
1) kg purchased	22.78	30.48	15.93	4.84	74.0
2) T.Sh./kg	1.86	2.23	2.66	3.50	
3) Total T.Sh.	42.4	67.8	42.4	16.9	169.5
4) T.Sh./kg of basket	(169.5 T.Sh.)/(74.0 kg) = 2.29 T.Sh./kg				
Magole:					
1) kg purchased	24.4	32.47	22.68	4.84	84.4
2) T.Sh./kg	1.98	2.38	2.13	4.00	
3) Total T.Sh.	48.3	77.3	48.3	19.3	193.2
4) T.Sh./kg of basket	(193.2 T.Sh.)/(84.4 kg) = 2.29 T.Sh./kg				

Step IV. Grams of utilizable protein imputed to production of cotton and sunflower.[a]

	Cotton GUP/kg	Sunflower GUP/kg
Dumila:	79.92	43.03
Mkundi:	74.90	--
Magole:	74.51	--

Table 16. (continued)

	Cotton GUP/kg	Sunflower GUP/kg
Kilosa 1	76.30	--
Kilosa 2	76.88	--

[a]Equation used to derive the relationship:

$$\frac{x \text{ GUP/kg crop}}{\text{GUP/kg of commodity basket}} = \frac{\text{Government price/kg}}{\text{Free market price/kg of commodity basket}}$$

Source: 1980 BC/S

Following the derivation of values in UP for the cash crops the FCL coefficients were developed. An important point in the development of this factor was the exclusion of the cash crops from the calculation for Loss. The demand for UP from income derived from cash crops is met through purchases in the market, only indirectly through production. The amount of UP purchased in the market is included in the total quantity of all commodities consumed. By deleting the value in UP for cash crops from the calculation of Loss double counting of the product is avoided. On this basis a considerable reduction in the difference between UP supplies and requirements (MINI) is effected. For instance, when summing all sources of UP, including that associated with cash crops, 96,302 GUP/FH/Year were available for consumption. However, not all this was consumed as seen from Table 17. Rather, an amount of approximately 73,000 GUP/FH/Year was consumed in Dumila from production of S-C crops. The amount which was actually produced and consumed on the farm plus the normally purchased amount of UP were used as a basis in the estimation of Loss. This was done according to the equation:

$$\sum_{j=1}^{6} N_j X_j - \text{Loss} = \text{MINI} \qquad (4.4)$$

where all variables are previously defined.

Table 17. Focus loss equation constraint coefficients.

	(1) Total GUP[a] (GUP)	-	(2) Loss (GUP)	=	(3) MINI (GUP)
Dumila	72,797		11,039		61,758
Mkundi	85,002		33,975		51,027
Magole	83,807		29,495		54,312
Kilosa 1	84,656		28,592		56,064
Kilosa 2	87,715		32,418		55,297

[a]Total GUP = $\sum_{j=1}^{4} N_j X_j$

where N_j = utilizable protein in grams/kilograms from $crop_j$.

X_j = quantity of $crop_j$ normally produced in kilograms.

Source: 1980 BC/S

MINI is known from estimations of the minimum requirements of nutrients. These are discussed at length in chapter five which deals specifically with nutrients.

Table 18 displays the process through which the FLCs were derived. The UP/kilogram by major crop is multiplied by the ratio of both output and UP yield on a whole farm basis. This ratio is a measurement of the loss which may be incurred by any crop or combination of crops without falling below minimum nutritional requirements, in this work protein. When this is applied to the UP figure the FCL coefficient is complete but also adaptable to other risk factors. For instance any index of risk may be applied directly to these coefficients. The additional or reduced risk will be reflected in the amount of UP which is necessary to meet the requirements of the FL constraints. The resultant product of UP and Ratio represents the UP which may be lost through falling consumption of any specific crop before reaching a maximum permissible loss for each or all crops. This appears to be the case no matter what factor is affecting the FH resulting in decreased consumption. The product of UP/kilogram and Ratio in Table 18 are then employed in the LPs.

4.7 <u>Summary</u>

To summarize, the focus gain is simply the normal production of UP by the representative FH. The focus loss is the amount of UP which may be foregone without falling below a

Table 18. Derivation of focus loss coefficients of major crops.

	Maize	Sorghum	Rice	Beans	Cotton	Sunflower
Dumila:						
1) GUP/kg	45.6	54.1	45.5	162.7	79.9	40.0
2) Ratio	.12	.24	.13	.09	.04	.32
3) FCL[a]	5.47	12.98	5.92	14.64	3.20	12.80
Mkundi:						
1) GUP/kg	45.6	54.1	45.5	162.7	74.9	57.7
2) Ratio	.29	.43	.47	.10	.26	.68
3) FCL	13.22	23.26	21.39	16.27	19.47	39.24
Magole:						
1) GUP/kg	45.6	54.1	45.5	162.7	74.5	57.7
2) Ratio	.29	.42	.40	.17	.27	.19
3) FCL	13.22	22.72	18.20	87.66	20.12	10.96
Kilosa 1:						
1) GUP/kg	45.6	54.1	45.5	162.7	76.3	57.7
2) Ratio	.25	.34	.43	.20	.13	.61
3) FCL	11.40	18.29	19.76	32.45	9.79	34.95
Kilosa 2:[b]						
1) GUP/kg	45.6	54.1	45.5	162.7	76.9	57.7
2) Ratio	.22	.37	.23	.10	.17	.41
3) FCL	10.32	20.26	10.68	15.52	13.06	23.78

[a]Derivation of Focus Loss Elements (FCL)

Step 1. Estimate the quantity, in kilograms, of food consumed from both production and purchases.

Step 2. Determine from Step 1 the quantity of UP consumed, in kilograms.

Step 3. Let; CD_j equal the percent of total production from $crop_j$.
LP_j equal the percent of UP from $crop_j$.

Step 4. Let; $PUP_j=(CD_j)(\Sigma N_j X_j)$; equal to the UP yield on the basis of production.
$Loss_j=(LP_j)(Loss)$; equal to the proportional loss of UP associated with $crop_j$.

Table 18. (continued)

where:

$\sum_{i=1}^{4} N_j X_j$ equals the UP from major S-C crops.

Loss equals the permissible loss of UP which will allow minimum nutrition requirements to be met, using normal consumption levels.

Step 6. Let; $Ratio_j = Loss_j / PUP_j$; equal to a unitless ratio of the loss assigned to each crop, divided by the proportion of UP from a kilogram of that crop.

Step 7. Let; $FCL_j = (GUP/kg)(Ratio)$; equal to the UP which may be lost through decreasing consumption of any major crop, on a kilogram basis.

[b] Weighted average of Dumila and Mkundi.

Source: 1980 B/CS

minimum nutritional requirement for the entire FH. Coefficients were derived for cash crops to measure their importance in the provision of UP to the FHs. The S-C crops and cash crops, together, were used to estimate coefficients which defined the focal loss assigned to each crop.

The restraint called MINI was conveniently derived after UP produced from each source had been estimated. MINI represents the minimum level of nutrition, in UP, that meets requirements for the FH on a yearly basis. The Loss vector was assigned a weighting factor of one-sixth for each crop in accordance with the number of consumption activities. This inclusion allows one to express the condition that the loss, in UP, associated with any one crop may not exceed 1/K of the total loss permitted.

The FL aspects of the model lay a groundwork for the development of the nutritional aspects of the model and vice versa. The two aspects of the model act as a direct link between the FS and the FH and as such cannot be dealt with as separate entities. The nutritional aspects which have been defined briefly in this chapter will be dealt with more directly and succinctly in the following chapter.

CHAPTER 5

CHARACTERISTICS OF NUTRITIONAL REQUIREMENTS OF THE FARM HOUSEHOLD

One of the most important factors affecting the FH is the quantity and quality of the food supply. Much work has been done in determining nutrient levels which are adequate in meeting nutritional requirements. Nutrition is a pertinent topic in most parts of Africa. In many Tanzania villages the ability to produce enough food is a question faced anew each year. This research incorporates nutritional information in a LP format compatible with LP similar to the way Dr. E.V. Smith of Michigan State University has done previously (Smith, 1975). Whereas Smith developed a model for macro economic analysis in Nigeria, this model is micro oriented and deals with the nutritional requirement of the representative FH. The representative FH is defined as the FH maintaining the average number of consumer units (CU) aggregated across all respondents within each village. The value for a CU is developed from the nutrient requirements found in Appendix B. Important relationships between protein, calories, vitamins and minerals are incorporated to insure that adequate nutrition for the representative FHs is met within the results of the modelling effort.

5.1 Protein-Caloric Interrelationships

The protein-calorie (PC) interrelationships are an important aspect of nutrition in the representative FH. In determining the quantity of protein actually used for building tissue in the body a minimum level of caloric intake is assumed to be present. The amount of utilizable protein (UP) from each source of protein (ie., foods consumed) must be determined. With minimum levels of calories available a procedure for the incorporation of other factors must be followed: 1) Essential Amino Acids (EAA) present in each food consumed must be estimated. This is done on the basis of grams of nitrogen per 100 grams of food protein; 2) The interaction among EAA and their ability to increase utilization of other AA consumed in combinations with one another must be investigated; 3) Estimation of the calories which are present in each protein source on a kilogram of food consumed basis and with normal consumption patterns introduced must be accomplished; 4) Subsequently, total UP required on a yearly basis for the representative FH must be estimated.

5.2 Essential Amino Acid Content (EAA)

Proteins are a subgroup of a group of related subsances consisting of different combinations of organic acids called amino acids (AA). Protein is derived for use in the body from different food sources. Within the food sources, different AA are present. Particular AA cannot be synthesized in the body and are therefore referred to as essential amino acids (EAA). The AA considered EAA for this research are: 1) lysine, 2) methionine, 3) threonine, and 4) tryptophan. Normally eight AA are considered EAA. However, only four, those listed above, are likely to be limiting (Smith, 1975). Cystine is included as a sulfur containing AA because it has a methionine sparing effect. Methionine may be used by the body to synthesize cystine when there may be a cystine shortage. With cystine supplied by the foods consumed the methionine necessary for synthesis of cystine may be used for other purposes.

The relationship of the EAA with one another are defined by nutritionists through use of a chemical score (CS). The CS is a measure of the quality of the protein based on its EAA composition with respect to a reference protein (RP). The RP is a protein which has an EAA composition such that practically 100% of the protein is used for anabolic purposes (ie., production of body tissue). The RP used in this research is that adopted by the 1965 FAO expert group on nutrition (FAO and WHO, 1965). That RP was egg. The CS of the EAA for the main commodities consumed in the villages is presented, along with information pertinent to the estimation of UP contents of food later in the chapter.
When a unit of food is consumed with a quantity of EAA

present in particular proportions, the maximum amount of protein in the unit of food that can be utilized is determined by the EAA with the lowest AA score relative to the quantity of the corresponding EAA in the RP. Schmitt suggests that the chemical score of a protein or mixture of proteins be calculated by the formula (Schmitt, 1979):

$$\text{AA Score} = \frac{\text{mg. of AA in 1 gr. of Test Protein}}{\text{mg. of AA in 1 gr. of RP}} \quad (5.1)$$

where: RP = reference pattern of AA in the substance used as a standard (egg)

The lowest of the scores for all EAA present in the food is the CS for the food or combination of foods under consideration.

The CS must be determined prior to estimating the net protein utilization (NPU). The NPU is defined for purposes of this study as the operative net protein utilization (NPU-op). This is itself defined as the proportion of nitrogen intake that is retained at consumption levels equal to or greater than maintenance levels. Previously, it was assumed that minimum levels of caloric intake were being met. This insures that more than the normal quantity of protein will not be broken down for use as an energy source. Thus, the application of NPU-op to the model is justified. Indeed, as will be shown, there is little reason not to maintain these assumptions under normal conditions affecting the FHs in Dumila, Mkundi and Magole. Drawing from the works of Smith and Miller and Payne the NPU-op can be calculated using the equation (Smith, 1975; Miller and Payne, 1963):

$$NPU\text{-}op = (CS+8)[1-K(P\text{-}C\%)] \quad (5.2)$$

where: CS = Eq. 5.1

8 = a constant associated with the qualitative relationship between the concentration of protein in the diet, the quality of protein, and NPU-op

P-C% = The protein-calorie percent which is the protein content of a food expressed as a percentage of total metabolizable calories

K = a constant equal to 0.0189

The NPU-op for each crop must be known to estimate the supply of RP. The RP, NPU-op, and crude protein (CP) are listed in Table 19. CP is the total amount of protein found in a unit of food whether it is utilizable or not.

The RP may be defined formally as a "protein of high biological value, containing a specified pattern of amino acids completely utilizable for anabolic purposes at maintenance levels" or more simply, "completely utilizable for

Table 19. Net protein utilization and reference proteins for major crops produced in Dumila, Mkundi and Magole.

	Maize (mg/100 gms)	Sorghum (mg/100 gms)	Rice (mg/100 gms)	Beans (mg/100 gms)	Sunflower (mg/100 gms)
NPU	44.83	47.98	57.88	40.81	43.18
	(gms/kg)	(gms/kg)	(gms/kg)	(gms/kg)	(gms/kg)
CP	95	101	75	221	126
RP	42.59	48.46	43.41	90.19	54.41

NPU-op = (CS+8) (1-0.0189 (P-C%))
CP is crude protein per kilogram of food
RP = (NPU-op)(CP)/100 for each crop

anabolic purposes" (Smith, 1975). The RP for the individual crop may be derived using the equation:

$$RP_i = (NPU\text{-}op)\ (CP_i)/100 \quad (i = 1,2,\ldots,5) \qquad (5.3)$$

where: NPU-op is defined previously

CP_i = the quantity of crude protein supplied in 100 gms of food of $crop_i$

The determination of the RP by crop lays the groundwork for the estimation of UP by crop as well as the coefficients for the LP model.

The estimation of UP on a kilogram basis for each crop may be made through use of the equation:

$$UP_i = [RP_i/1-((7.6)CP_i/C_i)]-.08(CP_i) \quad (5.4)$$

where: RP_i = reference protein per kilogram from $food_i$

CP_i = total grams of crude protein per kilogram of $food_i$

C_i = calories per kilogram of $food_i$

Supply of calories on a kilogram basis of food are derived from Latham's estimates which are presented in Table 20 by major food source (Latham, 1979). Quality of foods is assumed to be the same among villages, therefore the UP estimates in Table 20 are standard coefficients.

Table 20. Calories and utilizable protein per kilogram of food consumed.

Crop: / Nutrient:	Maize[a]	Sorghum	Rice[b]	Beans	Sun-flower
	cal/kg	cal/kg	cal/kg	cal/kg	cal/kg
Calories	3620	3470	3640	3360	4860
	gms/kg	gms/kg	gms/kg	gms/kg	gms/kg
Utilizable Protein	45.6	54.1	45.5	162.7	57.7

[a]Maize meal, 96% extraction rate.
[b]Rice, lightly milled and parboiled.

Source: Latham, 1979

Once the UP per kilogram for each food source has been determined the weighted average of UP may be derived. This is done on the basis of proportions of foods consumed in the different villages. The coefficients for this weighted average are given in Table 21. As seen from the table the coefficient for each village is the product of the division of UP normally consumed in the village by the total quantity, in kilograms of foods consumed. This provides a benchmark with which to compare the results of the LP models.

Table 21. Derivation of weighted basket of utilizable protein from consumption of major crops.

	Tot. GUP Available	÷	Tot. Consumption Major Crops	–	Weighted UP
	GUP		kg		GUP/kg
Dumila	72,797		1,311	=	56
Mkundi	85,002		1,472	=	58
Magole	83,807		1,544	=	54

Source: 1980 B/CS.

5.3 Utilizable Protein Requirements Over a Range of Consumption

One more series of computations must be made to determine the supplies of UP over a normal range of consumption.

This is done on the basis of the proportions of major crops and an aggregated measurement of UP from those crops when consumed. The first step in estimating an aggregated figure for UP from major crops is the estimation of UP required by the representative FH to meet minimum requirements on a yearly basis. Secondly, an estimate of total calories for the FH on a yearly basis must be made. Finally, information previously developed is incorporated into equation 5.5 to estimate the RP level when UP and CP are equal. This implies that the protein in the diet is 100% fully utilizable or in other words completely used for anabolic purposes. This is also the point defining the minimum amount of protein necessary to supply the representative FH on a yearly basis if it were all used in tissue formation.

Shimkin has suggested a per capita requirement of 41 grams of UP per day (GUP/day) for the individual in Tanzania (Shimkin, 1983). Latham has estimated the local protein requirements for Kenya to be 38.8 GUP/day and 41.7 GUP/day for Mozambique (Latham, 1979). Shimkin's suggested requirements are used in this analysis. The Shimkin estimate must be adjusted downward by an amount which represents protein consumption from sources other than the major crops. This estimate has been considered previously in chapter four.

The CUs per FH and for the representative FH by nutrient are found in Appendix B. These are used in conjunction with the UP by major food to derive yearly UP requirements. This information is available in Table 22 along with yearly requirements for calories in each village. It can be seen that the requirements are directly related to the CUs for the representative FH.

Table 22. Consumer units, utilizable protein and calorie requirements for Dumila, Mkundi and Magole.

	CUs No.	UP Requirement GUP/FH/Yr[a]	Calorie Requirement CAL/FH/Yr[b]
Dumila	5.64	61,800	4,735,000
Mkundi	4.96	51,000	4,164,000
Magole	4.66	54,300	3,912,000
Kilosa 1	5.12	56,000	4,298,000
Kilosa 2	5.05	55,300	4,365,000

[a]Rounded to nearest 100 GUP.
[b]Rounded to nearest k cal (1000 calories).

Source: 1980 B/CS, computer generated

The caloric requirement is an average of Shimkin and World Bank estimated caloric requirements (Shimkin, 1983; World Bank, 1981). This average was 2,295 calories per capita on a daily basis. This requirement, as was the protein requirement, is based upon the number of CUs in the FHs surveyed. However, rather than adjusting for the calories which are supplied from sources other than consumption of the products of major crops, the total requirement has been used. This is done to accomodate the differences in the supply of calories over the year. The survey data does not provide information on the time of the year that shortages of calories may occur. It is obvious that the supply of calories is greater immediately following the harvest of the earliest maturing crop. Prior to this period calories may be more scarce. Therefore, the total requirement for calories is used to insure sufficient calories over the entire period. This assumes that the ability to store crops, with little deterioration in quality, until the following harvest exists.

Now the information which has been developed may be incorporated into the equation for UP' for the combination of major food sources. The equation is the same as that for the UP from individual food sources.

$$UP' = [RP'(Q')/1-((7.6(CP))/C']-.08(CP) \qquad (5.5)$$

where: Q' = Quantity of food normally consumed in kg/yr

C' = Calories in food normally consumed in cal/yr

Setting UP'=CP and solving for RP' provides the reference protein on a kilogram basis for the basket of foods considered. Assuming normal patterns of consumption this represents the minimum quantity of UP' which must be consumed to meet UP' requirements if the CP were 100% utilizable. These coefficients are found in Table 23. In other words, at the point CP=UP', the chemical score is 100. Through the use of a linear approximation of the nonlinear constraint suggested by Smith a range of protein quantity/quality relationships may be observed (Smith, 1975). As the quantity of CP in the diet increases, the minimum acceptable ratio of UP' to CP decreases representing a declining chemical score, which one will remember is assumed to be a function of EAA proportions in the diet. This manifests itself in a decreasing reference

Table 23. Reference protein minimum levels with crude protein 100% utilized (UP'=CP).

	RP'	UP'=CP
Dumila	47.14	61,800
Mkundi	34.65	51,000
Magole	35.17	54,300
Kilosa 1	38.78	56,000
Kilosa 2	39.25	55,300

Source: 1980 B/CS

protein level. As was pointed out earlier, the consumption of combinations of foods may result in a higher chemical score and subsequently more protein utilization from the same quantity of food. The inclusion of both UP and UP' in the LP model provides information on both quantity and quality over a range of CP intake. With this accumulated information protein and caloric constraints may be defined. Coefficients for the LP by villages and for aggregated data from the villages may be ascribed to the constraints.

5.4 The Protein-Calorie and Amino Acid Model

The constraints dealing with EAA, calories and protein are listed below in their equational form. The coefficients associated with the equations are found in Appendix C.

The constraints dealing with essential amino acids (EAA) are presented in Table 24. Five constraints are necessary to adequately treat the EAA. These consist of constraints dealing with lysine, total sulfur containing amino acids (cystine and methionine), methionine, threonine and tryptophan.

The ratio of EAA to protein and nonessential amino acids (AA) which are required to provide protein in an economical way are derived from Smith's work (Smith, 1975). The proportions do not allow scarce EAA to replace the more abundant AA. This has been done in a fashion consistent with the recommendations of the 1957 FAO Committee on Protein Requirements and does not contradict the suggestions of the 1965

Table 24. Amino acid constraints.

Constraint No.	Constraint	b_i	Purpose Provides the minimum ratio of
1	$\Sigma a_{1j}x_j$ - 0.04000u	≥ 0	
2	$\Sigma a_{2j}x_j$ - 0.03424u	≥ 0	Total sulfur containing AA
3	$\Sigma a_{3j}x_j$ - 0.01712u	≥ 0	Methionine
4	$\Sigma a_{4j}x_j$ - 0.03168u	≥ 0	Threonine
5	$\Sigma a_{5j}x_j$ - 0.00992u	≥ 0	Tryptophan

Source: Adapted from the work of V.E. Smith, 1975.

FAO/WHO Expert Group or that of the 1971 FAO/WHO Ad Hoc Expert Committee on Energy and Protein Requirements (FAO, 1957; FAO/WHO, 1965, 1971). The ratios provide the required proportions between EAA and among EAA and AA. Methionine must provide at least 50 percent of the total sulfur containing amino acids and the ratio of EAA to AA is not allowed to fall below 32 percent. The latter restriction insures the use of AA when possible rather than EAA (Smith, 1975).

The EAA constraints are straightforward. They state that the summation of EAA from all foods consumed must be found in the diet at levels necessary to meet minimum proportional requirements. It is clear from the constraints that the quantity of EAA is a function of the quantity of UP which is available for consumption in the diet. UP ingested is itself a function of calories and the concentration of CP in the diet. These aspects of the nutritional model are presented in constraints six through thirteen.

One calorie constraint and six protein constraints are incorporated in the model. These provide minimum levels of calories and utilizable protein which must be consumed if the FH is to avoid the debilitative effects of undernourishment. These consist of the constraints in Table 25.

Constraints ten through thirteen may be explained using an example. Constraint ten sets a base for utilizable protein at a point where UP'=CP which corresponds to a chemical score of 100. This is the minimum level of CP consumption necessary from the diet assuming it is entirely used in the formation of tissue. Constraint thirteen defines the range within which choices among quantity and quality may be made. For example, assume the minimum level of utilizable protein for quality considerations (UP') in the diet is 61,800 GUP'/FH/year. This defines the beginning point where the minimum acceptable quantity of CP is also 61,800 GUP'/FH/year. One will remember this to be the point where the chemical score is 100 equating UP' and CP. If CP falls below this point it is not possible to meet minimum requirements. Each point Y_a through Y_f for equations eleven and twelve represent an endpoint of a linear segment. The linear segments may be as numerous as

Table 25. Calorie and protein constraints.

Constraint No.	Constraint	b_i	Purpose
6	$\Sigma a_{6j}X_j$	$\geq b_i$	Provides a minimum amount of calories in the diet
7	$\Sigma a_{7j}X_j$ $-CP$	$= 0$	Defines total Crude Protein (CP)
8	$\Sigma a_{8j}X_j$ $-U$	$= 0$	Defines total Utilizable Protein (U)
9	$\Sigma a_{9j}X_j$ $-S$	$= 0$	Defines total Surplus Protein (S)
10	U $-U'$	≥ 0	Defines Utilizable Protein prime (U') as the minimum acceptable level of U for any CP.
11	$-CP$ $+a_1Y_a+...+a_4Y_f$	$= 0$	Defines a range of CP which will meet minimum requirements with respect to U.
12	$-U'$ $+a_5Y_a+...+a_8Y_f$	$= 0$	Defines a range of U' corresponding to levels of Reference Protein (RP)
13	$+1Y_a$ $+....+1Y_f$	$= 1$	Defines the solution of eg. 11 and 12 to be a weighted Σ of the levels of $Y_a...Y_f$

Source: Adapted from the work of V.E. Smith, 1975.

specificity dictates. The endpoints are included in the LP model as column vectors whose elements are the coordinates (CP, UP') and the weighting factors of one associated with constraint thirteen. The solution may contain any of the infinite number of points on the linear segments or any combination of two of those points, but no others. For instance, let the points a_1Y_a=61,800 GCP, a_4Y_f=245,000 GCP and a_5Y_a=61,800 GUP', a_8Y_f=79,489 GUP'. Assume that an optimal solution is arrived at such that $.3Y_a + .7Y_f$ are chosen as a result of the maximization of UP. In determining the coordinates (CP, UP') one would simply multiply .3(61,800) + .7(245,000) in arriving at a value of CP=190,000 GCP/FH/year. Similarly, .3(61,800) + .7(79,489) = 74,182 GUP' would be produced to meet requirements for the representative FH for the year. In other words, total production of CP would be 190,040 grams which would yield 74,182 grams of utilizable protein. This corresponds to a chemical score of approximately 40 percent.

If one wishes to be deterministic with respect to the quality of protein this may be done through limiting the quantity of CP consumed. In response to the constraint a higher chemical score is necessary to provide the minimum amount of UP. This implies different consumption patterns which provide a higher quality of protein. This is an application of the model which may be useful when CP is in limited supply.

5.5 The Mineral and Vitamin Model

Other factors are important determinants of good health. Many of these are associated with vitamins and mineral consumption. Five of these have been considered as components of the LP model.

The nutritional model may be completed by the inclusion of the constraints displayed in Table 26. The mineral constraints included consist of calcium and iron, whereas the vitamin constraints consist of thiamine, riboflavin and niacin. These were considered to be the vitamins and minerals provided mainly through consumption of the major foods in the villages.

Table 26. Mineral and vitamin constraints.

Constraint No.	Constraint	b_i	Purpose Provides the Minimum Requirements for:
13	$\Sigma a_{13j}X_j$	$\geq b_{13}$	Calcium
14	$\Sigma a_{14j}X_j$	$\geq b_{14}$	Iron
15	$\Sigma a_{15j}X_j$	$\geq b_{15}$	Thiamine
16	$\Sigma a_{16j}X_j$	$\geq b_{16}$	Riboflavin
17	$\Sigma a_{17j}X_j$	$\geq b_{17}$	Niacin

Source: Adapted from the work of V.E. Smith, 1975.

The requirements are those provided by Latham and FAO data for East Africa (Latham, 1979; FAO, 1970). They are based upon representative FH requirements. These are the requirements to be met from all sources of food and are unadjusted downward to account for the nutrients available from food sources undefined in the survey results. As was the case in the calorie constraints a buffer against inadequate nutrient utilization is thus incorporated.

5.6 Summary

There exist ranges for intake of these nutrients on a daily basis. The lower limits of this range were used in the model as a basis for yearly estimates. This was done because of the inclusion of the buffer and also because the level of the Latham requirements was somewhat higher than those of Smith.

The mineral and vitamin constraints are straight forward in their intent and usage. They are expected to cause the model to produce foods which meet yearly requirements for the representative FH as were the calorie and protein constraints.

The EAA, energy and protein, and the vitamin and mineral constraints all interact to focus the production activities of the FH on those crops which will best meet the requirements given the land, labor and focus loss constraints present in the model. Figure 4 presents the complete matrix of the linear programming model used in this research.

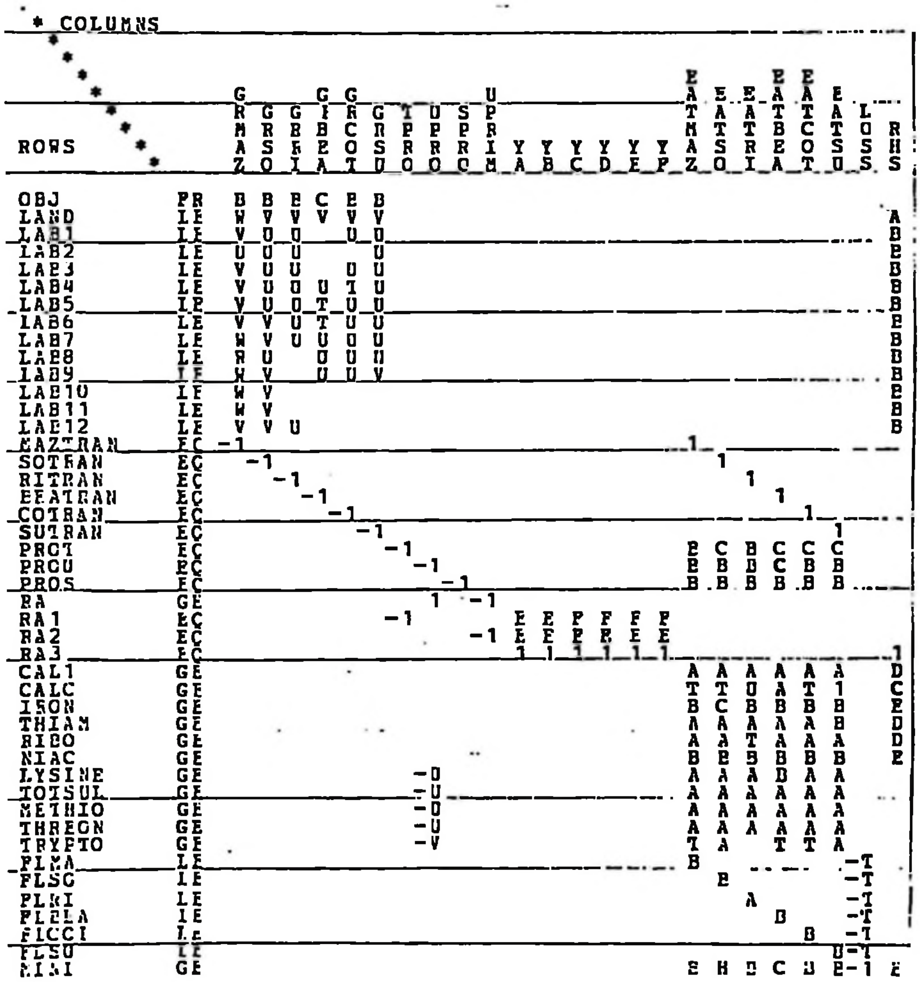

Figure 4. Matrix of linear programming model.

Source: Computer generated.

The first goal of the FH's responding to the survey and incorporated in this work was the provision of food. Constraints faced by the FH were identified and incorporated into the model. This allows the model to be used as one tool in measuring the effects of varying the availability of resources to the FS. This will be the subject of the following chapter dealing with the results of the modelling effort.

CHAPTER 6

THE RESULTS OF THE LINEAR PROGRAMMING ANALYSIS

6.1 Introduction

This chapter presents the results obtained from the linear programming analysis of the FS from a nutritional perspective in the villages of Dumila, Mkundi and Magole. Two aggregate models for the northern part of the Kilosa district are also presented and referred to as Kilosa 1 and Kilosa 2. The villages studied are located in the northern part of the district. The representative farms developed for the Kilosa district are based upon a weighted average of information obtained from respondents in all villages for Kilosa 1 and for Dumila and Mkundi for Kilosa 2. The representative farm for each of the villages is based on the median response to questions from nonmechanized FHs in each village with the exception of CUs which are based on the average response.

Section one will deal with the model results at successive levels of sophistication. The results obtained using only land and labor as model constraints will be compared with the results obtained after the inclusion, first, of nutritional constraints. Secondly, the focus loss constraints will be incorporated with highlighting of pertinent information.

Section two will focus on the ranging of cotton and rice values in the objective function to determine the sensitivity of the model to yield potential of these crops in terms of utilizable protein (UP). Cotton is a cash crop, the only purely cash crop in any of the FSs studied, therefore of special interest. Furthermore, it has been suggested by Manday that government influence requires a minimum of one hectare of cotton be cultivated by the FH (Manday, 1982). Rice is cultivated by approximately 20% of the FHs in Mkundi but by approximately 70% of the FHs in Dumila and Magole. However, it is not a dominant crop in the results for any of the villages or the aggregated Kilosa model.

Section three is used to investigate the effects of ranging the level of constraints for those which are binding. This has been done for land, labor and specific nutrients, all of which were found to be binding. Changes which occur as available resources are assumed to become more available are observed.

The final section deals with analysis of the sensitivity limits of both column and row activities. This is important because it helps to understand how stable the model is to changes in the availability of resources. Focus loss risk constraints are considered first, followed by limiting resources and then the active objective function coefficients.

6.2 Allocation of Resources at Successive Levels of Model Sophistication

A need existed to see what results would be arrived at if the model was run at successive stages of development. This was an enlightening process in that it was found that nutritional constraints significantly altered the allocation of resources among crop production activities. The inclusion of focus loss constraints did not result in large changes in this allocation, except in the case of Magole. Furthermore, while there was a decrease in the gross revenue in two of the villages there was a greater diversification of crop enterprises which is clearly superior in terms of consumption patterns of the villages. Results also suggest that large amounts of heterogeneity exists between the village of Magole and the villages of Dumila and Mkundi which appeared relatively more homogeneous.

Tables 27 through 29 present the development of the LP model at different stages. Each table presents information on the optimal cropping pattern subject to the differing constraints. Secondly, the total kilograms of each crop, and total grams of utilizable protein produced is presented along with marginal values for the crops not produced. These are listed as the marginal values and are interpreted as the GUP which must be deducted from the objective value when one kilogram of the particular crop is forced into production.

Table 27. Optimal plan - primal solutions for crop production activities with nutrition and focus loss constraints absent.

Crops: / Location:	Maize kg	Sorghum kg	Rice kg	Bean kg	Cotton kg	Sunflower kg	TOTAL GUP
1) Dumila							
Activity Level	2304	--	--	418	--	--	173,018
Marginal (GUP)		-51.8	-39.1		-71.1	-164.7	
2) Mkundi							
Activity Level	583	218	--	482	--	--	116,997
Marginal (GUP)			-32.2		-40.5	-16.8	
3) Magole							
Activity Level	--	1427	--	772	--	--	202,789
Marginal (GUP)	-16.6		-57.8		-136.1	-127.8	
4) Kilosa 1							
Activity Level	1937	--	--	493	--	--	168,600
Marginal (GUP)		-5.8	-40.5		-42.8	-74.2	
5) Kilosa 2							
Activity Level	1508	--	--	458	--	--	143,331
Marginal (GUP)		-18.2	-31.8		-21.4	-69.4	

Source: Computer generated.

Table 28. Optimal plan - primal solutions for crop production activities with focus loss constraints absent.

Crops:	Maize kg	Sorghum kg	Rice kg	Bean kg	Cotton kg	Sunflower kg	TOTAL GUP
Location							
1) Dumila							
Activity Level	1081	456	41	387	59	--	143,575
Marginal (GUP)						-37.2	
2) Mkundi							
Activity Level	475	310	--	431	--	113	115,102
Marginal (GUP)			-52.1		-63.3		
3) Magole							
Activity Level	--	1031	--	428	--	--	125,415
Marginal (GUP)	-6.2		-18.2		-8.6	-3.2	
4) Kilosa 1							
Activity Level	1720	165	--	495	--	--	167,643
Marginal (GUP)			-46.1		-44.8	-54.7	
5) Kilosa 2							
Activity Level	1618	--	--	395	--	23	139,368
Marginal (GUP)		-0.6	-65.9		-10.4		

Source: Computer generated.

Table 29 incorporates information generated by the addition of the focus loss constraints. The focus loss activity levels are found below the marginal values in Table 29. These are interpreted in the following manner. The FH is assumed to perceive some measure of security associated with nutrition from a diversified production pattern. This is incorporated in the focus loss and MINI constraints as developed in chapter four. A particular level of activity, either through production of the enterprise directly or through production sufficient to allow the resstraint,

$$\Sigma FCL_j(X_j) - 1/K \text{ Loss} \leq 0 \quad (6.1)$$

to be met through transfer of nutrients among cropping activities within the model while meeting the MINI constraint,

$$\Sigma N_j X_j - \text{Loss} = \text{MINI} \quad (6.2)$$

must be available for an optimal solution to be derived.

If the level of activity in Table 29 for a focus loss element is binding (BND) this means that the loss generated in the MINI constraint when incorporated in the focus element constraint are equated such that $FCL_j(X_j) - 1/K \text{ Loss} = 0$. The same principle applies to the other nonbinding focus loss activities. Each one when incorporated in the focus element constraint will be less than or equal to zero.

Table 29. Optimal plan - primal solutions for complete crop production activities.

Crops: / Location:	Maize kg	Sorghum kg	Rice kg	Bean kg	Cotton kg	Sunflower kg	TOTAL GUP	LOSS GUP
1) Dumila								
Activity Level	1081	456	41	387	60	--	143,575	
Reported Activity Level	997	413	--	158	--	--		
Marginal (GUP)						-37		
Focus Loss: Activity Level[a,b]	-6.2	BND	-5677	-250	-5692	-5882		35,440
2) Mkundi								
Activity Level	475	310	--	431	--	113	115,102	
Reported Activity Level	889	455	--	345	--	110		
Marginal (GUP)			-52.1		-63.3			
Focus Loss: Activity Level[a,b]	-936	BND	-7214	-197	-7170	-2746		43,196
3) Magole								
Activity Level	--	912	--	440	--	74	125,177	
Reported Activity Level	--	575	--	240	--	244		
Marginal (GUP)	-4.47		-19.5		-7.7	-3.2		
Focus Loss: Activity Level[a,b]	-11,837	BND	-11,837	-5394	-11,694	-10,818		70,877

Table 29. (continued)

Crops:	Maize kg	Sorghum kg	Rice kg	Bean kg	Cotton kg	Sunflower kg	TOTAL GUP	LOSS GUP
Location:								
4) Kilosa 1								
Activity Level	1630	226	--	496	--	--	167,297	
Marginal (GUP)			-39.1		-36.7	-69.1		
Focus Loss:								
Activity Level[a,b]	BND	-14,457	-18,587	-2440	-18,475	-18,587		111,297
4) Kilosa 2								
Activity Level	1370	160	--	416	--	--	138,750	
Marginal (GUP)			-47.3		-10.2	-26.6		
Focus Loss:								
Activity Level[a,b]	BND	-10,701	-13,936	-7486	-13,853	-13,853		83,451

[a]BND refers to binding constraint.
[b]All Focus Loss Activity Levels are constrained ≤ 0.

Source: Computer generated.

Information derived from Table 27 suggests that in a fully commercialized economy the cropping diversification associated with these villages might be reduced. This assumes that full commercialization is accompanied by greater security with respect to the supply of a variety of foods in the market. Mkundi is the only village which produces more than two crops in the absence of nutritional constraints. However when nutritional constraints are included, as in Table 28, only Magole FHs would produce two crops.

A two crop production system would affect both factor costs and product prices if all the nonmechanized FHs were to undertake similar cultural practices. While no empirical results are available to support the above contention it is likely the process, in a dynamic sense, would be detrimental to the welfare of the FHs given the present level of commercialization. Even though, in a static analysis, gross revenue is higher for Dumila and Magole, as seen from Table 31, the apparent benefits would be offset quickly. Lower incomes would result from potential over supply and higher free market prices for sources of nutrients not cultivated anymore in the villages and thus not available at a similar price. Furthermore, the differencess in gross revenue are not that large.

The cropping patterns found in Table 29 are quite similar to those which were reported, with the exception of Magole, in terms of kilograms produced, crops cultivated and the loss activity. The pattern of aggregated cropping activities from respondents is presented in Table 30 for the villages. This may be compared with the pattern suggested by the LP model.

Table 30. Median production of major crops by the nonmechanized small farm household.

	Dumila kg	Mkundi kg	Magole kg
Maize	997	889	594
Sorghum	412	455	575
Rice	480	240	390
Beans	157	160	240
Cotton	95	345	131
Sunflower	250	110	244

Source: 1980 B/CS

The results from Magole were ambiguous and it is presumed that results from Kilosa are biased for that reason. When Magole was disaggregated, as in the Kilosa 2 model, the results were more reasonable relative to the reported cropping patterns in Dumila and Mkundi.

It is interesting that at levels of land availability which are restrictive, diversification might be reduced. It is not intuitive that this would occur, however, the two FHs with the smallest amounts of land under cultivation did just that. One FH with 1.42 ha. cultivated reported land under maize production to be .40 ha. and .40 ha. under sunflower production. The additional .62 ha. was under minor crop production. The FH with the next smallest area of land under cultivation had .40 ha. under maize and .61 ha. under sorghum cultivation with an additional .32 ha. under pigeon peas and .40 ha. in other crops. While one other FH maintaining 1.74 ha. of cultivatable land reported producing three of the major crops another FH of 1.82 ha. produced only two. Three of the four smallest FHs were found to produce only two of the major crops for the district.

The total grams of utilizable protein are found to correspond to the demand for utilizable protein on the basis of consumer units in Dumila and Mkundi as well as Kilosa 2. The loss of UP, that which may be foregone without serious protein shortages occurring, also follows the expected pattern. The loss in Dumila which has the highest requirement is approximately 35,000 GUP and that for Mkundi 43,000 GUP. Kilosa 2 would also fall into the pattern if the constraints on calcium and tryptophan are lifted.

6.3 Gross Revenues from Different Stages of Model Development

Table 31 presents the results in terms of total gross revenue which would be generated if all production was sold rather than part of it being consumed. Free market prices are used for those crops bought and sold without government interference. For those crops which are only sold to the government parastatals, government prices were used. Price information is available in Appendix C. Farm gate prices are used. In each case the complete model reduces the total gross revenue as would be expected. It is not clear whether this results in more disposable income. However, in the cases where the difference is small such as Mkundi and the Kilosa 2 aggregate it can be reasonably assumed that disposal income would be greater given the complete model production guidelines. This follows from the fact that no transaction costs are in the analysis of gross revenue. The transaction costs associated with food purchases when deducted would be higher for the reduced model than the complete model. This would result from the need to purchase a greater range of foods which had not been produced to meet nutritional requirements and implicit palatability levels.

A very revealing picture of the disparity between government pricing and free market pricing practices is available in Table 31. Even though it is of little empirical value it is clear that a disincentive exists in sales made to gov-

Table 31. Gross revenue from production activities.

	Reduced Model:							Complete Model:						
	Maize T.Sh.	Sorg. T.Sh.	Rice T.Sh.	Beans T.Sh.	Cotton[1] T.Sh.	Sunfl.[1] T.Sh.	TOTAL T.Sh.	Maize T.Sh.	Sorg. T.Sh.	Rice T.Sh.	Beans T.Sh.	Cotton[1] T.Sh.	Sunfl.[1] T.Sh.	TOTAL T.Sh.
Free Market Valuation														
1) Dumila	4355	--	--	2299	--	--	6654	2043	1382	82	2129	174	--	5810
2) Mkundi	1067	852	--	2892	--	--	4811	869	1212	--	2586	--	193	4860
3) Magole	--	5237	--	4408	--	--	9645	--	3712	--	2477	--	129	6318
4) Kilosa 1	3642	--	--	2815	--	--	6457	3064	829	--	2832	--	--	6725
5) Kilosa 2	2835	--	--	2615	--	--	5450	2576	587	--	2375	--	--	5538
Government and Marketing Board Valuation	Reduced Model:							Complete Model:						
1) Dumila	2304	--	--	1379	--	--	3683	1081	492	72	1277	174	--	3096
2) Mkundi	583	218	--	1687	--	--	2488	475	310	--	1509	--	193	2487
3) Magole	--	1470	--	2571	--	--	4041	--	948	--	1465	--	129	2542
4) Kilosa 1	1937	--	--	1543	--	--	3840	1630	235	--	1652	--	--	3517
5) Kilosa 2	1508	--	--	1525	--	--	3033	1370	166	--	1385	--	--	2921

[1]Valued at government price. All production was either sold to marketing agencies or consumed by the FH.

Source: 1980 BC/S

ernment marketing agencies. The average difference in gross revenue between complete models for free market and government prices is 2844 T.Sh. This is a significant amount of revenue to be foregone by a small FH. It is practically half of the gross revenue of Dumila, 59% for Mkundi and 48% for Magole. It must be remembered that the physical and monetary capital requirements of these FHs are very small and thus gross revenue will not be distorted as greatly as one would expect when nontraditional agricultural practices are employed.

6.4 Ranging of Objective Function Values for Cotton and Rice

Tables 32 through 36 all pertain to the results of changes in objective function coefficients. The exercise carried out here is analogous to increasing yields associated with particular activities entering the objective function in a "traditional" LP model. In these tables the grams of utilizable protein per kilogram of both cotton and rice are increased. This is done for two reasons: 1) the exact amount of UP which equates a kilogram of cotton to the purchase of a kilogram of a representative food unit in the market is not known with certainty, 2) while rice is produced in all of the villages it enters the basis for the optimal program in none of them. A number of common characteristics are brought to the forefront when the ranging has been

Table 32. Optimal plan - results of ranging the objective function coefficient for cotton and rice -- Dumila.

1. A. Dumila - Cotton

	Cotton GUP/kg	Obj. Value GUP	Cotton Produced kg	Protein Score	Binding Constraints
1)	59.9	142382	60	58.6	3,8,9,30,41
2)	82.8	143746	138	58.5	3,7,8,9,40
3)	106.3	146990	139	58.5	7,8,9,39,40
4)	116.8	148452	146	58.4	7,9,39,40
5)	148.4	153060	272	54.9	7,30,39,40
6)	256.9	182495	274	54.4	3,7,30,40

[1]Total Gross Revenue at (6) = 5405 T.Sh.

B. Dumila - Rice

	Rice GUP/kg	Obj. Value GUP	Rice Produced kg	Protein Score	Binding Constraints
1)	25.5	143361	0	58.5	3,9,30,41
2)	40.3	143362	41	58.6	3,8,9,30,41
3)	53.7	143908	125	58.3	3,8,30,39,40
4)	87.1	148089	236	56.4	3,7,8,30,39,40
5)	173.3	168420	238	56.2	3,7,8,30,40

[1]Total Gross Revenue at (5) = 5248 T.Sh.

[1]Free market valuation

Source: Computer generated.

Table 33. Optimal plan - results of ranging the objective function coefficient for cotton and rice -- Mkundi.

1. A. Mkundi - Cotton

	Cotton GUP/kg	Obj. Value GUP	Cotton Produced kg	Protein Score	Binding Constraints
1)	54.9	115102	0	61.0	3,7,9,33,41
2)	138.2	115476	201	56.7	3,7,9,33,45
3)	140.1	115476	503	52.6	3,7,33,41

[1]Total Gross Revenue at (3) = 4159 T.Sh.

B. Mkundi - Rice

	Rice GUP/kg	Obj. Value GUP	Rice Produced kg	Protein Score	Binding Constraints
1)	25.5	115102	0	61.0	3,7,9,33,41
2)	98.6	119204	494	48.4	3,5,7,33,45
3)	106.1	119204	521	49.0	3,5,7,30,33,45

[1,2]Total Gross Revenue at (3) = 3226 T.Sh.

[1]Free market valuation used.
[2]Free market valuation is not available for rice in Mkundi, therefore government price is used.

Source: Computer generated.

Table 34. Optimal plan - results of ranging the objective function coefficient for cotton and rice -- Magole.

1. A. Magole - Cotton

	Cotton GUP/kg	Obj. Value GUP	Cotton Produced kg	Protein Score	Binding Constraints
1)	74.5	125177	0	62	33,41,46
2)	82.2	131066	154	63	7,33,41,46
3)	120.4	155813	160	63	7,33,41,46

[1]Total Gross Revenue at (3) = 6351 T.Sh.

B. Magole - Rice

	Rice GUP/kg	Obj. Value GUP	Rice Produced kg	Protein Score	Binding Constraints
1)	45.5	125177	0	62	33,41,46
2)	65.0	128481	489	56	3,33,41,46
3)	71.8	128481	556	56	3,30,33,41,46

[1,2]Total Gross Revenue at (3) = 5390 T.Sh.

[1]Free market valuation used.
[2]Free market valuation is not available for rice in Magole, therefore government price is used.

Source: Computer generated.

Table 35. Optimal plan - results of ranging the objective function coefficient for cotton and rice -- Kilosa 1.

1. A. Kilosa 1 - Cotton

	Cotton GUP/kg	Obj. Value GUP	Cotton produced kg	Protein Score	Binding Constraints
1)	76.3	167297	0	58.0	3,8,39,40,46
2)	120.5	167644	254	60	3,7,8,39,43,46
3)	204.1	188909	298	58	3,7,39,40,46

[1,2]Total Gross Revenue at (3) = 5894 T.Sh.

B. Kilosa 1 - Rice

	Rice GUP/kg	Obj. Value GUP	Rice Produced kg	Protein Score	Binding Constraints
1)	45.5	167297	0	58.0	3,8,40,46
2)	84.6	167644	49	58.0	3,8,39,40,46
3)	105.5	200868	555	61	3,8,30,41,46
4)	152.3	260325	638	60	3,8,30,33,41,46

[1,2]Total Gross Revenue at (4) = 6040 T.Sh.

[1]Free market valuation used.
[2]Free market valuation is not available for rice in two of the three villages, therefore a simple average of government prices is used.

Source: Computer generated.

Table 36. Optimal plan - results of ranging the objective function coefficient for cotton and rice -- Kilosa 2.

1. A. Kilosa 2 - Cotton

	Cotton GUP/kg	Obj. Value GUP	Cotton Produced kg	Protein Score	Binding Constraints
1)	76.9	138751	0	58	3,39,40,46
2)	87.1	178234	258	58	3,7,39,40,46
3)	240.1	188183	270	58	3,7,30,40,46

[1,2]Total Gross Revenue at (3) = 5289 T.Sh.

B. Kilosa 2 - Rice

	Rice GUP/kg	Obj. Value GUP	Rice Produced kg	Protein Score	Binding Constraints
1)	45.5	138751	0	58	3,39,40,46
2)	92.8	139252	28	58	3,30,39,40,46
3)	110.8	139368	197	57	3,30,39,40,46
4)	111.4	139368	312	57	3,30,33,39,46

[1,2]Total Gross Revenue at (4) = 4489 T.Sh.

[1]Free market valuation used.
[2]Free market valuation is not available for rice in two of the three villages, therefore a simple average of government prices are used.

Source: Computer generated.

accomplished. In each scenario the complete models are used. The coefficients were increased from their original values through a value which could be increased infinitely without changing the basis or to a point where the objective function could not be increased further given the set of constraints. The common characteristics alluded to earlier pertains to the models for Dumila, Mkundi and Kilosa 2. Kilosa 1 and Magole are variants due to the heterogeneity between Magole and the other two villages. These characteristics are the following. As the objective coefficients are increased:

1) The objective function value increases.
2) The quantity of the crop produced increases.
3) The protein score either stays the same or decreases.
4) The total gross revenue decreases relative to the total gross revenue associated with the optimal plan.

One of the most interesting facts is that the protein score decreases while at the same time the gross revenue decreases. This suggests the protein quality deteriorates as more cash crops are produced even though the quantity of protein increases in the case of cotton. In the case of rice production there is very little increase in the total quantity of utilizable protein associated with large increases in the utilizable protein imputed to a kilogram of rice. For instance the additional utilizable protein produced for a 342% increase in the objective coefficient of rice is only

4728 grams. Similar results are found both in Mkundi and Magole. One interpretation of this finding would suggest if the FHs were willing to forego a certain amount of gross revenue and had the correct environmental resource base they could produce rice as a substitute for another food source. This may be done in order to supply a more palatable combination of foods for consumption. On the other hand, the yield of UP from rice may not be an important objective of the FH. Still, gross revenue will decrease when rice is produced given the objectives of these models.

Neither of the objective function activities, rice or cotton production, are particularly sensitive to change. This is apparent from the range of the coefficients of these crops. There is little, if any, reduction in the number of constraints which may be binding as the coefficient values are increased. In each case land, labor and normally at least one nutritional constraint is binding. A list of constraints which are associated with the binding constraints number can be found in Appendix D.

The fact that increased production of cotton is detrimental to the financial welfare as well as the nutritional welfare of the small FH given the assumptions of this study is clear. The total gross revenue produced from inclusion of cotton production in the FS not only decreases but the associated ability to purchase required nutrients is reduced.

A similar case may be made for the inclusion of rice production in the FSs.

6.5 Increasing the Supply of Scarce Resources

6.5.1 Land

The results of Table 37 suggest that additional quantities of utilizable protein may be produced given additional cultivatable land and a similar resource endowment in other respects. Again, Magole is a variant with land not being a scarce factor of production in the optimal model. Dumila is constrained not only by labor but also by a nutritional constraint, thus there is no change in the marginal value product (MVP) of either land or labor until land becomes slack at 3.23 ha. The MVP of labor becomes larger as the constraints become tighter as more land is added to the FS. Mkundi is similar, however, the MVP of land is greater in this case. Approximately 30,000 GUP may be added by increasing land in the FS to approximately 3.3 ha. It is interesting to note that land becomes non-binding at approximately 3.2 ha. in Dumila and 3.3 ha. in Mkundi. At these levels 144,096 GUP and 145,890 GUP are produced in the villages respectively. Furthermore, the MVP of labor for June in both villages reflect the importance of a labor bottleneck during that time of year.

The results of Kilosa 1 are of relatively little importance except to suggest again that the heterogeneity among

Table 37. Ranging resource availability - land.

	Area Constraint ha	Obj. Value GUP	MVP Land GUP	MVP Labor (Binding) GUP
Dumila:				
Area Reported Cultivated	2.80	143575	1226	May=206: June=242
Activity Level Increased (.2 ha.)	3.00	143819	1226	May=206; June=242
Land in Surplus	3.23	144096	0	Feb=27;May=220;June=235
Mkundi:				
Area Reported Cultivated	2.47	115102	52593	Apr=190; June=17
Activity Level Increased (.2 ha.)	2.67	123939	41602	Apr=121; June=71
Activity Level Increased (.4 ha.)	2.87	131810	37035	Apr=105; June=276
Land in Surplus	3.324	145890	0	June=399
Magole: Land is not a scarce factor of production in the model.				
Kilosa 1:				
Area Reported Cultivated	2.81	167297	32652	May=1116
Activity Level Increased (.2 ha.)	3.01	173314	15639	May=812
Land in Surplus	3.21	176384	0	May=723
Kilosa 2:				
Area Reported Cultivated	2.60	139368	63710	NB
Activity Level Increased (.2 ha.)	2.80	144966	6199	May=71; June=351
Activity Level Increased (.4 ha.)	3.00	146206	6199	May=7; June=351
Land in Surplus	3.01	146255	0	May=369; June=147

Source: Computer generated.

Magole and the other villages is considerable and results in a much larger production of UP. Kilosa 2 results suggest that as land cost increases, the cost in GUP becomes greater for May labor which is not available. The MVP of May labor is 369 grams of utilizable protein per male equivalent day (GUP/MED). This corresponds to approximately 18 T.Sh./MED at 3 T.Sh./kg. Manday (1982) suggested that the wage rate per MED was 10.45 T.Sh. in the Kilosa district. On the basis of this rough calculation, one might expect labor to be a limiting factor in two respects. During the period April through June labor may be binding, however, it is not likely to be so great in April that the hiring of additional labor is justified. Therefore, even though labor is constraining the FH may not hire additional labor in anticipation of a positive return to the investment.

6.5.2 Labor

Table 38 presents the results of ranging labor while holding land constant. The labor periods which are binding at a given level of MEDs are presented in the first column by village or aggregate. The second column presents the MEDs for the particular labor period which is constraining. The intensity of labor use is presented for each level that labor is constraining. As would be expected the labor intensity increases inversely in response to decreasing labor constraints. The MVP of labor is given in the final column for

Table 38. Ranging resource availability - labor.

	Labor Constraint MED	Obj. Value GUP	Intensity of Labor Use (%)	MVP Labor (Peak Period) GUP
Dumila:				
Labor Period;				
1) May	72.0	143,575	46	May=206
June	70.0			June=242
2) May	87.4	151,550	51	0
June	91.5			0
Mkundi:				
Labor Period;				
1) April	67	115,102	42	April=190
June	67			June=17
2) April	84.8			0
June	75.3	117,887	44	0
May	69			May=91
Kilosa 1:				
Labor Period;				
1) May	71	167,297	44	May=1116
2) May	80.5	174,609	50	0
June	76.8			0
Kilosa 2:				
Labor Period;				
1) All	None Binding	138,751	39	0

Source: Computer generated.

the peak period labor requirements. It can be inferred from the results that labor is bound so tightly only in Kilosa 1 that the hiring of additional labor is justified. Using the rough calculation previously used to determine the potential for hiring labor at a savings this can be seen more clearly. Let us assume that: 1) The wage rate suggested by Manday is operative (Manday, 1982); 2) There is justification in Seckler's contention that:

> As a laborer's wage rate goes below 3 kg per day under the competitive pressures of underemployment his productivity decreases. As his productivity decreases there is more downward pressure on his wages as the employer tries to pay him at most the value of his marginal product. (Seckler, 1982)

This finally leads to illness and dismissal which in turn causes a labor shortage restoring wages to energy equilibrium; 3) The average price per kilogram of a representative food is 3.00 T.Sh. Using Kilosa 1 as an example, it is found that there is an incentive for hiring of labor. The additional MEDs required to increase the UP production to 174,609 GUP are 15.30 MEDs. The additional GUP are 7,312. At a protein score of 60 this corresponds to 121.8 kg. At 3 T.Sh./kg this corresponds to 365 T.Sh. The expense associated with the hiring of labor is approximately 160 T.Sh. Accordingly, 205 T.Sh. would accrue to the FH in gross revenue. In contrast, labor hiring in Mkundi is not justified under this criteria. The MEDs required to increase the UP production to 117,887 GUP are 26.1 MEDs for 2785 GUP. Using the same standards as above, 46.4 kg are produced at 3.00 T.Sh./kg. This is approximately 139 T.Sh. The MEDs hired would cost 273 T.Sh. Therefore, the cost to the FH in Mkundi would be greater than the gross revenue and would not justify the hiring of labor during peak periods in Mkundi. Dumila falls somewhere in the middle. Kilosa 2 is not constrained by labor.

6.5.3. Vitamins, Minerals and Amino Acids

The results of the inclusion and exclusion of binding vitamins and mineral constraints are evident in Table 39. While the MVP of the nutrients are small they have fundamental effects upon the optimal models. For example, when tryptophan is unconstrained, as in Kilosa 2, labor becomes a binding constraint to increased production. The most important findings here deal with the absence of calories as a limiting nutrient and the limiting effects of riboflavin in Mkundi. Table 39 deals with vitamins and minerals exclusively because calories were not limiting in any of the models. This suggests that in the normal year one would expect to see little protein/calories malnutrition in this area of Tanzania. Indeed this is true for the vast majority of individuals in the district. However, it does not apply to infants and young children. They are more susceptible due to weaning and abrupt changes in diet which may occur thereafter. In each case where a vitamin or mineral is limiting these effects are

Table 39. Ranging resource availability - vitamin, mineral and amino acid.[a]

Binding Nutrient	Unconstrained Nutrient	Obj. Value GUP	Marginal Value of Binding Nutrient(s)
Dumila:			
1. Unconstrained	All	143747	NB
2. Calcium	None	143574	-4.4
3. None Binding (NB)	Calcium	143747	NB
Mkundi:			
1. Unconstrained	All	118102	NB
2. Riboflavin	None	115102	-14.6
3. Tryptophan	Riboflavin	116101	-7.0
4. None Binding (NB)	Riboflavin Tryptophan	118102	NB
Kilosa 1:			
1. Unconstrained	All	167,297	NB
2. Constrained	None	167,297	NB
Kilosa 2:			
1. Unconstrained	All	142,474	NB
2. Tryptophan	None	138,750	-34.7
3. None Binding (NB)	Tryptophan	142,474	NB

[a]Units: Calcium, Grams; Riboflavin, Milligrams; Tryptophan, Grams.

Source: Computer generated.

exacerbated. Thus the need to meet or surpass nutritional requirements, especially for the young.

The riboflavin deficiency found in Mkundi is not normally a life threatening problem. It is debilitating and may allow for more serious complications. It is of interest here from a point of additional validation of the model. It has been suggested by Latham and Shimkin that riboflavin deficiencies are frequently encountered in Africa and in Tanzania (Latham, 1965; Shimkin, 1983). It is found to be one of the three most important nutrients as constraints are relaxed, tryptophan and calcium being the other two. This suggests that the models are within a reasonable range and pattern of production with respect to work carried out by others in the region.

6.6 Stability of the Optimal Plans

6.6.1 Focus Loss Constraints

Table 40 presents the sensitivity limits for the focus loss constraints included in the models. The lower limit and upper limit represent the minimum and maximum values respectively which the row activity can attain before a basis change is required. If we take Dumila as an example and look at focus loss maize an interpretation of the results may be made. Row activity focus loss bean (FLBEA) could increase to -244.9 GUP without a basis change. For each unit of increase from -249.7, which is the activity level of FLBEA, to -244.9

Table 40. Optimal plan: Sensitivity limits for the focus loss and MINI constraints - optimal organization of the representative FHs.

Resource	Constraint Level (GUP)	Sensitivity Limits Lower Limit (GUP)	Sensitivity Limits Upper Limit (GUP)
Dumila:			
Focus Loss Maize	≤ 0	-7744.2	312.6
Focus Loss Sorghum	≤ 0	-7737.9	6.2
Focus Loss Rice	≤ 0	-13414.5	-5671.8
Focus Loss Bean	≤ 0	-7987.7	-244.9
Focus Loss Cotton	≤ 0	-13383.7	-5687.4
Focus Loss Sunflower	≤ 0	-13574.6	-5878.3
Minimum Requirement	≥ 61,800	-INF	108,162
Mkundi:			
Focus Loss Maize	≤ 0	-4293.9	12.3
Focus Loss Sorghum	≤ 0	-3357.7	197.2
Focus Loss Rice	≤ 0	-10571.4	-5986.7
Focus Loss Bean	≤ 0	-3554.9	-197.2
Focus Loss Cotton	≤ 0	-10508.1	-6278.0
Focus Loss Sunflower	≤ 0	-6083.8	435.5
Minimum Requirement	≥ 51,800	-INF	71,906.3
Magole:			
Focus Loss Maize	≤ 0	-11836.5	-6990.9
Focus Loss Sorghum	≤ 0	-6853.8	1502.5
Focus Loss Rice	≤ 0	-11836.5	-6990.9
Focus Loss Bean	≤ 0	-6035.8	1859.6
Focus Loss Cotton	≤ 0	-11694.7	-6907.2
Focus Loss Sunflower	≤ 0	-11732.0	-2773.3
Minimum Requirement	≥ 54,300	45302.6	82565.6
Kilosa 1:			
Focus Loss Maize	≤ 0	-10905.8	872.8
Focus Loss Sorghum	≤ 0	-15060.0	-9275.1
Focus Loss Rice	≤ 0	-18586.6	-16210.8
Focus Loss Bean	≤ 0	-5503.2	4367.1
Focus Loss Cotton	≤ 0	-18475.3	-16113.7
Focus Loss Sunflower	≤ 0	-18586.6	-16210.8
Minimum Requirement	≥ 56,000	50773.6	69341.5

Table 40. (continued)

Resource	Constraint Level (GUP)	Sensitivity Limits Lower Limit (GUP)	Upper Limit (GUP)
Kilosa 2:			
Focus Loss Maize	≤ 0	-3266.2	1090.9
Focus Loss Sorghum	≤ 0	-13552.1	-3943.7
Focus Loss Rice	≤ 0	-13936.2	-10393.1
Focus Loss Bean	≤ 0	-8229.8	-3403.8
Focus Loss Cotton	≤ 0	-13852.7	-10330.8
Focus Loss Sunflower	≤ 0	-13852.7	-10330.8
Minimum Requirement	≥ 55,300	48767.4	74858.4

Source: Computer generated.

GUP a cost of .08057 GUP would be incurred. If FLBEA were restricted such that it was equal to 244.9 the objective function value would decrease to 145554.6 which is approximately 20 grams of UP less than that of the optimal production pattern. A decrease in the value will not result in a basis change until -7987.7 GUP are reached.

The minimum constraint may be interpreted in a similar fashion. In both Dumila and Mkundi the minimum constraint can be decreased infinitely without a change in the basis. This suggests that the provision of the minimum requirements of utilizable protein is not complicated by the introduction of other constraints. This is not the case in Magole or the aggregate models. In both Magole and Kilosa 1, it will be remembered from Table 29, that the introduction of focus loss constraints resulted in a change in the quantity of UP provided when comparing the three stages of the model development. In other words, as loss increases to a level such that Loss - MINI > $\Sigma FCL_j(X_j)$ the focus elements become important in the allocation of resources. However, it appears to be of primary importance only in this case.

6.6.2 Limiting Resource Activities

The sensitivity analysis of the limiting resource activities is more straightforward than those of the focus loss constraints. The results for the different locations are tabulated in Table 41. It is important to look at the ranges

Table 41. Optimal plan: Sensitivity limits for the limiting resources - optimal organization of the representative FHs.

Resource	Available Resources	Sensitivity Limits Lower Limit	Upper Limit
Dumila:			
Land	2.8	2.79	3.23
FH Labor (May)	72.0	71.0	72.0
FH Labor (June)	70.0	70.0	71.2
Calcium	786.9	748.0	787.0
Mkundi:			
Land	2.47	2.40	2.52
FH Labor (April)	67.0	59.3	67.5
FH Labor (June)	67.0	62.0	68.5
Riboflavin	1967.0	1958.0	2121.0
Magole:			
Riboflavin	2128.0	2068.0	2377.0
Kilosa 1:			
Land	2.81	2.77	2.98
FH Labor (May)	71.0	53.3	71.9
Kilosa 2:			
Land	2.60	2.54	2.67
Tryptophan	≥0.0	-107.3	49.2

[a]Units: Land, Hectares; Labor, Male Equivalent Days; Calcium, Grams; Riboflavin, Milligrams; Tryptophan, Grams.

Source: Computer generated.

within which these row activities are stable. It is apparent that the ranges for the limiting factors of production are not very wide. This suggests that the optimal allocation of resources is quite susceptible to change given the addition or restriction of resources; be they land, labor or nutritional. At the same time it must be remembered that the change which results may mean a change only in the quantities of a commodity produced rather than a production pattern consisting of new enterprise choices. This is indeed the case as has been seen from the development of the models and analysis of results when constraints are relaxed.

The limits may be interpreted in the following manner. When the activity is forced to its lower limit a basis change results which causes a reduction in the quantity of UP produced. The amount of the reduction is based on the MVP of that resource. For instance, if Dumila land is forced to 2.79 ha. there will be a corresponding decrease in GUP produced of 1226 grams. In the case of labor this loss for May labor would be 205 GUP. The opposite is true for increasing supplies of binding resources. As the supply increases the objective function will increase at decreasing rates as the MVP of the constraint is reduced. In each of the locations there seems to be ample opportunity for slackening of constraints dealing with nutrients as is suggested by the aggregate models. They appear to be more stable than the individual models. The MVP of land in Kilosa 1 is 32561 GUP. This amount is relevant over the range 2.77 ha. to 2.98 ha. If land were constrained at 2.79 ha. the objective function value would be 165,614 GUP or a loss of approximately 1680 GUP. May labor's MVP is 1116 GUP for the range 53.3 to 71.9 MEDs. An additional MED would increase the objective function by this amount if the range were at least 53.3 to 72 MEDs. At 71.9 MED approximately 1000 GUP would be added.

6.6.3 Stability of Objective Function Coefficients

Sensitivity of the objective coefficients is important in determining the stability of the optimal plan with respect to a range of yields in grams of utilizable protein. All of the coefficients appear to be relatively stable as can be seen from Table 42. For example, the objective coefficient for sorghum is 54.1 which could be increased to 58.16 without resulting in a basis change. It may also be decreased to -288 without a basis change. Presumably this is because of the availability of other required nutrients supplied by sorghum in this model at the optimal level. It is not intuitive why this should be unless the latter is the case. In other respects the sensitivity limits are straightforward and consistent. Of all the production activities entering the basis, bean appears to be the most stable. This same conclusion might be drawn from the stability one sees in production of beans at different levels of constraints.

Table 42. Optimal plan: Sensitivity limits of objective function coefficients in the complete model.

Activity	Value of the Objective Function Coefficient GUP/kg	Sensitivity Limits for the Objective Function Coefficients Lower Limit GUP/kg	Upper Limit GUP/kg
Dumila:			
Maize	45.6	19.56	46.95
Sorghum	54.1	53.00	59.85
Rice	45.6	40.28	53.66
Beans	162.7	150.59	186.67
Cotton	79.9	52.72	82.79
Mkundi:			
Maize	45.6	37.73	46.39
Sorghum	54.1	-288.21	58.16
Beans	45.6	154.75	+ Inf.
Sunflower	57.7	56.59	74.50
Magole:			
Sorghum	54.1	52.09	+ Inf.
Beans	162.7	141.99	182.70
Sunflower	57.7	49.25	60.94
Kilosa 1:			
Maize	45.6	41.35	+ Inf.
Sorghum	54.1	19.31	59.87
Beans	162.7	61.75	471.47
Kilosa 2:			
Maize	45.6	40.84	+ Inf.
Sorghum	54.1	39.70	64.55
Beans	162.7	128.13	210.46

Source: Computer generated.

This type of information would be useful in choosing hybrids which would both increase yield of required nutrients and be most effective in doing so. For instance, if the UP yield from maize was increased to 46.4 GUP an additional 582 GUP would be added to the objective function. A similar analysis could be made with respect to each nutrient·under different objective function specifications. This could be done on the basis of scarce nutrients where related deficiency symptoms are found. This would be useful in areas where symptoms of nutritional deficiency are chronic.

6.7 Summary

This chapter has been used to present the results of various scenarios which have been employed with the models. Information gathered from the 1980 B/CS and secondary sources allowed the development of the models. Each location was modelled at three different stages. The first included both nutritional and focus loss constraints. The second included nutritional components but not focus loss. The third stage included all components and it was found that better results were obtained at each stage relative to survey results.

Following the development of the complete model the effects of ranging objective function coefficients for cotton and rice were investigated. Decreases in protein score and gross revenue were associated with increased production of the crops.

Flexibility was given binding constraints in the third part of the chapter. This was done to investigate the increased production of UP which resulted and also to view the changes in other constraints. It was found that land, labor and nutrients tended to be in short supply.

The final section dealt with the stability of the optimal production scenarios. Focus loss constraints, land, labor, nutrient and objective function coefficients were considered. It was found that little stability existed with respect to land, labor and nutrient constraints but it was felt that this instability would result in quantity changes rather than enterprise changes. The objective function coefficients were found to be very stable.

Chapter seven will consist of a summary of the research undertaken and the conclusions and recommendations generated from the research. Finally, limitations of the study and aspects needing further research will be discussed.

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Summary

A linear mathematical programming model was developed for the FSs in Dumila, Mkundi and Magole villages in Kilosa district, Morogoro region of Tanzania. Two aggregate models, one for all three villages and one for Dumila and Mkundi, were also developed. They are named Kilosa 1 and Kilosa 2 respectively.

This study was based on cross-sectional data from forty-six small FHs during the 1980 BC/S. Data from thirteen FHs in both Dumila and Magole and twenty in Mkundi were utilized in building the models. It was supplemented extensively by information from secondary sources. The FHs were nonmechanized and used a negligible amount of other capital. Therefore, capital was not included as a factor of production.

Initially, a brief historical background was presented which informed the reader about some of the peculiarly African agricultural problems facing the small FH. The focus was information dealing with pests, disease and colonial intervention. All of these factors had an effect on the evolving FSs in the district.

A description of the FSs and the FHs from information collected during the 1980 BC/S acted as a benchmark and data source for the development of the models. Information from secondary sources dealing with environmental, tenure and cultural aspects affecting the FS were incorporated.

The literature dealing with linear programming applications to African agriculture was reviewed as was that for nutrition and focus loss components of the models. This led to the development of these components. The focus loss constraints developed relied heavily on the nutritional constraints and vice versa. The components of the model were then operationalized.

The models present the FSs in relationship to the nutritional requirements of the FHs focusing on the production of utilizable protein. An attempt was made to explain the production patterns of the nonmechanized FH through nutritional demand rather than on the basis of price as an allocation mechanism. This was done in response to the large percentage of FH, over 90%, which stated their main objective in farming to be the provision of food.

The focus loss risk component was included in the model to consider some of the production risks encountered by the FH. It was felt that the FH, implicitly in its production pattern, chose that pattern which most successfully guarded against the chance of a disastrous loss of nutrient supplies.

The model was then run at the three different stages of development; 1) Inclusion of the factors of production, land and labor, 2) Inclusion of the factors of production and nutritional constraints, and 3) Inclusion of the factors of production, nutritional constraints and focus loss constraints.

Results of each stage offered a more "rational" production pattern while meeting the requirements of the model. The reported production pattern was quite similar to that presented by the complete model. This was an important finding. This was encouraging but also resulted in questions about production of other crops which did not take place. To understand this better the objective function coefficients for both cotton and rice were increased. It was found that while the crops could be forced into production both protein score and gross revenue decreased as a result.

Resources which were scarce, in the context of the optimal plan, were increased in supply to determine at what level they became slack. This was done for land, labor, vitamins, minerals and amino acids. Findings suggested that, in general, relaxation of these constraints would initially yield large quantities of utilizable protein. However, the MVP of additional resources fell rapidly as other constraints became more scarce.

Sensitivity analysis of constraints and those activities being produced provided information on the stability of the optimal plans. It was found that the focus loss constraints were quite stable but the range over which land, labor and some nutrients were stable was not as large. The objective function coefficients were also found to be quite stable suggesting that considerable increases in the yield of UP would be necessary for the production of a new enterprise to occur. This is important given the opportunities for diversification faced by the FHs in the villages. It is also revealing in the context of introduction of microbiological technology. This will be discussed in the following section dealing with conclusions.

7.2 Conclusions

The first objective of this research has been to examine the major economic determinants of agricultural commodity supply in the villages. This was done through analysis of survey results and additionally through the LP models. The most important factors have been found to be fourfold:

1. The nonmechanized FH produces to supply food. Only secondarily are enterprises undertaken to produce income. This is not to say cash crops are not produced. It suggests that if a choice must be made between income and a questionable supply of UP and calories or surplus in UP and calories and reduced income the latter will be chosen by over 90% of the small FHs. This should be interpreted to mean that the FHs make decisions on cropping patterns on the basis of nutritional requirements. The surplus production will be sold for income.

2. Land is in short supply in two of the three villages but the MVP of land decreases quickly as more land is brought under cultivation. Other factors, such as labor constraints and nutritional requirements are restricting in the attempt to bring more land under cultivation.

3. Labor is a serious constraint during peak labor periods. However, the rural wage rate when held at a certain level does not justify the hiring of labor in any of the months other than the most restricting. If the wage rate is lowered there is evidence that it may fall below the rate necessary for nutritional replenishment. In this case there is little incentive for the hiring of labor, which at the lower wage rate is inefficient due to nutritional deprivation. Likewise, there is no incentive for the laborer to supply the service since the rate may not be high enough to purchase an equilibrium level of nutrients. Thus there is a breakeven level with respect to the MVP of labor, the nutritional equilibrium level and gross revenue accruing to the FH. It appears that only during the most constraining periods is this breakeven level reached in the villages on the basis of utilizable protein production.

4. Nutritional considerations have considerable effect on the decisions of the FHs. They also result in significant changes in the production patterns in the FS. It is clear that cultural practices, pricing and preferences also lead to

adjustments in production patterns. However, the inclusion of nutrient constraints in the model resulted in changes which much more clearly resembled the actual patterns reported. It is clear that the inclusion of nutritional factors in models dealing with nonmechanized FHs in Tanzania is important. Continued use of income measures as the only mechanisms for simulating the FSs is misleading. However, the simple inclusion of base levels for nutrients in models of this sort is also insufficient.

The second objective entailed measurement of food supplies used in consumption, the requirements of the FHs for different nutrients and the calculation of the difference between the two. In each case there was no sign of shortages in UP or calories. This must be tempered by repeating that infants and young children are more susceptible to protein/calorie malnutrition. The optimal programs were sometimes tightly constrained by calcium, riboflavin and tryptophan. It is important in areas where these nutrients may be in short supply to emphasize their production.

Objective three was dealt with indirectly through development of gross revenue figures for the optimal plans. These were then compared to gross revenue resulting from the substitution of cropping enterprises. While this was done with the use of a crude measure some interesting conclusions can be drawn from the exercise. As cotton and rice enter the models the gross revenue accruing to the FHs decrease. In the case of cotton, this is directly related to the government acting as sole purchaser. Cotton's price is held low and its production is not justified either on the basis of price or nutritional makeup. Consequently it is concluded that only under conditions of much higher prices for cotton should it be produced by the small FH as a substitute for S-C crops. Rice is only produced in Dumila under the optimal plans. In the other location its nutrient supply is not large enough relative to resource demand to justify its production. Some FHs do produce rice. These FHs may have an environmental endowment not clearly delineated in the survey results. It may also be a preference of the FHs.

As the factors of production are increased agricultural output also increases. It has been pointed out previously that the MVP of these factors decreases rather rapidly as constraints are relaxed. One would conclude that if large gains in production are to be encouraged it must be done by other means. These might include increased capital availability, greater commercialization within the agricultural sector to draw off excess supply quickly in grain surplus areas or the development of a modern storage capacity to avoid the necessity of selling at low prices, technological packages directed toward increasing yield, etc. None of these options appear to be easily obtained by Kilosa's small FH. Another alternative would be to place emphasis on higher quality sources of nutrients which would result in a larger surplus for sale. This is one of the purposes of the Bean Cowpea Collaborative Research Support Program. However, the focus appears to be placed on quantity rather than both quantity and quality within a given species of crop.

7.3 Policy Recommendations

Two clear cut policy recommendations may be made with respect to the nonmechanized farm household in these villages. First, the price paid by the government marketing board to the nonmechanized FH for cotton must be substantially increased to provide a noncoercive production incentive. If it is not the FHs tend to lose gross revenue in producing the crop while at the same time decreasing their ability to be self-sufficient in production of basic nutrients. The disparity between prices paid by government marketing boards for subsistence-cash crops and free market prices was almost two to one. The resulting difference in gross revenue the FHs would expect are even greater due to the fact that no open market exists for cotton or sunflower in these locations. Both in the short and long run, from a microeconomic perspective, it would be preferable for these crops to be commercialized in an open market setting. At the macroeconomic level, revenue might be decreased in the short run but these could be offset by productivity increases which would occur as the price of cotton increased to competitive levels.

Secondly, nutritional requirements may be used as a benchmark by these FHs and government when considering whether to introduce enterprise changes into the FSs. A number of different combinations of enterprises may be used to insure nutritional sufficiency. If the FH has preferences which dictate the production of rice or cotton over other crops such as maize and beans, a farm program may be developed which will insure adequate nutrition. Since nutrition is reportedly the major goal of these FHs, regardless of consumption patterns, leaders should consider this goal in the decision making process. Surplus production may be sold in the market to meet income requirements. Again, for those who choose to produce cotton, a free market should insure adequate income for purchase of nutrients in the market.

A straightforward method exists for the determination of the gains from the introduction of new microbiological technology into the system. Assume that the nutrient targeted is protein. One need only look at the sensitivity of the objective function coefficients to determine which are most sensitive to change. If the technology exists to breed an acceptable strain of the crop which has a protein yield greater than the upper range, progress will have been made. This is tantamount to what is being done in many regions on the basis of price incentive, sometimes without success. It is suggested that this type of component be considered in project analysis.

The government has an opportunity to view the introduction of crops on the basis of both national welfare criteria and from the perspective of the FH. Only when nutritional requirements are met or surpassed by the revenue generated by new enterprises will satisfactory opportunity for introduction exist. In the case of cotton production this criteria has apparently not been met without some coercion (Manday, 1982). Less than half the FHs produce cotton in the locations. It is the opinion of the author that this production could be substantially increased if greater price incentive existed. This, accompanied by the development of a processing industry, would have multiple effects of creating more demand for labor in slack labor periods as well as introducing a processed good for domestic use and export.

The recommendations presented here are only viable given the correctness of the model. However, the model was in no way "massaged" which lends credence to the applicability of this type of analysis. The results are encouraging.

7.4 Limitations of the Study

Several limitations of the research exist which must be noted and considered when reflecting upon results. These are listed:

1) One period linear programming models using cross-sectional data fail to deal effectively with carryovers of resources into future periods and they are static by nature.

2) The cross-sectional data available supplied only average annual farmgate prices. The data dealt with consumption on a yearly basis resulting in gross annual figures. Consumption data, by period or season, would be much more revealing due to the nature of nutritional demand.

3) The survey was carried out in a "one visit" format which results in questionable responses by the FH due to memory lapse.

4) No fixed standard exists for nutritional requirements of individuals. Bias therefore exists in the development of the C.U. as a standard, however, the bias is minimized.

5) Labor data were provided on the basis of cultural activity. This was not adaptable to the model without standardization. Bias may exist with respect to this standardization process.

6) The choice of maximand is experimental and based upon the assumption that UP protein is the object of the FHs cropping decisions.

7) The effects of intercropping have been excluded from the model.

8) The models are representative for each village. Whether this representativeness is affected by aggregation bias

is not clear due to the spurious results associated with Magole.

9) Finally, since the sub-sample size was small, statistical significance of the results may be questioned.

7.5 Recommendations for Future Research

Future research should focus on two areas. The first should be the collection of primary data with more specific price and consumption information. It is clear that nutritional requirements fluctuate throughout the year depending on level of activity, illness associated with particular periods of the year as well as age and sex composition of the FH. An attempt to delineate the level of demand for major nutrients should be made. This would allow a more conclusive criteria for maximization of one nutrient rather than another. Normally, one would expect either UP or calories to be the nutrient of most importance. Situations may arise where a vitamin or mineral is more important. The emphasis, however, should be placed on measuring nutritional adequacy at different times during the year and incorporating this into the model.

Secondly, the model needs to be expanded to include the secondary goal of adequate income. Clearly, income is necessary for clothing, food, tools, taxes and many other necessities. This could be done using goal programming which would deal with nutrition requirements first and subsequently maximize an income measure incorporating prices as an allocative mechanism.

Additional activities, such as purchasing and selling of crops and labor should be experimented with in the nutritional context. The inclusion of capital made available to the FH would also be interesting. These additions will maintain their appeal only if the primary goal of food supply is adhered to closely.

Finally, these prescriptions should emphasize the commercialization of agriculture which leads to greater food security for the nonmechanized FH. The security resulting from commercialization will allow a broader spectrum of FS choices for the FHs in Dumila, Mkundi and Magole as well as the Kilosa district.

APPENDIX A

EXPLANATION OF ABBREVIATIONS IN THE LINEAR PROGRAMMING MATRIX

Row/Column No.	Abbreviation	Complete Heading
Constraints		
1	LAND	Total land cultivated
2	LAB1	Labor available in January
3	LAB2	Labor available in February
4	LAB3	Labor available in March
5	LAB4	Labor available in April
6	LAB5	Labor available in May
7	LAB6	Labor available in June
8	LAB7	Labor available in July
9	LAB8	Labor available in August
10	LAB9	Labor available in September
11	LAB10	Labor available in October
12	LAB11	Labor available in November
13	LAB12	Labor available in December
14	PROT	Total crude protein
15	PROU	Total utilizable protein
16	PROS	Total surplus protein
17	RA	Utilizable protein transfer
18	RA1	Total crude protein quantity

APPENDIX A (continued)

Row/Column No.	Abbreviation	Complete Heading
Constraints (cont'd)		
19	RA2	Utilizable protein quantity
20	RA3	Protein quality weighting
21	CAL1	Calories per farm household
22	CALC	Calcium per farm household
23	IRON	Iron per farm household
24	THIAM	Thiamine per farm household
25	RIBO	Riboflavin per farm household
26	NIAC	Niacin per farm household
27	LYSINE	Proportion of amino acid Lysine per farm household
28	TOTSUL	Proportion of total sulfur containing amino acid per farm household
29	METHIO	Proportion of amino acid methionine per farm household
30	THREON	Proportion of amino acid threonine per farm household
31	TRYPTO	Proportion of amino acid tryptophan per farm household
32	FLMA	Focus of loss on maize production
33	FLSO	Focus of loss on sorghum production

APPENDIX A (continued)

Row/Column No.	Abbreviation	Complete Heading
Constraints (cont'd)		
34	FLR1	Focus of loss on rice production
35	FLBEA	Focus of loss on bean production
36	FLCOT	Focus of loss on cotton production
37	FLSU	Focus of loss on sunflower production
38	MINI	Minimum production of utilizable protein
Activities		
A1	GRMAZ	Production of maize
A2	GRSO	Production of sorghum
A3	GRRI	Production of rice
A4	GRBEA	Production of bean
A5	GRCOT	Production of cotton
A6	GRSU	Production of sunflower
A7	TPRO	Production of crude protein
A8	UPRO	Production of utilizable protein
A9	SPRO	Production of surplus protein

APPENDIX A (continued)

Row/Column No.	Abbreviation	Complete Heading
Constraints (cont'd)		
A10	UPRIM	Transfer of utilizable protein to quality component of model
A11	YA	Production of utilizable protein at point 1
A12	YB	Production of utilizable protein at point 2
A13	YC	Production of utilizable protein at point 3
A14	YD	Production of utilizable protein at point 4
A15	YE	Production of utilizable protein at point 5
A16	YF	Production of utilizable protein at point 6
A17	EATMAZ	Consumption of Maize
A18	EATSO	Consumption of Sorghum
A19	EATRI	Consumption of Rice
A20	EATBEA	Consumption of Bean
A21	EATCOT	Consumption of Cotton
A22	EATSU	Consumption of Sunflower
A23	LOSS	Permitted loss of utilizable protein without falling below minimum requirement

APPENDIX B

EXPLANATION OF THE DERIVATION OF THE CONSUMER UNIT

The derivation of the value assigned to a consumer unit was based on the nutrient requirement at a medium level of activity for individuals of different sex and ranges in age. The requirements for an adult female were used as a base against which a nutritional requirement index was developed. The index is presented below:

Nutritional Index

Requirement:

	Calories	UP	Calcium	Iron	Thia-mine	Ribo-flavin	Nia-cin
Adult Male	1.34	1.29	1.00	0.34	1.25	1.36	1.35
Adult Female	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adolescent Male	1.35	1.25	1.32	.43	1.25	1.45	1.35
Adolescent Female	1.14	1.21	1.32	.73	1.12	1.18	1.14
Children:							
< 1	0.44	0.58	1.22	0.36	0.37	0.45	0.43
1-3	0.72	0.67	1.00	0.36	0.62	0.72	0.73
4-6	0.97	0.83	1.00	0.36	0.87	1.00	0.98
7-9	1.16	1.04	1.00	0.36	1.12	1.18	1.17

Source: The index was developed from requirements found in; Latham, M.C. Human Nutrition in Tropical Agriculture, Food and Agricultural Organization Food and Nutrition Series, No. 11, Rev. 1, 1979, Appendix 1.

APPENDIX B (continued)

Each of the individuals in the FH has the appropriate index coefficient for their age and sex assigned. These factors are then summed for the FH. The cumulative score of all individuals in a FH is the number of CUs in that FH and participating in the FS activities. The average number of CUs for each village was determined and a weighted average for Kilosa district was developed. These are listed:

Table of Representative Consumer Units (CU) for
Each Location by Required Nutrient

Location:	Dumila	Mkundi	Magole	Kilosa 1&2
Nutrient:	CUs	CUs	CUs	CUs
Calories	5.81	4.81	5.16	5.26
UP	5.64	4.66	4.96	5.12
Calcium	5.39	4.30	4.75	4.81
Iron	2.86	2.40	2.53	2.44
Thiamine	5.54	4.58	4.93	5.02
Riboflavin	5.95	4.90	5.30	5.31
Niacin	5.83	4.81	5.18	5.20

Source: 1980 BC/S.

APPENDIX C

LIST OF PRICES USED[1]

Location:	Dumila T.Sh./kg.	Mkundi T.Sh./kg.	Magole T.Sh./kg.	Kilosa 1&2 T.Sh./kg.
Free Market				
Maize	1.89	1.83	1.92	1.88
Sorghum	3.03	3.91	4.07	3.67
Rice	2.00	1.74[2]	1.74[2]	1.74[2]
Bean	5.5	6.0	5.63	5.71
Government				
Maize	1.00	1.00	1.00	1.00
Sorghum	1.08	1.00	1.03	1.04
Rice	1.75	1.75	1.73	1.74
Bean	3.30	3.50	3.21	3.33
Cotton	2.95	3.25	3.20	3.13
Sunflower	1.83	1.71	1.67	1.74

[1] 1 T.Sh. was ≏ $0.125 United States.

[2] No free market price was reported for rice in Mkundi and Magole, therefore, government price was assumed.

Source: 1980 BC/S.

APPENDIX D

BINDING CONSTRAINTS FOR TABLE 32 THROUGH TABLE 36

Constraint No.	Abbreviation	Complete Heading
3	LAND	Cultivatable land
5	LAB2	Labor in February
7	LAB4	Labor in April
8	LAB5	Labor in May
9	LAB6	Labor in June
30	CALC	Calcium
33	RIBO	Riboflavin
39	TRYPTO	Tryptophan
40	FLMA	Focus loss maize
41	FLSO	Focus loss sorghum
43	FLBEA	Focus loss bean
45	FLSU	Focus loss sunflower
46	MINI	Minimum requirement for utilizable protein

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VITA

Thomas Edward Gillard-Byers was born on December 13, 1951 in Detroit, Michigan. Shortly thereafter he moved to Fremont, Nebraska, where his childhood came and went. In December 1970 he married Nancy Ann Gillard. He received his B.S. in agricultural economics from the University of Nebraska at Lincoln, Nebraska, in May 1977. While working for the City of Lincoln, Nebraska, and later as a research assistant and research associate in the Institute of Agriculture and Natural Resources, he earned his M.S. also in agricultural economics. Prior to receiving his M.S., the family moved east where Mr. Gillard-Byers had been accepted into the Department of Agricultural Economics at the University of Illinois, Urbana-Champaign, to work toward his Ph.D. In December 1979, Nicholas Aaron Gillard-Byers became part of the family.

During the period 1979-1984, Thomas Gillard-Byers cofounded the International Colloquium, coordinated the "Food Problems in Africa" symposium, earned his private pilots license, worked as assistant technical leader for the International Soybean Program's "Technical and Economic Aspects of Soybean Production" short course in production, consulted for Arthur D. Little, Inc. in the Sultanate of Oman and carried on the everyday activities of graduate research assistant.

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