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The Role of Dimba Land and Small Scale Irrigation in Smallholder Farmers' Food Security in Malawi: An Application of Safety First Chance-Constrained Target Motad Mathematical Programming

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THE ROLE OF DIMBA LAND AND SMALL SCALE IRRIGATION IN SMALLHOLDER FARMERS' FOOD SECURITY IN MALAWI: AN APPLICATION OF SAFETY FIRST CHANCE-CONSTRAINED TARGET MOTAD MATHEMATICAL PROGRAMMING

By

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Department of Agricultural Economics

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ABSTRACT

THE ROLE OF DIMBA LAND AND SMALL SCALE IRRIGATION IN SMALLHOLDER FARMERS' FOOD SECURITY IN MALAWI: AN APPLICATION OF SAFETY FIRST CHANCE-CONSTRAINED TARGET MOTAD MATHEMATICAL PROGRAMMING

By

Naomi Aretha Ngwira

The potential of intensive dimba (flood recession) land cultivation and small scale irrigation to improve smallholder farmers' food security is investigated. The objectives are to: 1) estimate the current contribution of dimba crops and potential contribution of irrigated crops to household food security; 2) identify technically feasible crop/irrigation technology packages for increasing crop production; and 3) select those that can contribute most to food security.

Smallholder farmers make up 80% of Malawi's population. The majority are food insecure owing to low productivity agriculture. Yet adoption of intensive cultivation has been constrained by limited access to inputs and yield risk due to erratic rainfall. Cultivation on dimba (flood recession) and irrigated land may offer a solution.

A survey of smallholder farmers was conducted in Chiradzulu North Extension Planning Area of Blantyre Agricultural Development Division. The data collected are used to implement a Target MOTAD programming model to select optimal crop activities. It uses Telser's safety first criterion to model risk avoidance behavior. Current, intensive and irrigated crop production practices are analyzed for small (0.7 hectares), medium (>0.7 to 1.49 hectares) and large farms (>1.49 hectares). Sensitivity analysis is done for alternative output prices, costs and crop yields.

Results show that dimba land and irrigation can contribute from 30% to 80% of total income depending on farm size and crop production practices. With current cropping practices, only large farms can achieve minimum cereal consumption requirements in 75% of cropping seasons. Even these larger farms need intensive dimba cultivation or irrigation to

generate incomes that meet subsistence requirements in 75% of cropping seasons. Small farms can produce cereal consumption requirements in 75% of the cropping seasons only when irrigation is used for cereals; they can achieve subsistence income requirements only when horticultural crops are irrigated.

When farmers use an income safety-first strategy, stable incomes from intensive dimba cultivation or irrigation of horticultural crops can make it optimal to adopt maize fertilization or hybrids on rainfed land. Intensive dimba cultivation and small scale irrigation require credit and extension programs to encourage crop diversification. Small farms with no dimba can benefit from programs for cereal irrigation, as well as horticultural crops, where markets for the latter exist.

"Since the rains have been insufficient, the people will now concentrate on cultivating on moist areas along the dambos and rivers." Louis Chimango, M. P., Minister of Finance, *Daily Times,* March 16, 1992.

DEDICATION

To my dear husband Chimwemwe

who provided the support I needed to pursue my doctoral studies.

ACKNOWLEDGEMENTS

I wish to acknowledge with gratitude the contributions made by members of my dissertation and guidance committee, Dr. James Shaffer, Dr. Michael Weber, Dr. Ann Ferguson and Dr. Scott Swinton. A special word of thanks goes to Dr. Swinton for ably advising and encouraging me through all the stages of preparing the dissertation.

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CHAPTER 1: INTRODUCTION

The central focus of this study is the problem of food insecurity among smallholder farming households in Malawi. The goal is to investigate the potential of dimba[1] land and small scale irrigation to improve the food security position of these households.

1.1 The Concept of Household Food Security

In general, household food security can be defined as the ability of a household to provide its members access to a timely, reliable, and nutritionally adequate food supply (World Bank, 1986 p 216). For Malawian farmers, the concept of food security is defined by two factors. Staple food is maize. Except in a few ecological zones--the northern lake shore, the southern and northern tip of the country--maize has no competition from secondary staples such as cassava, rice, and sorghum.

Peters and Herrera (1989) have aptly recorded the sentiments of smallholder Malawian farmers with respect to maize:

> "Chimanga ndi moyo," say the farmers in Zomba South[2]: "Maize is our life." Nothing captures so forcibly the goal of all households--to produce all the maize they could possibly want. In this area maize is equated with food...the first criterion of wealth is to have enough maize to eat; to have land is to grow maize. More than an income generating activity in the dry language of analysts, cultivating maize is a way of life... to cultivate without cultivating maize was an impossible thought.

Maize is grown once a year under very uncertain rainfall conditions. This, added to the situation of incomplete and imperfect markets, makes farmers desire to produce as much

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[1] Dimba land is flood recession land along rivers and in depressions. It is cultivated after the rainy season.

[2] Zomba South is an EPA contiguous with Chiradzulu North.

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as possible of their maize consumption requirements. Again, Peters (1991) has succinctly recorded this motivation:

> The people's wish to produce as much of their own maize as possible is related to both their assessment of their ability to pay the higher prices in deficit period (December-January) as measured against their needs for cash immediately after maize harvest; the insecure set of income opportunities available to them, which are more restricted for the poor; and the fluctuation in supply at the local ADMARC selling centers, as well as costs in time and cash, involved in buying maize. For these reasons, as well as for taste preferences, the more of their food supplies people are able to produce for themselves, the less risk they face (of increased prices or of short supplies).

Thus for the Malawian case, household food insecurity is primarily the failure of a household to <u>produce enough maize</u> to meet its annual consumption requirements. But not all households can produce their maize requirements from their land holdings. Because of very small land holdings, a large majority depend on off-farm income earning activities (IEAs) or sale of horticultural crops produced on dimba land. Thus, the operational definition of household food security for this study is the ability of households to produce maize and/or generate enough cash to meet any the shortfall in maize production.

1.2 Food Security Among Smallholder Farmers in Malawi

Smallholder farming households make up 80% of Malawi's population. For policy analysis and planning, the Ministry of Agriculture groups these households into three categories based on the size of their land holdings: those with less than 0.7 hectare of land holdings, those with 0.7 to 1.49 hectares, and those with more. This grouping is related to food security issues and to the kinds of income and employment support programs that farmers can benefit from. The group with less than 0.7 hectares represents those households who cannot meet their subsistence needs from their land alone with present crop production technology. This category constitutes 36.7% of all smallholder farming households in Malawi and 57.4% in Blantyre Agricultural Development Division (ADD) where this study was conducted.

1.3 Objectives of the Study

The basic questions the study will address are:

a) What is the current contribution of dimba production to food security and income in Chiraduzlu Extension Planning Area (EPA)?

b) Can intensive dimba cultivation and small scale irrigation be used to improve the food security situation?

The specific objectives are:

1) to understand the current pattern of land use of both dimba and rainfed land for agricultural production in Chiradzulu North Extension Planning Area (EPA);

2) to compile enterprise budgets for farm activities congruent with land and time use as determined above;

3) to estimate the contribution of dimba crops to household farm income and food security;

4) to estimate the possible contribution of irrigated crops to household income and food security;

5) to identify technically feasible crop/irrigation technology packages that can be used to increase production of crops;

6) to select crop-technology packages that can contribute most to improving food security;

7) to make policy and research recommendations based on the findings of the study to appropriate institutions.

1.4 Need for the Study

Alternative ways of improving smallholder food production and security are needed for the following reasons:

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1) At present, many farmers have too little land to produce adequate food given current technology and farming systems.

2) There are limited employment opportunities outside agriculture, and irrigated agriculture may absorb underemployed labor.

3) Rainfall is unreliable, and adequate means for insuring against crop loss and failure are not available.

Recent studies indicate that maize research has released semi-flint hybrid maize varieties, e.g. MH18, with characteristics desired by farmers (Smale et al 1993). Wide-spread adoption is still to occur. In the past, the available non-flint hybrids did not meet the farmers' storage and processing preferences. Farmers grew local maize varieties. Yields were very low due to limited access to inputs (Kydd 1989, Smale 1991). The result was yields below annual consumption requirements of households.

Employment opportunities outside agriculture are very limited. For those households with less than 0.7 hectares of land the government has suggested a policy of finding alternative employment (Malawi Government 1990). However, there is no suggestion of where they can get work or how to generate the jobs. In 1987, the population census enumerated 81.3% of the labor force as employed in the agriculture sector. Farmers who do not work on their own farms work on other farmers' gardens or in the estate sector. The estate sector employed 9% of the labor force in 1990 (Mkandawire et al 1990). The conditions of employment in this sector are exploitative, not engendering long term household food security. Intensification of smallholder agriculture is thus a more plausible option given the economic base of the country.

In the past three cropping seasons (1990/91, 1991/92, and 1992/93), drought has led to serious food shortages among as many as 90% of farming households in most of Central and Southern parts of the country. Coupled with the organizational and financial uncertainties of managing national grain reserves, the drought has put the majority of rural farms at risk of sta

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starvation. The remarks quoted earlier from the Minister of Finance indicate that Malawian farmers cannot rely on rainfed cultivation.

The nature of drought in Malawi and the existence of large water bodies make irrigation an attractive albeit pecuniarily more costly alternative technology for agricultural production and improving food security. Irrigation can serve both a) to alleviate the risk of drought between one season and the next, and b) to smooth out intra-season fluctuation of water supply to plants. It can also permit higher productivity cultivation practices, with a direct impact on the volume of output and farm incomes. In this sense, irrigation is not just a risk reduction strategy. It also has a major impact on output via its complementarily with double cropping, increased fertilizer use, and improved seeds. In the past, neither dimba cultivation nor expanded formal irrigation has been given due attention. The recent experience with drought in the last three years has renewed interest in irrigation. A large scale irrigation project is being implemented for the irrigation of the Lower Shire Valley. However, intensive dimba cultivation and small scale irrigation may be the only feasible options in other parts of Malawi.

There is inadequate information on how to plan and organize for small scale irrigation. A pivotal question is whether irrigation with different kinds of techniques would sufficiently improve food security to justify the requisite investments. This study proposes to address this information gap by determining the crop mixtures that farmers can profitably grow, given that their overriding objective is to maximize the probability of producing enough maize for home consumption and/or earn income to buy those food requirements.

1.5 Related Research

Decision making concerning irrigation planning can be phased into three: The first one is how much irrigation land to develop, given water resources and other uses of land; the second level addresses the issue of what crops to grow in a given season; the third level deals w

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with how to optimally allocate water to crops that are planted (Duddley 1971). This study belongs to level two.

No in-depth farm level financial studies have been done on small scale irrigation in Malawi. There is also a paucity of literature on irrigation in sub-Saharan Africa in general. The little literature available is concentrated on the Gezira Scheme in Sudan and developments along the Nile. Most of the irrigation projects existing in sub-Saharan Africa are traditional or small scale self-help schemes run by farmers on which governments did not have to spend large sums of money or carry out careful financial assessments. It is the analyses of these large scale projects that are mostly published in international journals and media (Barnett 1994). What follows in this section is a review of financial studies of small scale irrigation that were done in other parts of the world.

The closest studies in objectives and methods of this study are those conducted by Maji and Heady (1978), Islam (1973), Preibprom (1982) and Laki (1992). Maji and Heady dealt with the issue of how to allocate water to six irrigation blocks of a large project with command area of 530,528 acres in Mayurikshi, India. They used a chance constrained linear programming (LP) model to develop an optimal cropping pattern and a reservoir management policy for the project. The optimal plan allowed the probability of drought or floods to be less than 10%. This was necessary to attract farmers who have low risk bearing capacity.

Islam analyzed the economic and financial returns to low-lift pump irrigation in Bangladesh. He used an LP model to determine the impact of three different rental rates and command area (area irrigated by one pump) as measured by net returns to fixed farm resources, optimal cropping patterns, marginal value products, and amount of inputs used. Economic returns were calculated using internal rate of return, net present value and benefit/cost ratio. The results indicated that there would be substantial specialization of crops under irrigation conditions, unless the yield of some crops increased substantially. Sensitivity to yields and prices was very high. He concluded that the government of Bangladesh could expand irrigation to all areas with suitable hydrological resources. Subsidies could be

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significantly reduced without adversely affecting farmers' incentives. A package combining rental charges, credit, and supply of equipment and inputs was necessary to expand command area.

Priebprom (1982) approached the problem from a labor use point of view. He appraised the alternative uses of farm, non-farm and off-farm work, and their impact on production, employment and income of rural households in the Khon Kaen province of Thailand. A poly-period LP model was used to represent farm households with three different farm size groups for both rainfed and irrigated area. Major non-farm and off-farm employment was included in the model to test the complementarity and competitiveness of farm, non-farm enterprises and off-farm employment. He found that for rainfed farms, those with small holdings derived most of their income from off-farm work. Both rainfed and irrigated farmers could combine farm, non-farm enterprises and off-farm work to achieve maximum net income.

Laki (1992) analyzed the impact of changes in resource use, enterprise mix on farm income on a typical Gezira tenancy, and assessed the impact of government policy on productivity. A static LP model was used to maximize gross margins, subject to minimum sorghum consumption requirements of the tenant households. Sensitivity analysis was done to analyze the impact of different technologies, policies and resource levels on cropping pattern, farm productivity and income. The results showed that 1) labor, capital and water were constraining during peak periods; 2) elimination of mandated cropping pattern increased income; 3) levels of income achieved were sensitive to prices, yield levels and irrigation water supply. The second finding is relevant to Malawi where farmers on rice settlement schemes have been discouraged partly by coercive production regulations.

Faki (1982) used an LP model to examine the financial and managerial aspects of irrigation water in the Gezira Scheme. Running his model at various capacities he concluded that water was in short supply in October and November. Returns to water were high.

Cotton was the most profitable crop followed by sorghum and groundnuts, and wheat had negative returns. He also found a cropping intensity of 60% below the planned 75%.

Hazelwood and Livingstone (1978) conducted studies in the irrigated Usangu Plains of Tanzania. Using an LP model, they concluded that large and small scale farms are not alternatives in the bid to maximize paddy production. In a separate study in 1982, they used an LP to determine the demand for irrigation water, and also discussed issues surrounding supply of water.

Ndiame (1985) used a production function econometric analysis to evaluate large and small irrigation perimeters in the Flueve region of Senegal for their contribution to that country's objective of food security. He found that large scale perimeters led to more per capita availability of food, even though small scale perimeters have higher yields. He recommended more economical strategies of food security based on simultaneous development of irrigation with rainfed and flood recession agriculture. This finding is relevant to Malawi: flood recession (dimba) cultivation, and small scale capital extensive irrigation may be complementary to large scale capital intensive irrigation.

Diallo (1980) did a comparative financial and economic analysis of capital and labor intensive rice perimeters in Senegal River Valley. He found that large perimeters are less efficient than small perimeters. Both small and large perimeters have production cost above the total of purchase price, insurance and freight costs of rice from Asian countries to Senegal. Domestic resource cost ratios were 125% and 233% for rice produced on small and large perimeters respectively. Reasons given were cheap rice quality that is imported from Asia, and inefficient irrigation policies followed by the country's irrigation board.

The studies reviewed show that irrigation can be financially feasible under various arrangements and has potential in improving incomes and meeting food requirements of farmers. This may be the case even when cropping intensity or command areas are lower than optimum.

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1.6 Organization of the Study

The study is organized as follows. Chapter 2 provides a synopsis of agriculture and irrigation policies in Malawi. The rationale for the choice of methods and techniques used in this study is presented in Chapter 3. The planning and implementation of the farm survey are outlined in Chapter 4. Following in Chapter 5 is a presentation of the major descriptive characteristics of the survey households, especially those connected to food security. Chapter 6 contains documentation on the compilation of enterprise budgets, and the formulation of the programming model used. Chapters 7 through 9 present and discuss the results of the model. In Chapter 10 is a summary of the findings and conclusions. It also contains recommendations to appropriate agencies and for future research.

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CHAPTER 2: AGRICULTURE AND IRRIGATION POLICIES IN MALAWI

This chapter provides a synopsis of agricultural and irrigation potential and policies in Malawi. It furnishes a macro-economic overview and illustrates the need for small scale irrigation. The aim is to facilitate the understanding of research objectives and design, and also to provide a context for assessing the findings of the study.

2.1 Macro-Economic Performance

Malawi got independence in 1964 from Britain, in one of the worst national economic conditions and political legacy for a people whose leader was ambitious to lead them to prosperity. The colonial government had strategic legislation concerning land and important economic resources, the purposes of which was to entrench colonial hegemony (Nankumba 1981, Chipeta 1992). The country has no exploitable mineral resources and so it was treated as a labor reserve for the South African mines and also Zimbabwe and Zambia, which together with Malawi were part of the British Colonial federation.

The country's economic development strategy is based on rapid increase in agricultural productivity to boost export crop production and ensure adequate food supply. It produces its own basic foodstuffs, and exports tobacco, tea, sugar, groundnut, rice, cotton and coffee. Tobacco contributes 74% of export earnings. (See Table 2.1.)

The way that the agricultural sector has been organized to implement the policy is purely a political matter. This is discussed in the following section. However, before that an overview of the macro-economy and its performance is provided.

Between 1964 and 1979, the economy maintained a strong upward trend: GDP growth rates averaged 5%. The country was acclaimed for some the best performance amongst small landlocked countries and by the World Bank and the International Monetary Fund as one of the examples of adopting their current policy prescriptions for least developed countries, and doing well. Others feel that those who held out Malawi as a virtuous case ten

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Table 2.1
Principal Domestic Export Commodities 1992

Agricultural crops	Value(MK[1] million)	Proportion(%)
Tobacco	1029.8	74.2
Tea	106.1	7.6
Sugar	97.8	7.0
Rice	2.0	0.1
Cotton	16.6	1.2
Pulses	7.0	2.0
Coffee	27.0	0.5
Other Exports	100.5	7.2
Total Domestic Exports	1387.4	100.0

tended to exaggerate the strengths while ignoring the weaknesses (Kydd and Christiansen 1981, Lele 1990). An important motif in their argument was that the pattern of growth chosen was not optimal, especially when distributional issues are considered.

These misgivings were actually born out. Between 1979 and 1982, GDP growth reached a standstill. Most of the immediate causes of reduction in economic activity were external: rapid deterioration in Malawi's terms of trade, a second rise in oil prices, a drought which compelled maize imports, closure of Malawi's main transport link to outside markets due to the war in Mozambique, and historically high interests rates in international markets (Malawi Government, series of Economic Reports).

After implementing structural adjustment programs with lending from the IMF and World Bank the economy was resuscitated, although the performance of key macro-economic variables has been mixed. During 1983-1985 GDP grew at 4% from below zero in 1981. Between 1985 and 1987 there was another decline; the economy picked up in 1988. Inflation reached an all-time high of 31.4% in 1988 but fell to under 10% in 1989 due to availability of goods under the import and industrial liberalization schemes that are part of structural adju

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adjustment. Poor performance in this period has been attributed to contractionary macro-economic policies, which wrung growth prospects from the economy. Some recent analyses point to poor entrepreneurship and management styles, but it is difficult to conceive what better management would have achieved without resources (Meyers 1990). Besides, Malawi has had very strong economic institutions and probably the least corrupt African civil service.

Under the structural adjustment, the poor have paid a heavy price (Harvey 1987, Cornea et al 1988, Kandoole 1989). They have suffered because social services were initially de-emphasized due to the inflationary effect of currency devaluation and the way that agricultural marketing liberalization increased uncertainty in food markets. Although producer prices were increased as part of structural adjustment policies, the majority of smallholder farmers have failed to respond to the incentive due to small land holdings and/or no access to inputs (Lele 1990). Also, most are net purchasers of food, not sellers.

Despite these programs and policy changes, the performance of the economy is far from favorable. The export base is still narrow, and the economy is still highly vulnerable to exogenous and natural shocks. In 1992, "real GDP declined by 7.9% compared to a growth rate of 7.8% in 1991, mainly due to short-fall in small-scale agricultural production arising from the drought" ([Malawi Government 1993(c)] p4). The public sector still runs large deficits. Between 1991 to 1993 the deficit in the government budget increased from MK328m to MK848m (6.48% to 9.36% of total GDP). Investment as a ratio of GDP declined in the same period. The balance of payments, which was in surplus in the 1990-1992, plunged to MK505.5m in 1993. These economic data combined with high population growth (3.3%), lead to a forecast of no per capita GDP growth between 1993 to 1996 ([Malawi Government 1993(c)] p21). An important lesson from the analysis is how drought can seriously impact the macro-economy. These effects may be dampened with more extensive use of irrigation.

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2.2 Agricultural Development Policy

Emanating from a mistrust of the capacity of smallholder farmers to grow and handle export crops, and from a need to use the profits from estate production to reward political allies and create a support base, a dichotomous estate and smallholder agricultural sector was created. The ultimate effect of this has been to deprive the rural poor of their potential source of increased income through preferential land and marketing policies.

2.2.1 The Estate Sector of Agriculture

Until recently, the estate sector was the domain of people the government wanted to reward or appease for political reasons. They have had the privilege of easy access to land and credit. Commercial banks have been made to give agricultural loans to top civil servants and politicians. These asset entitlements were complemented by the subsidization of inputs, preferential marketing procedures and a supply of cheap labor.

Resources have been funnelled to the estate sector, while conspicuously slighting the smallholder sector. Although government planning documents emphasized the need to ensure an adequate food supply to save foreign exchange, there was no real effort to equip the majority of the smallholder farmers with the capacity to produce food. With particular reference to maize there was this explicit policy:

> The increased production for maize should be a result of higher yields per acre, and no encouragement should be given to growing maize on land at present used to grow other crops. It is important that this be understood by all concerned as any tendency to increase the proportion of cultivated land planted with maize would be directly contrary to the nation's long term objectives (Malawi Government 1979) p 16.

To produce more maize per unit of land, farmers need more fertilizer which at present is the only feasible way of increasing production. But the allocations of fertilizer credit to smallholder farmers have not increased at the same rate as credit to estate agriculture, despite the poor credit record in the estate sector[3] (Kydd and Christiansen 1982).

Estate and smallholder agricultural together now contribute nearly 40% to gross domestic product (GDP) and provide over 90% of total domestic exports. However, since 1964 the estate sector has expanded considerably, such that smallholder agricultural output as the percentage of total agriculture output fell from 93% to 80% between 1965 and 1980 and is now at 72%. In 1970 only 23.5 % of the tobacco area was under estate agriculture, but this rose to 47% in 1985. Productivity has also been higher in the estate sector for export crops like tobacco and tea. In the case of tobacco, yields in the smallholder sector are only half in the estate sector. The yield and area factor have led to a situation now where 73% of tobacco is produced in the estate sector compared to only 40% in 1970 (Malawi, Government Series, Economic Reports 1970-1993).

The estate sector accounts for 80% of export earnings, mostly from tobacco, but also from tea, coffee and sugar. It employs about 10% of the labor force. Recent studies of the sector indicate that there has been a structural change in the sector with more ownership by graduated smallholder farmers (Mkandawire et al 1990). These smallholder farmers have graduated by consolidating land with relatives and registering it as leasehold to enable them to get quotas to sell high value burley tobacco to international buyers. This is certainly an important policy of relevant finding.

However, the conclusion that leads one to question the long held position that smallholder farmers have not benefited from development of export-led agriculture is lopsided. It is certainly the case that the incomes of those who participate in estate sector

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[3] Fertilizer use intensity averages 154 kg/ha in the survey households compared to an average of 328 kg/Ha in the estate sector, where most of the fertilizer is 'leaked' from ADMARC subsidized fertilizer intended for smallholder farmers (Mkandawire et al 1990).

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improves. However, any farmer who can consolidate or buy 30 hectares of land is not the typical smallholder farmer discussed in policy issues in Malawi. It is the tenants who work in these estates that fit into this category. Concerning them, the authors question "if under prevailing price and cost conditions, tenancy arrangements can alleviate poverty on any significant scale" (Mkandawire et al 1990 p xiv). All estates account for only 20% of total land. Besides, even if the graduated smallholders constitute half of the estate owners, the graduated smallholder farmers are a minuscule proportion of smallholder farming families. Evidence still supports the position that the majority of smallholder farmers have not benefited from the development strategy based on large-scale agriculture.

2.2.2 The Smallholder Sector of Agriculture

Immediately after independence, the approach to smallholder agricultural development was based on the transformation approach. But between 1965 and 1969, the government felt that the efforts to develop agriculture without concerted programs would not achieve much. It sought to concentrate on promising regions, "through the establishment of high productivity projects while maintaining the policy of gradual improvement for the mass smallholder framers through general extension and marketing operations, and a particular concentration on the more responsive farmers through the Achikumbe[4] programs and irrigation settlement schemes[5]" (Nankumba 1981).

Four projects were established which followed the integrated intensive package approach, the first of its kind to be financed by the World Bank (Lele 1978). Financing was provided for construction of roads and social services as well as providing extension and credit and marketing services. Emphasized crops were cotton, groundnut and rice. However,

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[4]Achikumbe are progressive farmers who maintain the highest possible standards in their farming without falling back for five years. They are awarded the prestigious Achikumbe certificate.

[5] These are described in section 2.3.2

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the efforts proved to be to expensive and the yields did not increase as projected (Mkandawire 1985). There was little growth in the volume of marketed surplus. A new approach, the National Rural Development Program (NRDP), was thus adopted where emphasis is placed on provision of credit, extension and marketing services. Coverage was increased to the whole country, and implementation has been incremental on a project-by-project basis.

Under the NRDP, the country is divided into 8 semi-autonomous Agricultural Development Divisions (ADDs) (see Figure 2.1) which oversee the planning and delivery of agricultural services to farmers. At the level of the farmer, services are organized as follows. An extension service based on the training and visit system is available to all farmers. The government provides a cadre of extension workers who teach and demonstrate crop and animal husbandry and home economics topics. Each extension worker has approximately 800 farm families to reach. She divides her area into blocks. Farmers in each block meet with her on a specified day in a rotation. Although these meetings are open to everybody, it is mostly those who have received credit for inputs who attend. In principal, anyone can get credit; however, because of requirement of credit worthiness, only those who have resources for collateral receive credit. In all, only about 25% receive credit and patronize the block meetings (Ngwira 1988).

Agricultural marketing is done by the Agricultural Marketing and Development Board (ADMARC) through a chain of markets which purchase and sell crops. During the harvest season, additional rural markets are opened to allow farmers to sell their crops easily. Since May 1987, an act of parliament liberalizing agricultural marketing has made it possible for private traders to buy and sell crops. This has created problems for farm households because the traders have no incentive to go back to the rural areas and sell produce due to high storage and transport costs (Kalua 1991). There are also problems for monitoring the food security situation because it is difficult to follow the activities of private traders.

Marketing through ADMARC effectively imposes an export tax on smallholder farmers because they receive only a small percentage of the world or urban market price even

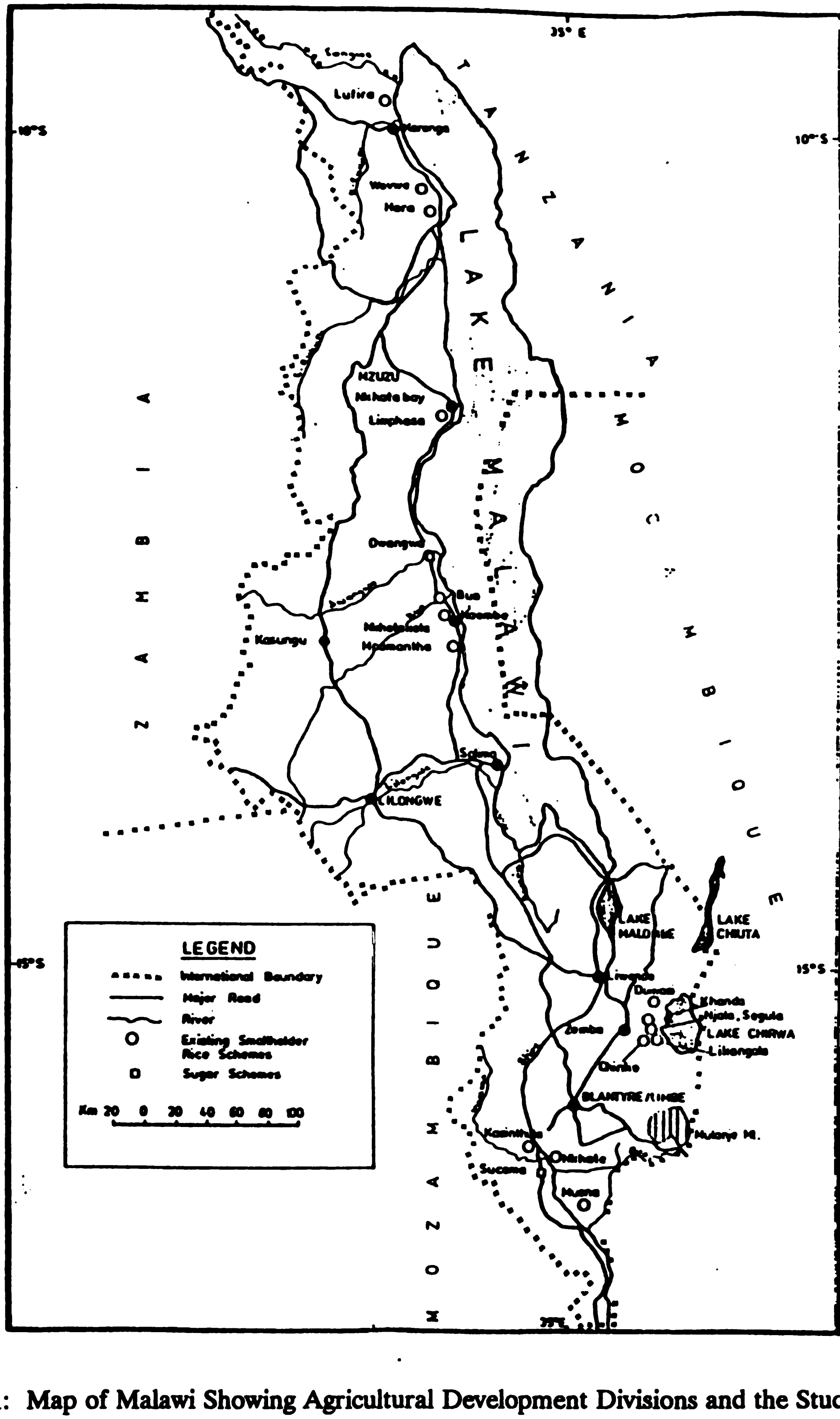

Figure 2.1: Map of Malawi Showing Agricultural Development Divisions and the Study Area

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considering administration and transportation costs. In contrast, estate producers sell their crops straight to the international buyers and receive the world market price.

Most assessments of the Achikumbe and irrigation settlement schemes, integrated rural development projects and the NRDP are negative (Lele 1975, Mphande 1984, Kydd and Christiansen 1981, Mkandawire 1985). In the case of food crops, performance of the smallholder sector with respect to maize production has been disappointing. The National Sample Survey of Agriculture (1968 and 1981) show that yields have not changed. Until recently, the country was regarded as an exception to the African food crisis, in that self-sufficiency has been maintained in the main food crop, maize. However, the low productivity and the increasing population have led to low per capita food availability. To date, low productivity has meant that agricultural programs and policies have failed to ensure that the majority of smallholder farmers are food secure.

2.3 Irrigation Potential in Malawi

2.3.1 Hydrological Resources

Malawi is a long, narrow landlocked country, some 840 kilometers from north to south and varying in width from 80 to 160 kilometers. It is situated in Central Africa lying between latitude 9 degrees and 17 degrees south and longitudes 33 degrees and 37 degrees. Its total area is 118,484 square kilometers of which 24,208, or 20%, are covered by water, mostly Lake Malawi. It is contiguous on the north and northeast with Tanzania, on east, south and southwest with Mozambique and on the west with Zambia.

The country is aligned along the southern continuation of the east African rift valley system, but it is mostly a plateau. The northern part of the rift valley contains Lake Malawi which is 568 km long, varying in width from 18 km to 80 km. The River Shire, which flows from Lake Malawi in the south, takes a serpentine route proceeding through Lake Malombe to the Zambezi River. Throughout its course, it provides many opportunities for gravity fed water abstraction for irrigation (Malawi Government 1992). The Shire Valley from

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Kasinthula onwards is practically irrigable land because of easy access to water and the fertile valley soils. This area is perhaps the single most under utilized resource in the country.

The plateaux are on the western side of the rift valley with the highest elevations in the north and several mountain ranges in the central and southern regions. The Nyika and Viphya Plateaux in the north, and the Dedza mountains and the Kirk range rise to between 1,524 and 2,440 meters in places. In the south, the Shire highlands, and the Zomba and Mulanje mountain ranges rise to 2,100 meters. The plateaux are drained by many perennial rivers which provide opportunities for irrigation in the flood plains and at their confluences to the Lakes Malawi and Chirwa. Examples of this are Wovwe and the Likangala rice schemes.

The great variations in latitude and attitude are responsible for a wide range of climatic, soil and vegetational conditions within the country's comparatively small land area. There are three climatic seasons. During the cool season, from May to August, there is very little cloud cover. Temperatures in the plateau areas are 15.5 C to 18 C, and in the rift valley 20 C to 24.5 C. The coldest month is July, maximum temperature is 22.2 C and the minimum 11 C. Light rain may occasionally fall on the higher southeastern and northeastern slopes. The rain is sufficient to grow a second crop of beans or field peas. In September and October before the rains start there is a short hot season with high humidity. Mean temperatures range from 27 C to 30 C in the valley and 22 C to 24.5 C on the plateau. During the hottest months, October to November, temperatures may exceed 37 C in the low lying ares. The rainy season lasts from November to April, and over 90% of the annual rainfall occurs during this period. Most of the areas receive an annual rainfall of 760 to 1,015 mm, but some areas on the plateau get over 1,525 mm.

The country of Malawi almost never experiences complete rain failure. Most of crop failures are due to inadequate rain at critical times in the cropping season. But during the 1991/92 cropping season the country experienced the worst drought in more than 40 years (Malawi Government 1993). The last famine of 1949, however, is considered worse in its impact. The recent drought started in Southern Africa and spread to the whole country by c

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mid-January. The southern part of the country was the hardest hit. Rainfall was below half of the normal level and food production dropped to less than half of the normal level.

In 1990/91, most parts of Malawi received less than half of expected rainfall in the first half of the season (October to December) (Malawi Government, 1991). The 1992/93 cropping season started very well, but rains were interrupted up to mid-December. These references to recent drought are used to illustrate the need for supplemental irrigation.

2.3.2 Irrigation Policies

There are two kinds of irrigation establishments in Malawi: government supported small scale irrigation projects and private projects. The latter can further be divided into two: self-help small scale projects and large scale commercial irrigation. The government of Malawi has not financed or organized large scale irrigation projects. The government-sponsored projects are commonly referred to as settlement schemes. Tenants are brought in from other parts of the country to work on land that has been developed by government agencies.

In 1967, the Irrigation Branch was formed under the Ministry of Economic Affairs to design, construct and maintain smallholder irrigation schemes. In 1968, the Settlement Branch was formed to look after the settlement of farmers and to manage the irrigation schemes. The aims were:

a) to prepare the country for the time that rainfed agriculture could not produce enough food to feed the population; and

b) to make it possible to produce certain export crops in the wet and dry season (Mphande 1984).

Figure 2.2 shows the schemes that have been developed by the Irrigation Branch and the Chinese Agricultural Mission to Malawi. The schemes are located along the Lakeshore plains and in the Shire Valley. The main crop grown is rice. The highest yields achieved by farmers is 4.7 tons per hectare and average yields are estimated at 3 tons per hectare (the

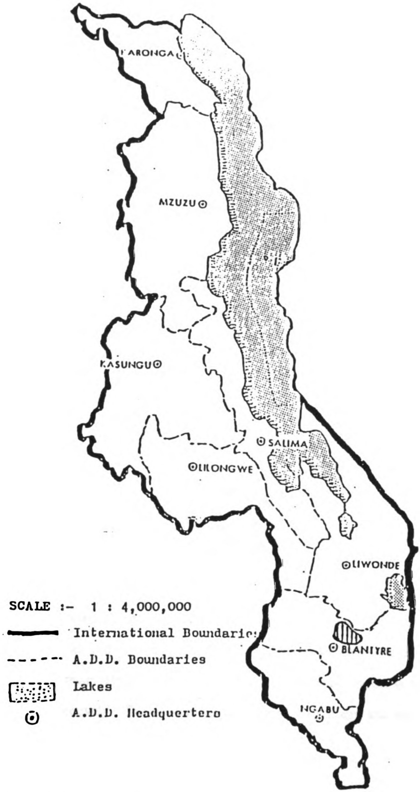

Figure 2.2: Map of Malawi Showing Existing Projects Area

Table 2.2
Irrigation Development (Hectares)

Year	Total Area Developed	Developed within Year	Area Planted with Crops
1969/70	802	654	593
1970/71	1396	594	1288
1971/72	1841	445	1764
1972/73	2343	502	2094
1973/74	2590	2472	671
1974/75	2590	---	2081
1975/76	3696	1106	2359
1976/77	3798	101	3078
1977/78	3899	101	3484
1978/79	3928	29	2750
1979/80	4016	88	2201
1980/81	4171	155	2546
1981/82	4171	---	3852
1982/83	4171	---	3548
1983/84	4171	---	2377
1984/85	4535	364	3628
1985/86	4899	364	3819
1986/87	5273	374	4218
1987/88	5633	360	4506
1988/89	5903	614	600
1989/90	6054	421	4843
1990/91	6354	300	5083
1991/92	6654	100	5083
1992/93	7000	220	5349

Source: Malawi Government, Agricultural Statistics, Annual Bulletin (1993)

potential yield is 6 tons). The total land area developed is estimated at 7,000 hectares.

The Department of Irrigation conducted appraisal studies on the possibility of upgrading self-help schemes and increasing the number of gravity-fed irrigation schemes (Malawi Government, January 1992). Twenty-three and 18 sites were evaluated in Mzuzu and Blantyre ADDs respectively. The evaluations were based on primary and secondary indices.

The primary index included such criteria as presence of perennial source of water, possibility of gravity irrigation, ease of abstraction, topography, drainage and soil fertility. The secondary index captured experiences in committee organization, water management, and communal work, and also economic considerations such as cropping intensity and increase in production and costs of construction. The assessment shows that there is potential for up to 12 self-help projects to be redesigned and upgraded to assisted status in Mzuzu and Blantyre ADDs.

Self-help irrigation projects are based on three tenets:

a) the projects should be farmer managed;

b) the area should not exceed 50 hectares;

c) abstraction of water should be by gravity (diversion): pumping or sprinkling is not included.

Using the criteria above, it is estimated that another 2,000 hectares can be developed on a self-help basis in these ADDs only. This excludes areas suitable for formal, larger schemes as well as small areas where the parent river is too large to make small-scale abstraction feasible. At present, 1,500 hectares of land are under self-help schemes in the whole country, this is 7% of total irrigated land.

The irrigation projects that are envisaged in this study include cases where it is financially feasible to pump water for irrigation, and are financed and run independently from the government. Government assistance to self-help projects is a very sensitive affair, yet in many cases this assistance is needed first to create the awareness of possibilities through extension and demonstration. The second stage is to provide technical guidance, especially in constructing intake works, but also in formalizing marketing channels for the produce. The third and most sensitive step is financial support. These aspects are reviewed in the next section.

Large scale commercial irrigation is used mostly in the estate sector for sugarcane production. The major establishments owned by the Sugar Corporation of Malawi are at

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Nchalo and Dwangwa. Some tobacco and coffee growing estate farms use sprinkler irrigation to counter the effect of drought or to make possible early planting. The potential for commercial overhead irrigation is technically unlimited since there are many perennial rivers and suitable arable land. In many cases overhead irrigation could be used to grow off-season crops on rainfed land. Only financial constraints can limit its use for production of some crops. The total area developed by commercial agencies is about 16,000 hectares.

It is estimated that 290,000 hectares of land in Malawi can be irrigated by different means, but only 7% of this has been irrigated (FAO 1986). This potential plus the valuable experience the Ministry of Agriculture has had with irrigation makes investments in irrigation a very effective way to address the problem of rain dependence and risky, low productivity smallholder agriculture. However, some institutional issues may have to be addressed to realize greater returns from investments.

2.4 Implementation of Irrigation Projects

There is considerable evidence that the potential gains from irrigation in developing countries are far from being fully realized (Barnett 1984, Makhado 1984, Carruthers and Small 1991). This evidence also shows that inappropriate institutions contribute to the situation (Barnett 1984). This section provides a cursory review of these and other problems that need to be addressed to improve chances of successfully implementing small scale irrigation projects. The problems can be grouped into five.

The first relates to deficient design and technical management, which eventually leads to insufficient delivery of water to farmers with negative impact on yields.

The second is inadequate financial resources, inappropriate institution arrangements for financing projects, and low priority for maintenance of irrigation works. The mechanisms for financing irrigation projects affects their performance (Carruthers and Small 1991). Issues concerning maintenance are important for success of irrigation projects. If a project already suffers from other difficulties, the use of technically insupportable technology guarantees

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failure. Morris (1984) cites a project in Mali where irrigation pumps were ordered from India because they were considered technically optimal (the alternative was to get them from France). But it proved difficult to order spare parts and find or train people to maintain them in a timely manner.

The third, poor production techniques, has caused failure of many irrigation projects. Irrigation projects which aim to reduce farmers' exposure to naturally caused production risk end up exposing them to institutional risks by participating in projects. For example, the report for Mchenga Project pointed out the following problems:

a) farmers' inexperience with the crops, in particular direct seeding, led to poor germination;

b) lack of experience in pest control led to 75% loss of tomato crop in the first cropping season;

c) farmers were wrongly sold by the National Seed Company choumollier instead of rape, which resulted in undersupply of seed because of the difference in plant population for the two (although almost the same) leafy vegetables. Choumollier has lower plant population and the seed package contains less seed grains. The more popular rape needs more seed per unit area. This led to a situation where some beds meant for rape remained empty, and also to marketing problems since customers prefer rape. The solution proffered farmers in this report, suing the company, is not adequate.

There has also been a problem with cropping patterns. Crops were either under- or over-watered. This problem was being solved at the time of conducting the study by following independent blocks for every crop. The first method had a block for each farmer. Since the sprinklers have a wide reach, it was difficult to control water for each crop on the farmer's block. Most of the problems at Mchenga and Diamphwe projects were exacerbated by poor farmer supervision.

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The fourth group of problems originate from low motivation of project staff. There is need to reward irrigation extension officers based on criteria related to project performance. This may be difficult if the extension workers are part of the Civil Service, hence the need for irrigation projects to be autonomous from government.

Another disadvantage of public irrigation projects is that extension workers are relocated every three to four years so that they do not feel responsible for the projects. It also leads to discontinuity in rapport between farmers and staff.

The fifth problem concerns marketing. Mchanga and Diamphwe projects were experiencing problems with marketing of leafy vegetables. Some farmers dropped out from the project because of this. It is thus imperative to plan properly for marketing of horticultural crops. In the first season, there was no market for lettuce. In the second season, there was tough competition from dimba crops produced by other farmers. The report of the Lilongwe ADD recommends:

> intensification of market research to establish demand and supply as a guide on what and how much to produce at a specific time period taking into account other producers (Lilongwe ADD 1993, p4).

The sixth problem is poor water management. The result is usually inadequate water provision to farmers. In rice growing projects, inadequate water management is held to be the single most important factor in explaining the gap between actual and potential yield (FAO 1986). A simple calculation from the figures from Mchenga and Diamphwe projects show that only the best farmers (with highest yields) should participate in the project if it is to be independently financially viable. There is need to reduce constraints to increasing yields.

Finally, irrigation projects experience problems if they are based on assumptions reflecting inadequate understanding of social relations of production. This is particularly true in the area of labor supply. Project officers tend to deal with men or use abstract concepts of the household. "Planning documents frequently contain calculations which involve counting of person-days required to produce a certain crop mix and reconciling this with the available person days. This is a crude and destructive method which deforms reality" Barnett (1984).

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Women tend to be ignored by planners or taken for granted. In some cases, targeting women can lead to more efficiency:

> if irrigated rice plots and the whole technology of growing rice together with credits originally given to men by the Taiwanese and World Bank programmers had been made to women as well as men, it is probable that double cropping of irrigated rice would have been achieved in women's fields at least. Women are in a much stronger position than men to cultivate irrigated rice in the rain season as labor demands fit in with customary sexual division of labor (Dey 1980).

2.5 Summary

This chapter reviewed agricultural and irrigation policies in Malawi, to provide a macro-context for evaluating the objectives, methods and findings of the study. The chapter emphasized the negative synergistic impact on household food security of poor performance of smallholder agriculture; increasing population pressure; and a small manufacturing sector. It is argued that the risky nature of rainfed, low input cultivation makes irrigation an attractive prospect. The country has suitable hydrological and land resources, as well as valuable past experience to enable implementation of financially feasible irrigation projects. However some institutional reforms and innovative management may be necessary to ensure success of projects.

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CHAPTER 3: ANALYTICAL METHOD

This chapter discusses the rationale for the selection of analytical method used in this study. It begins with a brief review of smallholder farmer objectives and decision making in risky environments, to justify the selection of a linear programming model based on Target MOTAD with Telser's safety first probablistic criterion.

3.1 Smallholder Farmer Objectives

Ellis (1988) provides a lucid review of the several theories posited in agricultural production literature about the economic behavior and goals of smallholder farmers. The following theories are included: the profit maximizing peasant; the risk averse peasant; the drudgery averse peasant; the farm household peasant; and the share cropping peasant. His definition of peasant is also our concept of 'smallholder farmer' as "family farmers only partially integrated into incomplete or imperfect markets. The threefold emphasis is on family, on partial engagement in markets, and on the imperfections of those markets", p181.

Schultz (1964) was among the first to suggest that smallholder farmers in developing countries might be optimizing economic agents. His hypothesis of smallholder farmers being 'efficient but poor' has been researched and evaluated extensively. This hypothesis derives its importance not from accurately describing farmer behavior, but from its success in placing smallholder farmer rationality firmly on the research and policy agenda. Prior to Schultz the literature on traditional agriculture was permeated with stereotypes of laziness, perversity, lack of motivation and irrationality on part of peasants as economic agents.

The Schultzian hypothesis ascribes to peasants the motive of profit maximization. Profit maximization has both a behavioral content and a technical-economic content. Most of

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the research in this area has rejected the efficiency hypothesis in its pure form in favor of some form of constrained profit maximization (Lipton 1968, Ray 1985).

In most economic modelling, utility maximization is equated with profit maximization. This is correct if farmers have no other objectives and are operating in risk-free environments. Empirical work shows that economic agents' desires to maximize profits are often constrained by the need to avoid or manage risk. Research studies support the proposition that small farmers are risk averse (Wolgin 1975; Schluter and Mount 1976; Dillon and Scandizzo 1978; Binswanger and Sillers 1983). Maximizing utility under uncertainty may result in lower use of resources, lower levels of returns and diversification of activities (Samuelson 1967, Sandmo 1976, Brink and McCarl 1978, Weimar 1988).

An important problem in the empirical literature is attributing to risk aversion all departures from economic efficiency. This is especially true in studies that use variations to objective data, like prices and rainfall patterns, as the basis for drawing conclusions on the subjective behavior of farmers (Binswanger 1980, Binswanger and Sillers, 1983). So, for example, mixed cropping has been explained as a response to risk when actually it may also be a way of maximizing returns to labor and land.

In this study, smallholder farmers are perceived to be utility maximizers who are risk averse. The most important type of risk is yield risk (and hence income risk) as affected by rains and augmented by market imperfections. Risk aversion plus cultural preferences and taste considerations for local varieties of maize lead to farmers trying to produce their local maize consumption requirements (Peters and Herrera 1989, Smale 1991 and Kydd 1989). Thus farmers exhibit a safety first response to uncertainty. However, farmers may fail to optimize in many cases perhaps because of cognitive (relating to the way problems are structured and the strategies), not necessarily motivational (relating to the amount of emotional effort expended) (Schoemaker 1982), limitations. This is one reason for well

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3.2 Decision Making Under Uncertainty

3.2.1. Risk and Uncertainty

Risk refers to situations where probabilities can be attached to the occurrence of events. Uncertainty refers to situations where outcomes of activities are stochastic but there is lack of information on probabilities of occurrence of outcomes (Knight 1921). This definition ushers in the philosophical problem of what probabilities are. Probability lacks primary sensory evidence as to its existence and may be an invention rather than a discovery. Churchman (1961) expressed the problem this way, "almost every one knows what it means to say that the event is probable--except those who have devoted their lives to thinking about the matter." Additionally, there is evidence that people from one culture may perceive uncertainty more in probablistic terms than those from another culture (Hacking 1975, Lawrence and Wright 1977).

Uncertainty characterizes the environment confronting farmers. This environment contains a wide variety of uncertain events to which farmers will attach their subjective probability beliefs. Economic analyses are sometimes based on the decision maker's personal belief about the probability of occurrence of uncertain events rather than objective probabilities. In the case of rainfall, for example, what is important is not the known past average occurrence of drought, but rather the farmers' personal view about the likelihood of drought.

This distinction between objective and subjective probabilities is important for two reasons. First, historical data may be an unreliable indicator of future events. Second, in many cases if a disaster strikes, people react as if it will strike again sooner than evidenced by historical data. Their behavior is not based on historical data but on most recent experiences. This is consistent with the concept of re-inforcement in behavioral psychology (Schoemaker 1982). It is this manifest decision maker behavior that matters in risk modelling because it affects farmers' decisions about resource allocation (Ellis 1988). The distinction between objective and subjective probabilities is also important for evaluation of the expected utility hypothesis that undergirds the decision making models reviewed and used in this study.

3.2.2. Models of Risk Analysis in Agriculture

The decision making process under uncertainty can be reduced to five steps (Crawford 1992):

1) Identification of the set of alternative actions. Actions $X_1,\ldots,X_j$ should be mutually exclusive and exhaustive of alternatives available.
2) Identification of states of nature which may occur.
3) Assignment of probabilities to the states of nature. These are degrees of belief held by the decision-maker of the likelihood of each state of nature occurring.
4) Specification of the outcomes of each activity under the various states of nature.
5) Choice of criterion for deciding the optimal plan.

When there many possible farm plans to choose from, a farm manager can be guided by what proved successful in the past for herself and others. She will adjust her program marginally using some informal arithmetic or a more or less systematic budget approach. However, there are more structured methods to solving risky decision problems. They range from using conservative estimates for certain random variables (e.g. price and yield), through methods which explicitly incorporate density functions for the random variables. With i

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increased computational and software facilities these models can be easily solved by researchers and decision makers through mathematical programming.

Mathematical programming allows the testing of a wide range of alternative actions and analyzes their consequences thoroughly with a comparatively small input of time. Questions relating to proposed changes to a farm plan can be answered rigorously and quickly (Beneke and Winterboer 1973). A general linear programming model to represent optimal farm decision making process is:

$$\max Z = \Sigma c_j X_j$$

such that:

$$\Sigma a_{ij} X_j < b_i, \quad \text{for all } i \in [1, m]$$

$$X_j > 0, \quad \text{for all } j \in [1, n]$$

where:

Z = total gross margin

X_j = the level of the jth farm activity, and n is the possible number of activities

c_j = the expected gross margin per unit of activity j

a_{ij} = the amount of resource i needed to produce a unit of j

b_i = amount of the ith resource available

The problem is to identify the mix of farm activities that maximizes the total gross margin Z, using no more than the resources available, and not involving negative levels of activities. In matrix form the problem can be presented in this way:

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Table 3.1

A Simple Linear Programming Table

Row name	X_1	X_2	.....	X_n	RHS[a]
Objective function	C_1	C_2	.....	C_n	Maximize
Resource constraints					
1	a_{11}	a_{12}	.....	a_{1n}	$< b_1$
2	a_{21}	a_{22}	.....	a_{2n}	$< b_2$
.	.	.	.	.	.
.	.	.	.	.	.
m	a_{m1}	a_{m2}	.....	a_{mn}	$< b_m$

a/ RHS = right hand side

In ordinary analysis, the parameters c_j, a_{ij} and b_i are assumed to be known with certainty. However in agricultural production, activities have uncertain outcomes owing to the biological nature of enterprises, variable weather and environmental conditions, changing demand and unpredictable government policies which affect prices. All these lead to yearly or seasonal variation in incomes. Under these circumstances, the ordinary LP does not give optimal results because the decision criterion used in ordinary LP does not take into account the riskiness of alternative plans.

Many criteria are available for risk analysis problems. The choice of decision criterion for a particular risk analysis problem depends primarily on the following: a) the nature of risk being dealt with, e.g. objective function or constraint set risk; and how the risk is defined for programming purposes, e.g. deviations below target or variance around mean; and b) how the farmers are perceived to respond to risk e.g. safety first response.

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3.2.1.1 Direct Expected Utility Maximization

Most of the risk analysis criteria that use mathematical programming have their foundations in the expected utility model (EU). The first group uses the expected utility model directly and the second group, cognizant of the weaknesses of the model, attempts to improve on it.

The expected utility hypothesis postulates that under certain assumptions or axioms, an ordinal utility function exists by which prospects can be ranked. The foundation of this hypothesis as developed by von Neumann and Morgenstern (1953) consists in a set of four axioms which are: ordering, transitivity, continuity and independence of prospects. The ordering axiom requires that for any of the prospects X_1 and X_2 the decision maker either prefers X_1 to X_2, X_2 to X_1 or is indifferent between them. Transitivity implies that if X_1 is preferred to X_2, and X_2 is preferred to X_3, then X_1 is preferred to X_3. Continuity implies that if X_1 is preferred to X_2, and X_2 to X_3, then there is a mixture of X_1 and X_3 that is preferred to X_2, and a mixture of X_1 and X_3 over which X_2 is preferred. The independence axiom says that a risky prospect X_1 is preferred to a risky prospect X_2 if and only if a p chance of X_1 with a (1-p) chance of X_3 is preferred to a p chance of X_2 with a (1-p) chance of X_3, for arbitrary positive probability p and risky prospects X_1, X_2, and X_3. It is the independence axiom which gives the EU model theory its empirical content by placing a restriction on the functional form of the preferences by implying that it must be linear in probabilities.

According to the EU model, for any utility function U(X):

a) if a risky action, X_1 is preferred to another X_2, then $U(X_1) > U(X_2)$, and

b) $U(X_j) = E_iU(Y_{ij}) = \Sigma p_iU(Y_{ij})$,

The optimal X_j is the one that maximizes expected utility.

$$EU(X_j^*) = \text{Max}\ [U(X_j)] = \text{Max}\ [\Sigma p_{ij}U(Y_{ij})].$$

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where $U(X_1),\ldots,U(X_j)$ = utility of choices $X_1,\ldots, X_j$

X_j^* = ex ante optimal choice among actions;

p_i = probability of state of nature S_i occurring; and

Y_{ij} = the outcome of Xj when S_i occurs

Alternative actions are thus ranked according to the probability of the states of nature and the relative preferences concerning the outcomes as embodied in the utility function.

The foregoing definitions enable the illustration of key concepts in risk analysis (Figure 3). First, risk aversion leads to a concave utility curve so that the utility of the expected monetary value of a risky plan is higher than the expectation of the utility of the action. Risk averse decision-makers maximize expected utility, not utility of the expected value of the risky plan. The certainty equivalence (CE) is the amount that will give the same utility as the risky plan--EU(Y). The risk premium is the difference between the monetary outcome of a risky plan and the CE. This amount will make the decision maker indifferent between receiving the certain amount, CE, and taking the risky plan. The risk premium is positive for risk averse individuals, and they prefer certain outcomes above the CE to the risky action, and prefer the risky action if the certain outcome is below the CE.

The degree of risk aversity can be measured by the Arrow-Pratt absolute risk aversion function

$$ry = -U''(Y)/U'(Y)$$

The direct application of expected utility maximization requires assumptions concerning the nature of the utility function. Tobin (1958) used the utility function

$$U(y) = (1+by) + by^2$$

for which maximizing expected utility is equivalent to maximizing:

$$(1+b)\,\mu + b(\sigma^2+\mu^2)$$

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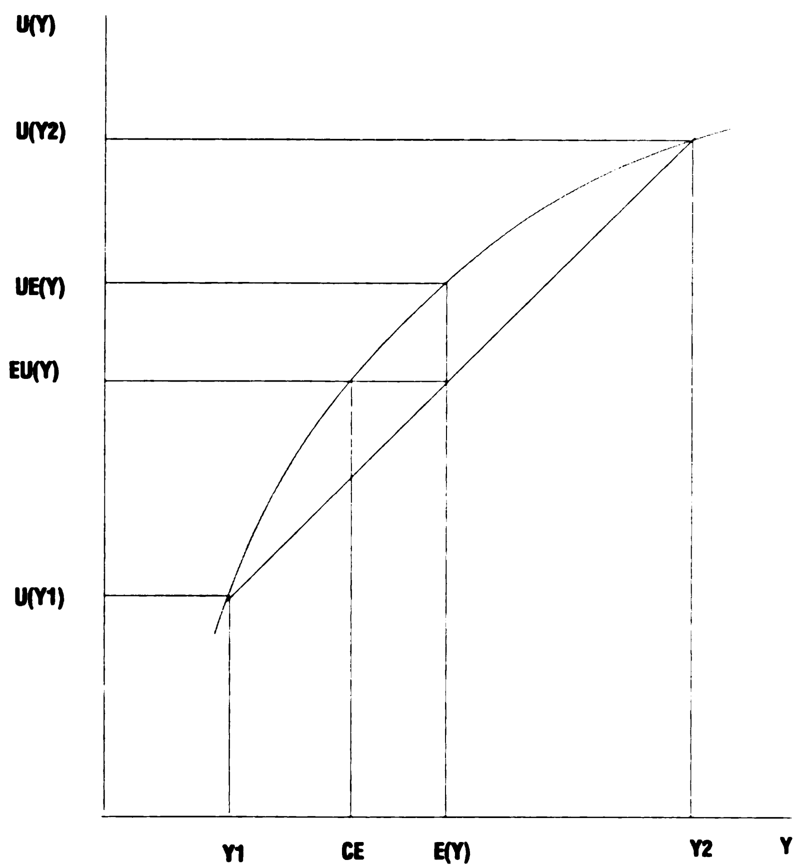

Figure 3: Illustration of the Concepts of Risk Aversion, Certainty Equivalence, and Risk Premium

Freund (1956) proposed the use of negative exponential utility function

$$U(y) = 1 - e^{-ay}$$

where a > 0 a is measure of the decision-maker's attitude toward risk. In this case maximizing utility is equivalent to maximizing:

$$\mu - a\sigma^2/2$$

where μ = mean of y

σ = standard deviation of y

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Another approach to direct expected utility maximization is the Exponential Utility Moment Generating Function (Lambert and McCarl 1985; Collender and Chalfant 1986; Babcock, Chalfant, and Collender 1987). It is based on the assumption of an exponential utility function, and the maximization of expected utility is based on the moment generating function for the random variable. In some variations of the model the probability distribution of the random variable has to be specified. Each type of distribution yields a different moment generating function.

Although the expected utility hypothesis is consistent with economists' concept of rationality, empirically it holds as an exception rather than rule. Schoemaker (1982) has extensively reviewed research that evaluated the model. He concluded that the model fails to describe how people behave: They do not structure problems holistically and comprehensively as the hypothesis suggests; they do not process information, especially probabilities according to the EU rule; and it poorly predicts results for experiments. Another difficulty is related to the existence and nature of probabilities, and whether they are subjective or objective.

Research results tend to agree that many careful, intelligent decision makers do violate some axioms of expected utility theory even upon reflection of their choices (MacCrimmon and Larson 1979). The independence axiom has been shown not to stand up to the data. There are four systematic violations of it: the common consequence effect, the common ratio effect, over sensitivity to small probability changes and the utility evaluation effect (Machina 1985).

So the EU model holds only in exceptional cases, with well trained decision makers, for well structured tasks. It is thus worth while to explore the option of considering modification to standard theory. Loomes and Sugden (1981) and Fishburn (1981) have developed alternatives that drop some of the axioms, and Machina (1982) has shown that major concepts and tools of EU do not depend on the independence axiom. Part of the proble

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problem in expected utility hypothesis stems from lack of consensus on how to encode language and context concerning preferences, for investigation.

Although some results of empirical work are still consistent with the hypothesis (Friedman and Savage 1948, Tobin 1958), its use in empirical applications continues to be constrained by the need to define suitable utility functions. The knowledge of this is not always available. This has led to a search for other ways to deal with risk in programming. The risk efficiency approach is the most common one taken. Risk efficiency criteria can provide a partial ordering of alternative courses of action for the decision makers whose preferences conform to a specified set of conditions placed on the utility function. The first one to surface was the Mean-Variance criterion.

3.2.1.2 Mean-Variance Analysis

The mean-variance (E-V) criterion is based on the proposition that for any two distributions of equal means, a risk avoider will prefer the one with smallest variance. The criterion is not always consistent with the EU model. When decision variables are normally distributed or the distributions differ only by location and scale, the optimal results selected by the E-V and EU will be the same (Meyer 1987). Levy and Markowitz (1979) demonstrated that solutions to the expected utility maximization problems are equivalent to maximization of a linear combination of the mean and variance. This corresponds to the maximization of expected utility of income when either the utility function is quadratic or the random variable is normally distributed. Thus the application of E-V criteria results in a quadratic programming model of the form

$$\max Y - \phi \, \sigma_Y^2 = \Sigma c_j X_j - \phi \Sigma \Sigma \sigma_{ij} X_i X_j$$

such that:

$$\Sigma a_{ij} x_j \leq b_i \quad (i= 1, \ldots,m)$$

$$x_j \geq 0 \text{ for all } j$$

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The objective function maximizes expected total gross margins less a risk aversion parameter (ϕ) times the variance of total gross margins. If the gross margins are normally distributed, a = 2ϕ the coefficient of absolute risk aversion parameter in the exponential function U(y) = 1- e^{-ay} (Freund 1956). Another formulation is to minimize variance subject to a given level of income (Markowitz 1952). The difference between the two is that solving the first one requires specifying ϕ while in the second, mean income has to be specified.

E-V analysis leads to quadratic utility functions which have the theoretical implications of increasing absolute risk aversion to which there are objections (Arrow, 1964). Additionally, empirical work shows that crop yields have negatively skewed distributions such as the gamma or beta (Day 1965) making it difficult to uphold assumption of normality in agricultural production modelling. This has significant implications for the study at hand because yield variability is the major cause of uncertainty. When implementing E-V programming the mean and variance of the population has to be estimated from a sample. This may introduce bias leading to selection of optimal decisions that differ substantially from those based on true population, if distributions of variables are not normal (Chalfant et al 1990). Levy and Markowitz (1979) have also argued that this criterion is acceptable where risks are small relative to total wealth. Being based on the EU model, the E-V criterion carries over some of the same weaknesses.

The use of variance as a measure of risk in E-V analysis implies that both low and high returns are undesirable. Yet empirical literature shows that decision makers frequently associate risk with failure to attain a target return (Patrick et al 1985, Peters and Herrera 1989). The mean-semivariance criterion was developed to redress this problem.

3.2.1.3 *Mean-Semivariance (Lower Partial Moments)*

Porter (1974) has shown that efficient sets selected using semivariance around the mean are more closely aligned with second degree stochastically dominant efficient sets, than are E-V efficient sets. He also showed that when risk efficient sets are calculated about a fixed

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fixed point (versus mean) they are consistent with maximizing utility, where the utility function, U(Y), of a random variable Y, is of the form:

$$U(Y) = a + bY + c\{(Y-h)^2\} \qquad \text{if } Y < h$$
$$= a + bY \qquad \text{if } Y > h.$$

where a, b, and c are constants and h is the fixed reference point of Y. This semi-quadratic utility function is consistent with the premise that high returns are not inherently undesirable.

3.2.1.4 Stochastic Dominance

Stochastic dominance is a major risk analysis tool in agricultural production studies. It is used independently to select optimal plans, but also to evaluate the robustness of alternative risk analysis criteria. Stochastic dominance permits the elimination of clearly dominated distributions for all decision makers whose utility preferences exhibit certain properties. It uses the whole income distribution, not just the mean and variance. There are several types of stochastic dominance analyses: first and second degree stochastic dominance due to Hadar and Russell (1969) and Hanoch and Levy (1969); third degree stochastic dominance (Whitmore 1970), stochastic dominance with respect to a function Meyer (1977), and convex set stochastic dominance (Fishburn 1974). Only the first two will be discussed.

The first degree stochastic (FSD) ordering rule for two risky cumulative probability distribution functions F(Y) and G(Y) is: F dominates G if and only if $F(Y) \leq G(Y)$ for all y with a strict inequality at least in one value. FSD imposes the restriction that the utility function must be monotonically increasing, and its first derivative, U'(Y) should be greater than zero. Thus the marginal utility of the maximand should be positive. This restriction defines a class of decision makers who prefer more to less income. It can accommodate decision makers characterized by Arrow-Pratt risk aversion parameters varying from negative infinity to positive infinity. However, FSD is limited in its ability to order action choices since most choice sets have few alternatives whose cumulative probabilities functions do not cross.

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For Second Degree Stochastic Dominance (SSD), an additional restriction is imposed on the utility function that, the second derivative, $U''(Y) < 0$. The marginal utility of the maximand should be increasing at a decreasing rate. It identifies the class of all risk averse decision makers. The risk aversion parameter can vary from 0 to positive infinity. SSD produces smaller efficient sets than FSD.

E-V efficiency is neither a necessary nor sufficient condition for SSD efficiency but the two are equivalent when the utility function is quadratic (Tobin 1958) or all probability distributions are normal allowing the moments of distribution higher than the second to be ignored (Samuelson 1967). Stochastic dominance is consistent with the EU hypothesis (Anderson 1974). Its major limitation is selecting efficient alternatives through a pairwise comparison process, and that FSD and SSD tend not to eliminate many action choices from the efficient set.

3.2.1.5 Minimization of Total Absolute Deviations (MOTAD)

The MOTAD, developed by Hazell (1971), is mean-absolute deviations (E-A) criterion which has an important advantage over the E-V criterion in that it leads to a linear model. The following utility function is assumed in MOTAD:

$$U(Y) = a + Bx - c|Y - E(Y)|$$

It minimizes total absolute deviations subject to the usual constraint set and, in addition, subject to a specified mean income level.

It is represented as follows:

$$\text{Min } Vy^-$$

Such that:

$$AY \leq b$$

$$RY = E$$

$$(R-R^-)Y + Iy^- - Iy^+ = 0$$

$$Y, y^-, y^+, \geq 0$$

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Where:

V	= 1-by-s vector in which each element is 1 and where s is the number of years (observation of states of nature) considered
A	= m by n matrix of technical co-efficients, where m is the number of constraints and n is the number of activities
Y	= n by 1 vector of activities
b	= m by 1 vector of resource levels
y^+	= s by 1 vector of annual positive income deviations from Y
y^-	= s by 1 vector of annual negative income deviations from Y
E	= mean income
r	= a 1 by n vector of expected income for each activity
R	= an s by n matrix of income for each activity
R^-	= an s by n matrix consisting of s r vectors
I	= an s by n identity matrix
0	= a column vector of appropriate length composed of zeros.

Hazell, who developed the MOTAD as an alternative to E-V and mean-semivariance criteria, pointed to the advantages of computational ease, the model being linear and requiring smaller matrices. Defining risk as negative deviations also makes the MOTAD criterion more attractive than the E-V criterion since only negative deviations need be minimized. If the E-A is an acceptable representation of farmers utility function, MOTAD offers a single alternative to both the quadratic programming of the E-V criterion and the semivariance models for all types of gross margin distributions. Also it leads to a linear model of farm plans, making it better adapted for post-optimality analysis.

Objections to the MOTAD include the charge that it introduces a lot of estimation error in the variance. But Johnson and Boehlje (1981) have shown that if Y_1 and Y_2 are symmetrically distributed with the same means: and density functions $F_1(Y)$ and $F_2(Y)$ are such that $F_1(Y) \geq F_2(Y)$ everywhere in the region μ-d $< Y < \mu$+d with at least a strict inequality in one interval in the region, and else where $F_2(Y) > F_1(Y)$ then $F_1(Y)$ will have smaller variances and smaller MOTAD variance estimates. Thus the MOTAD may introduce varia

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variance error but the ranking of prospects by quadratic programming will be the same as by MOTAD.

The MOTAD model does not have direct linkages to the EU. But since it was developed as an alternative to the E-V criterion which has EU model theoretical foundations, it is thought to carry over the weaknesses of EU model (Boisvert 1988, 1990). Recent theoretical developments indicate that MOTAD can be improved to bring its results more in line with other acceptable decision criteria. For example, comparing or calculating risk from points (means) that are not equal is misleading. Watts et al (1984) have shown how MOTAD can fail to discriminate between two choices where one is clearly dominated using SSD or the Target MOTAD. Hazell himself acknowledged that the MOTAD "can not be rigorously justified as a substitute of quadratic programming in deriving E-V plans" (Hazell 1971).

3.2.1.6 Target Minimization of Total Absolute Deviations

Target MOTAD due to Tauer (1983) is a negative absolute deviation model. It seeks to maximize expected returns while making sure the sum of negative deviations from a target income level is kept below a specified minimum. It contains some elements of the mean-semivariance and MOTAD. The following utility function is assumed:

$$U(Y) = a + bY + c|(Y-h)| \qquad \text{if } Y < h$$

$$= a + bY \qquad \text{if } Y > h$$

where U(Y), Y, a, b, c and h are defined as before.

The model is represented as follows:

Maximize RY

subject to:

$$AY < b$$

$$R + Iy^{-} + q > 0$$

$$vy^{-} - d = 0$$

$$Y, y^{-} > 0$$

Where:

q = s by 1 vector in which all elements equal a fixed target of the random variable of interest;

d = the maximum acceptable total negative income deviations from the target;

y- = is an s by 1 vector of annual negative deviations from the target and all others defined as above.

The target MOTAD frontier is developed by parameterizing d.

Minimizing negative deviation from a target is more congruent with 1) actual behavior of decision makers, 2) Von Neumann-Morgenstern utility functions, and 3) stochastic dominance relationships [Fishburn (1977), Holthausen (1981) and Porter (1974)].

Target MOTAD improves on the MOTAD by increasing the discriminatory power through using a target rather than the mean as a reference point for risk. It also uses a criterion that is more consistent with reality, i.e negative returns are the measure of risk. The E-V and MOTAD imply that the only way to reduce risks is to reduce income. Target MOTAD does better on this. One disadvantage of Target MOTAD is that the both of the attributes being parameterized are in the constraint set and so may require more time and resources.

3.2.1.7 The Safety First Approach

Safety first is defined as behavior in which the probability of failing to achieve farmer goals impacts and constrains the activities undertaken (Atwood 1988). It is more a way of defining risk than a method of risk analysis. However once risk is defined in safety first concepts, it has operational implications for the specification of risk models used. Various specifications of the safety first behavior are available but all are concerned with the probability of failing to achieve farmer goals. The probability of concern is expressed as:

$$Pr(Y < g) < p$$

where Y is a random variable like income, g is a given goal of the firm, and Pr(.) is the probability of the prospect, and p is upper limit on probability.

Examples of the safety first criterion are:

a) Min Pr (Y $<$ g) [Roy (1952)]

b) Max E(Y) subject to Pr (Y $<$ g) $<$ p [Telser (1955)]

c) Max Y subject to Pr (Y $<$ g) $<$ p [Kataoka (1963)]

where E(Y) is expected income, Y is income and g is the goal, usually the lower limit or disaster level of income.

Chance constraints were initially used to deal with random coefficients in the constraint set (Charnes and Cooper 1959). Imposing safety first chance constraints in optimization models can be difficult if the income distribution is non-normal. An alternative is to translate the probablistic constraint into a deterministic equivalent constraint. This is difficult if the random variable is endogenously determined in the model (Sengupta 1969). Another approach utilizes the assumption of a multivariate normal distribution and the ability to generate a E-V set of solutions (Pyle and Turnovsky (1970). Musser (1981) employed the assumption of normal distribution of the stochastic variable to use the expected gain-lower confidence limit criteria due to Baumol (1963) to implement a safety first model. These methods require knowledge of the cumulative or probability density functions of the stochastic variable. This knowledge is frequently not available.

The use of a stochastic inequality to impose safety first probablistic constraints has been considered by several authors, e.g. Anderson, Dillon and Hardaker (1977); Sengupta (1969); Berck and Hihn(1982). The first two used a Chebychev-type inequality to calculate the upper limits on probability of failure. The inequality is:

$$Pr(|Y - \mu| > k\sigma) < 1/k^2$$

where Y is a random variable,μ is the mean, k is some constant and σ is the standard deviation. It states that with any probability density function the probability of a random variable Y falling more than k standard errors from the mean μ, is less than the inverse of k^2. If the distribution is symmetric, a modified version is used

$$Pr(Y < \mu - k\sigma) < 1/2k^2$$

The upper limits so derived using Chebychev-type inequalities are generally overestimates which lead to selecting a more conservative activity mix than is necessary when imposed in optimizing models. Also, being nonlinear, they can be quite difficult to implement. Berck and Hihn (1982) introduced an inequality which offers the potential to provide less conservative probability limits than the Chebychev inequality if the population is asymmetrical.

This inequality is:

$$Pr(Y < \mu - m\sigma) < 1/m^2$$

where m is some specified reference point.

3.3 Telser's Safety First Probablistic Criterion in Target MOTAD

Atwood (1985) and Atwood et al (1985) adapted this inequality to improve safety first probability limits. The following inequality was used:

$$Pr[Z < t - LQ(\alpha,t)] < 1/L^{\alpha}$$

where:

$Q(\alpha,t)$ = $\Sigma(t-Z)^{\alpha} f_i$,

f_i = probability density of Z, the random variable, in state i

t = reference level or target below which deviations are measured

α = some constant

L = probability limit

If $\alpha = 1$, $Q(\alpha,t)$ becomes a linear lower partial moment (LPM) and the equation above becomes:

$$Pr[Y < t - LQ(t)] < 1/L$$

Atwood later illustrated how enforcing a sufficiency condition in a Target MOTAD model guarantees that the inequality is satisfied (Atwood et al 1988). The sufficiency condition is:

$$t - L^{*}Q(t) > g$$

where:

t = target income endogenously selected, and

g = goal of the firm or farm

Q(t) = is sum of deviations measured from t; and

L* = 1/L, the reciprocal of the probability limit

This particular version of the sufficiency condition corresponds to Telser's safety first criterion. The Target MOTAD with Telser's safety first criterion can be represented as follows:

max RY

subject to:

$AY < b$	3.3(a)
$R + Iy^{-} + q \geq 0$	3.3(b)
$vy^{-} - Q(t) = 0$	3.3(c)
$t - L^{*}Q(t) \geq g$	3.3(d)
$Y, y^{-} \geq 0$	

(All parameters and variables defined as before.)

This method will select the activity mix which optimizes the choice variable while simultaneously enforcing probabilistic constraints upon the deviations of income from the optimal expected income with the least constraining LPM stochastic inequality.

The method differs from the plain Target MOTAD in two main ways. First, the target, t, is no longer the same as the goal, but it is set endogenously by the algorithm at a level which satisfies the sufficiency condition, $t - L^*Q(t) \geq g$. Simultaneously, 3.3(b) and 3.3(c) compute the corresponding weighted deviations. If the sufficiency condition is constraining, the level of t selected will correspond to the least constraining LPM possible. This is the same as selecting the least constraining LPM from the set of LPMs for which $t - L^*Q(t) \geq g$.

Atwood's LPM method is superior to the plain Target MOTAD with respect to the level of difficulty in making a prior determination of some parameters. While the plain Target MOTAD requires selecting a target for the choice variable and setting an upper limit on deviations, with Atwood's method, the modeler must choose the goal and level of probability limit. Making these choices reduces the set of target incomes and expected deviation levels to be considered because the algorithm selects the target (McCamley and Kliebenstein 1985). Also, the goal and probability limit can be set more objectively than a target income or minimum deviations.

Imposing a safety first constraint does not reduce the number of questions to be answered, but the questions may be easier to answer. In addition, the method will not always find the solution that maximizes expected income subject to the upper limit on probability. It may fail because the safety first constraint involves a trade-off between a target level and expected deviations from that target. Another weakness of the model is that if the decision maker is concerned only about the probability of below goal incomes, and not the magnitude of the deviations, then a different approach would be appropriate.

3.4 Conclusion

Target MOTAD with Telser's safety first probabilistic criterion using Atwood's LPM is selected for this study because it mixes the desirable elements of several decision criteria, viz: the safety first concept of risk and measuring risk as negative deviations from a target. Also, Atwood's LPM does not require the knowledge of the mean or variance of distributions. This is advantageous in this study because the assumption of normality may be difficult to uphold. Because it is a linear model, it is easier to implement, and its dual information has full decision making interpretation unlike those of quadratic models.

CHAPTER 4: DATA COLLECTION

Data collection activities for this study began at the end of September 1992. A survey was conducted between November 1992 and February 1994. The data sought included labor available to households and allocation to crop production activities, use of land and size of gardens. Several government offices were contacted to prepare for the survey and get useful secondary data. The Department of Irrigation (DI) and the Blantyre Agricultural Development Division (BLADD) management were most important in this regard.

4.1 Selection of Study Area

The study was conducted in Chiradzulu North Extension Planning Area (EPA) of BLADD. This is an area in the Southern Region of Malawi, part of the Shire Highlands. (See Figure 2.1). This EPA was selected for several reasons:

a) It has a high percentage of farm households with small land holdings compared to other regions of the country, and these are the households most in need of intensive agriculture.

b) It has topographical and hydrological resources that will permit irrigation.

c) Prior food security studies have been conducted in the EPA and an adjacent EPA, Zomba South (Center for Social Research 1990 and Peters and Herrera 1989, 1992) which makes it easier to design the study and validate results.

d) The researcher is familiar with the area.

4.2 Sampling

We had initially decided to interview those households with dimba gardens in the EPA who had been sampled in the Market Liberalization Study carried out by the Center for Social Research, University of Malawi. Their sample was a random one and as a result there were very few households with dimba gardens. To get enough households with dimba gardens in the EPA we resorted to purposive sampling. This was done with the help of the field assistants in the EPA, each of whom is responsible for a section. The field assistants were asked to furnish lists of farmers who had dimba land. However, the numbers were not sufficient to perform stratified random sampling, so it was decided to interview all those farmers with dimba land in order to meet the sample requirements. The households were divided amongst the enumerators who interviewed enough farmers to fill the quota for a section. Where present the heads of households were interviewed. In a few cases arrangements had to be made for a visit.

A total of 270 household heads were interviewed, 19.7% of which were female. Several studies show gender to be strongly related to food security variables (Msukwa 1990, Chipande 1987, Peters and Herrera 1889). The proportion of female headed households in this particular area is 30% to 40% (Malawi Government 1981). Although the aim was to stratify the survey sample accordingly, it appears that the share of female headed households among farmers with dimba land is considerably less than 30%.

4.3 The Questionnaires

A structured questionnaire was used to collect data consistent with the objectives of the study. It had three parts: the household questionnaire; the enterprise questionnaire; and the garden measurement sheet (see Appendix B). In all cases the respondent was the head of household or spouse. The household questionnaire contained sections on labor availability, patterns of land use, use of credit and extension credit services and food security strategies. It also included open ended questions on willingness to participate in and pay for irrigation.

The enterprise questionnaire was administered for every plot[6] of land on which there was a different crop mixture. Thus, several enterprise questionnaires could be administered for a parcel of land. The information collected through this questionnaire included: labor use

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[6] In this study a plot is defined as a piece of land with same the crop mixture. A parcel is a contiguous piece of land which may have several plots. In some cases a plot and parcel may be the same.

for the various activities on the plot, quantity of inputs used, (such as pesticides and fertilizer), crops grown, quantity harvested and sold, and sale prices.

The garden measurement sheet was used to calculate area of the plots. Since most of the gardens are polygons, the length and angles for each side were recorded. Total area was computed using calculators which were programmed with a triangulation algorithm.

4.4 Preparation for the Survey

Four enumerators and four enumerators' assistants were hired. The hiring criteria were experience in collecting survey data and good pass grades in mathematics, English and agriculture at 0-levels. Enumerators went through a three-week training period, the propose of which was to:

a) acquaint them with the overall objectives of the study;

b) explain the role of an enumerator in a survey;

c) explain how to conduct a good interview;

d) communicate the purpose of each question in the questionnaire;

e) explain how to record responses to questions.

Draft questionnaires were prepared with the help of faculty and colleagues at the Center for Social Research. The draft questionnaires were used for mock interviews during the training of enumerators. Pretesting these questionnaires gave an opportunity to gauge the clarity of concepts in the local language as well as providing more interviewing experience to the enumerators. Three field tests were done. After each test, ambiguous questions were reviewed. The major criteria for keeping or revising questions were as follows:

a) Does the question elicit the needed information?

b) Will the respondent understand the question?

c) Will the respondent know the answer?

d) Will the respondent reveal the answer? (Casley and Lury 1981)

Preparing enumerators for measuring gardens took one week of training in reading bearings and taking land measurements. This was done in a second visit after the household survey was completed. Although enumerators were very familiar with the arithmetic processes involved, the physical implementation is a meticulous exercise. A closing gap error of 5% was the maximum accepted in making computations.

4.5 The Survey

By December all the instruments for the study were ready. Each household was visited at least twice. The first time was to complete the household questionnaire, and the second time to measure the parcels or plots of land. In some cases, measuring the gardens took more than one day if the household had many plots or if they were far apart. Each enumerator interviewed 2 to 3 heads of households in a day. The household survey took 40 working days to complete. The measuring of gardens was the most difficult job of the survey. Torrential rains made it difficult to measure the gardens because of flooding. This was especially difficult for dimba gardens where in some cases water was knee high. A second problem was to get the farmers to reveal all of their gardens. Some were suspicious that enumerators were government agents trying to confiscate their land. Others, by then convinced that enumerators were not government agents, revealed more plots for which additional enterprise sheets had to be completed.

4.6 Secondary Data Collection

Secondary data collection was necessary to supplement the data collected through the farmer survey. This was particularly important to gather information on yields of irrigated crops and the techniques used for irrigation.

Extensive discussions were held with groups of farmers at Mchenga and Diamphwe irrigation projects and their extension workers, as well as senior officers in the Department of

Irrigation and the Land Husbandry section of Lilongwe ADD. This was done to get information on:

- crop yields for irrigated crops not currently grown by farmers practicing rainfed agriculture
- suitable crop combinations for proposed irrigation technologies
- input cost and labor requirements of these crops
- costs and serviceability of some of the irrigation technology
- limitations and expected problems with technologies
- organizational arrangements for multifamily irrigation projects

A visit was made to the pilot sprinkler irrigation projects in Lilongwe district. Information collected included experience in organizing for the project (e.g. land re-allocation, set-up logistical problems, marketing of produce, operation of equipment). The investigator's experience of supervising a nutrition survey in an irrigated rice growing area, Bundi, in Karonga district also proved to be beneficial. This gave some perspective on farmers' problems in running communal irrigation schemes. This area has both government-assisted and self-help schemes. In Zomba, there is an irrigated vegetable garden which offered an opportunity to learn of the tank/furrow irrigation method.

4.7 Summary

This chapter describes the planning and implementation of the survey that provides the data for this study. Information was collected from households using structured questionnaires for interviews and measurement of gardens. Sampling of households was purposive to get households with dimba land.

Secondary data sources were used to supplement the farmer survey mostly with data for yields of crops not currently grown with irrigation. Other data included types of irrigation techniques and their costs.

CHAPTER 5: CHARACTERISTICS OF SURVEY HOUSEHOLDS

This chapter describes survey households, using variables of immediate concern to the study. These include size of farms; cropping patterns and yields; use of inputs and hired labor, food security strategies and willingness to participate and pay for irrigation. They are extensively compared and contrasted with the findings of other agricultural household studies conducted in the area.

5.1. Household Characteristics

5.1.1 Social and Demographic Characteristics

The major socio-demographic characteristics of households are presented in Table 5.1. Among the 270 households interviewed, 53 (19.7%) are female headed. This is below the nearly 40% average proportion of female headed households in Blantyre ADD. Since the survey was a census of households with dimba land in the area, this result implies that the proportion of female headed households with dimba land is less than in the general population.

Fifty two percent of the heads of households can be considered literate: having four or more years of formal schooling. The Center for Social Research (1990) reported a proportion of 48% for this datum, for 1990 in this area. The mean household size is 4.8, ranging from 1 to 12. The median size is 5, and 75% of households have 6 or less people. There is an association between size of landholding and size of households. At the mean of 5, medium and large farms have one more person than the small farms.

5.1.2 Size and Distribution of Land Holdings

The distribution of households into the three categories of landholding (small, medium and large) is 16.3%, 36.3% and 47.4% (Table 5.1). This compares with 57.4%, 31.6%, and 11.0% respectively for Blantyre ADD from the National Sample Survey of Agriculture results

(NSSA 1981). It appears that farmers targeted for this study, those with dimba land, have larger landholdings.

Table 5.1
Socio-Economic Characteristics of Households by Size of Landholding

Household Characteristics	Size of Landholding(Hectare)			
	Small <0.7ha	Medium >0.7-1.49ha	Large >1.49ha	All Farms
Sample Size	44 (16.3%)	98 (36.3%)	128 (47.4%)	270 (100%)
Female-headed	9	22	22	53
Male-headed	34	77	105	217
Size of Household(Mean)	4.2	4.7	5.2	4.8
Education(% literate >3 years of school)	62.8%	57.6%	45%	52%

Source: Survey Data 1993

In Table 5.2 are displayed data on size of farms. The mean size of total land holdings was 1.7 hectares. Means are 0.46, 1.12, and 2.49 for the three farm sizes. The overall mean size of rainfed land was 1.5 ha and for dimba land 0.24 ha. Land holdings are usually fragmented into several parcels of land. The median number of parcels of land was 2, ranging from 1 to 5. The median number of enterprises was 3. At the mean of 2.9 parcels, small farms have more fragmented land holdings than medium or large farms, both categories having 2.4 parcels. But they have fewer enterprises, 2.4 compared 2.7 or 3.2. These statistics are significantly different at the 5% level. The production significance of this fragmentation of land is linked to reducing risk of potential losses from localized environmental, pest or other adverse conditions, and of exploiting variable eco-niches suited to different crops (Ellis 1988, Peters and Herrera 1989). Some crops do well in dimba soils, others on high ground. For example pumpkin plants last longer if grown on extinct anthills.

Table 5.2
Size (Hectares) and Distribution of Land Holdings of Households

Cultivated Area	Small	Medium	Large	All
Survey Size	44	98	128	270
Total Land				
Mean	0.45	1.12	2.57	1.70
Median	0.45	1.10	2.32	1.45
Std. dev.	0.13	0.22	1.00	1.11
Rainfed Land				
Mean	0.40	0.98	2.24	1.51
Median	0.39	0.94	2.00	1.25
Std. dev.	0.17	0.24	0.99	1.07
Dimba Land				
Mean	0.13	0.17	0.33	0.24
Median	0.09	0.12	0.21	0.14
Std. dev.	0.12	0.16	0.36	0.29
Rainfed Maize Land				
Mean	0.39	0.90	1.58	1.16
Median	0.39	0.89	1.50	1.02
Std. dev.	0.12	0.29	0.74	0.70
No. of parcels (mean)	2.9	2.4	2.4	2.5
No. of enterprises (mean)	2.4	2.7	3.2	2.9

Source: Survey Data 1993

These data show that survey households have more land than is the case in the Blantyre ADD. The larger mean land holding is likely because only households with dimba were included. Dimba land is prime land which not all households have access to. Only those who have lived in the area for a long time and have familial ties to the chief and clan heads are likely to have this land, and more of rainfed land.

However, Blantyre ADD, and particular Chiradzulu district, is an area with the highest concentration of near landless farmers. For example, 35.2% of all the nation's households with less than 0.7 ha of land are in Blantyre ADD, yet the latter has 24% of all households in Malawi (Center for Social for Research/NSSA 1988, Malawi Government 1984). It is these farmers who need intensive cultivation methods to make good use of their limited land.

Medium and large farms have on average one more person than small farms. These statistics agree with the findings of earlier studies in this part of Malawi. For example, Chipande (1987) reported that a higher proportion of men in small or near landless households migrate in search of paid employment. Additionally, a large proportion of female headed households are characteristically short of one male adult, being either never married or divorced. Peters and Herrera (1989) also concluded that 'land holds men', p. 52.

5.2 Farm Characteristics

5.2.1 Cropping Patterns

The survey households have a total of 395 rainfed hectares of land and 59 hectares of dimba land. The most dominant crop mixtures according to frequency and area planted, on both land types are shown in Tables 5.3 and 5.4. A total of 785 enterprises were surveyed for the 270 households. Of these, 385 (49%) are rainfed enterprises and 403 (51%) dimba enterprises. An enterprise was identified by asking farmers to name up to three of the most important crops grown on a plot of land. There is a wide variety of crop mixtures planted in the area. For rainfed land, 28 enterprises were identified. However, only 8 were grown on more than 2% of the plots, and these 8 accounted for 90% of the plots of land. Table 5.3 lists crop mixtures grown on more than 2% of plots. The most common crop (mixtures) are maize/beans, peas, maize/beans/pigeon peas, maize alone, and maize/beans/groundnuts for

Table 5.3
Most Dominant Crop Mixtures[a]

Rainfed Crops	%	Dimba Crop	%
Maize/Beans	32.6	Sugarcane	24.1
Peas	23.5	Maize	12.2
Maize/Beans/Pigeon peas	10.1	Tomato	9.7
Maize	6.7	Cabbage	7.9
Maize/Beans/Groundnuts	4.4	Chinese cabbage	5.5
Maize/Pigeon peas	3.1	Peas	4.0
Maize/Peas	3.1	Rape	3.0
Maize/Pigeon peas/Groundnuts	2.1	Tomato/peas	2.5

a/ grown on more than 2% of plots

rainfed land. Because of the way that enterprises were defined, it is highly probable that the maize/beans combination has some pigeon peas or groundnuts but farmers did not feel that these were important enough crops to mention. Also, the maize/peas mixture may actually be maize followed by peas. Maize based mixtures make up 80% of all rainfed enterprises.

For dimba enterprises, 47 crop mixtures were identified. Eighteen of these were grown on more than 2% of plots and made up for 89% of the dimba plots of land. In dimba gardens farmers mostly grow sugarcane, maize, tomatoes, and cabbage. Chinese cabbage is similar to rape or mustard greens, and these crop mixtures together are grown on 10.6% of dimba plots. Similarly, tomato mixtures are grown on 15.6% of all dimba plots.

These findings are similar to those of Peters and Herrera (1989) who reported maize, beans and pigeon peas as the most important crops of the area. Due to small representation of dimba plots in their sample, sugarcane, tomato, cabbage and other leafy vegetables do not feature prominently in their results.

Multiple cropping and intercropping are important agricultural practices in the study area. (Multiple cropping is used to refer to cases where crops are grown sequentially on a

Table 5.4
Most Important Enterprises by Area (Hectares) Covered

Enterprise	No. of Hectares	% Area Covered	Mean	Min	Max
Rainfed Area	395	87%	1.51	0.13	5.80
Dimba Area	59	13%	0.24	0.01	2.05
<u>Rainfed Enterprises</u> (5% and above)					
Maize/Beans	141.00	35.7%	1.12	0.19	3.88
Peas	91.40	23.5%	1.00	0.09	3.11
Maize	30.25	7.7%	1.16	0.26	2.75
Maize/Beans/Pigeon Peas	40.50	10.3%	1.06	0.28	2.90
Maize/Beans/Groundnuts	19.62	5.0%	1.22	0.23	2.45
<u>Dimba Enterprises</u> (3% and above)					
Sugarcane	22.43	38.0%	0.23	0.02	1.49
Maize	5.56	9.4%	0.12	0.04	0.51
Cabbage	4.54	7.7%	0.14	0.01	0.53
Tomato	4.13	7.0%	0.11	0.01	0.51
Maize/Beans	1.95	3.3%	0.32	0.03	0.95

Source: Survey Data 1993

piece of land in one cropping season. Intercropping is used to refer to cases where crops are cultivated concurrently.) Only 32% of dimba enterprises were intercropped and this was 65% for rainfed enterprises. Eighty-two percent of all parcels of land were either multiple cropped or intercropped. Peters and Herrera (1989) reported that 71% of all the plots in their sample were intercropped. The difference may be due to a low representation of dimba gardens, which in their sample indicates 13%, compared to 51% in our sample. It is in dimba gardens that farmers mostly practice monocropping.

5.2.2 Estimating Yields

Yields for four harvests prior to the survey were estimated from recall data. They are reported in Tables 5.5 and 5.6. A clear pattern emerges. All crops yielded poorly in 1992 because of drought. It is difficult to assess the reliability of yield data because there are very few crops for which farm based yields exist. Government documents tend to report average yields for a particular crop. The best are those of maize. The comparison for maize is shown in Table 5.7.

The yield of beans depends on the plant population and the planting patterns. If planted in the same hill as maize, the yields are generally lower. The decision to plant on the same hill or not depends on the variety. Climbing varieties are usually planted in the same station as maize so that maize plants provide support. Assuming the same planting station, yields ranging from 41 kg to 235 kg have been reported (Jere 1990). The survey results are within this range.

5.2.3 Family Labor Available and Use

An estimate was made of total family labor available, and its allocation to farm enterprises. These estimates are used in formulating enterprise budgets and technical coefficients that are used for programming.

Family labor available to a household for its farm activities depends on the number of adults and the amount of time they are available to work in the gardens. Labor allocated to various enterprise is reported in Table 5.8. It is possible to check these data in the case of maize-based crop mixtures against ARU data as shown in Table 5.9. The comparison is very good except in a case of land preparation where the survey results are very high. Jere (1990) has suggested caution in using these ARU data. Since farm workers were under observation, they may have worked faster.

The differences between ARU and the survey data may be due to the different method used to collect them in the two studies. The ARU used observation, while in this study the recall method was used. Farmers were asked how many people performed a production activity, and for how many days and hours per day. Land preparation takes a long time (mode number of days is 30), and when written records are not kept, farmers may have reported general estimates. This may also be the case for labor use for irrigation, although there is no data to compare with. The figures on planting and fertilizing are lower in the survey results. Despite these differences, the survey results are used in programming without adjustment.

Table 5.5
Mean and Median Yields of Rainfed Crops Enterprises (kg/ha)

	1989		1990		1991		1992	
	FT[a]	NFT[b]	FT	NFT	FT	NFT	FT	NFT
Maize/Beans								
Maize	1,152	677	1,159	615	1,124	514	579	292
	696	**481**	**744**	**447**	**640**	**370**	**370**	**219**
Beans	88	41	84	44	69	45	50	25
	41	**22**	**42**	**37**	**39**	**23**	**30**	**18**
Maize	1,232	789	1,110	713	1,051	488	341	185
	1,005	**375**	**911**	**386**	**882**	**340**	**223**	**189**
Maize/Beans/Pigeon Peas								
Maize	1,717	770	1,741	994	1,459	989	668	433
	1,113	**670**	**1,210**	**582**	**1,227**	**574**	**356**	**287**
Beans	126	36	289	123	111	97	60	64
	63	**36**	**77**	**40**	**56**	**45**	**36**	**63**
Pigeon Peas	104	104	130	82	72	76	59	69
	62	**100**	**44**	**70**	**43**	**64**	**43**	**58**
Maize/Beans/Groundnuts								
Maize	1,327	---	1,333	---	1,212	---	593	---
	597	**---**	**874**	**---**	**622**	**---**	**291**	**---**
Beans	76	---	112	---	92	---	36	---
	49	**---**	**31**	**---**	**40**	**---**	**21**	**---**
Groundnuts	104	---	160	---	186	---	114	---
	133	**---**	**66**	**---**	**98**	**---**	**62**	**---**
Rainfed Peas	---	144	---	174	---	195	---	118
	---	**119**	**---**	**81**	**----**	**105**	**---**	**59**

Note: Plain type figures are means; bold figures are medians
a/ FT = Fertilized
b/ NFT = Non-fertilized

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.6
Mean and Median Yields of Dimba Crop Enterprises (kg/ha)

Crop	1989 FT[a]	1989 NFT[b]	1990 FT	1990 NFT	1991 FT	1991 NFT	1992 FT	1992 NFT
Cabbage	5,705	7,742	8,188	5,732	7,873	5,650	7,867	2,066
	3,770	**2,330**	**6,073**	**2,000**	**6,328**	**2,914**	**4,507**	**1,620**
Sugarcane[c]	----	4,758	----	9,265	----	8,546	----	8,612
	—	**2,347**	**—**	**4,069**	**—**	**4,121**	**—**	**3,636**
Tomato	8,704	6,514	9,139	5,571	10,559	6,240	8,030	4,539
	1,292	**4,848**	**2,353**	**3,265**	**2,686**	**2,636**	**2,197**	**1,752**
Dimba Maize	23,235	3,348	17,009	3,050	12,708	2,614	10,069	2,146
	1,852	**2,271**	**2,505**	**2,250**	**2,323**	**1,848**	**3,157**	**1,277**
Chinese Cabbage	13,100	2,255	11,540	2,037	10,674	2,004	7,437	1,176
	6,761	**2,288**	**5,600**	**1,333**	**2,188**	**1,524**	**1,959**	**631**

a/ FT=Fertilized
b/ NFT= Non fertilized
c/ This is in canes

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.7
Comparing Local Variety Maize Yields (Mean kg per ha) with Other Reports

Source	Yields			
	Year	Fertilized	Unfertilized	All
Survey Data	1992	579	292	----
	1991	1,051	488	----
	1990	1,100	713	----
	1989	1,232	789	----
Smale	1990	1,200	700	----
BLADD	1991	----	----	726
ARU	1989	1,859	----	----
GTAPM	several	----	----	800-1,200

Note: BLADD = Blantyre Agricultural Development Division
ARU = Adaptive Research Unit
GTAPM = Guide to Agricultural Production in Malawi (1992)

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.8
Family Labor Allocated to Crop Enterprises (Median Person-hours)

Enterprise	Land Prep*	Planting	Weeding	Irrigation	Fertilizing	Harvesting
Maize/Beans	301	37	169	---	51	95
Maize	398	37	164	---	55	75
Maize/Beans/Pigeon Peas	280	48	214	---	61	136
Maize/Beans/Groundnuts	343	41	220	---	58	117
Rainfed Peas	115	37	95	---	---	55
Cabbage	1,029	185	231	6,279	77	756
Sugarcane	547	114	221	----	---	455
Tomato	1,830	292	449	1,975	---	1,000
Dimba Maize	1,351	135	442	2,074	108	255
Chinese Cabbage	2,800	609	526	2,449	316	612
Maize/Pumpkin Leaves	2,019	223	400	1,698	----	261

* Land Prep = Land Preparation

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.9
Comparison of Labor Allocation to Maize/Beans Crop Mixture
(Person-hours)

Farm Operation	ARU1	Own Survey (Median)
Ridging	70	301
Planting	63	37
Fertilizing	84	51
Weeding	170	169
Harvesting	76	95
Total labor required	463	653

1/ Source: Blackie M.J. (1989)

5.2.4 Production Expenses

5.2.4.1. Hired Labor Expenses

Farm production need not be constrained by the availability of family labor is casual labor is available for hire. Forty percent of households in the sample hired some labor and nearly all of it was used on maize. The mean for only those who hired labor is 351 person hours, and out of this an average of 312 was used on maize. The total amount hired increases on average with land holding size. However, when the data are put on a per hectare basis, the smaller households hire significantly more labor. This may be due to the fact that a large minority of those who have small land holdings are employed so that they have to hire labor (see Table 5.12).

On an enterprise basis, the survey results on hired labor (Table 5.10) indicate that it is mostly used on maize-based fertilized crop mixtures. The total amount of labor hired for these crop mixtures is shown in Table 5.11. Labor is hired mostly for land preparation and weeding.

Expenses for hired labor were estimated to be on average MK42.3, based on an assumed wage rate of MK0.25. If lower wage rates are used[7], the estimate may be close to that reported by Peters and Herrera (1989). They reported that 40% of their sample households had hired labor, and a modicum of expenses for hired labor: MK2.99, MK8.51, and MK34.00 for three categories of farmers respectively. Smale (1991) reported an overall mean hired labor expenses of MK14 per year in BLADD.

5.2.4.2 Fertilizer Expenses

Eighty-one percent of the households used some fertilizer. The proportion of households using fertilizer varies from 67.4% in the smallest land holdings to 75.8% in the

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[7] The actual wage rates used are not well established empirically. In this study we used sensitivity analysis to assess the impact of lower wages on returns to farming activities.

medium category to 89% for the largest land holdings. These figures compare well with the findings of the Center for Social Research of 72% for 1990 in Chiradzulu North EPA.

On average, 147 kg of fertilizer was used on all crops. Most fertilizers cost MK1.00 per kg. The total amount used varies from 25 kg to 1,725 kg and increases with landholding size. Seventy-eight percent of households used fertilizer on maize in the 1991/92 cropping season, applying an average of 132 kg. Of the dimba plots, 29% had some fertilizer applied to them, and this was 55% for rainfed enterprises.

Although many dimba plots were fertilized, only two enterprises were fertilized by more than 10 farmers: cabbage and chinese cabbage. They applied a mean of 82 kg per ha and 48 kg per ha of fertilizers respectively. The four major maize-based mixture crops had fertilizer applied to them in varying quantities. These levels of fertilizer use are reflected in the yields of the enterprises: maize/beans/pigeon peas having the highest yields and fertilizer application. See Table 5.12 and refer to Table 5.5.

Table 5.10
Use of Hired Labor (Person-hours) by Enterprise by Crop Production Activity

Crop Enterprise	Crop Production Activity Land Prep.	Planting	Weeding	Fertilizing	Harvesting
Maize/Beans (n)	28	8	37	6	11
Mean	287	32	260	43	245
Median	165	24	210	43	126
Stddev	56	10	40	15	101
Maize(n)	5	---	4	---	---
Mean	213	---	295	---	---
Median	300	---	255	---	---
Stddev	54	---	112	---	---
Maize/Beans/Pigeon Peas(n)	15		19		3
Mean	229	---	228	67	273
Median	240	---	84	48	180
Stddev	40	---	84	38	117
Maize/Beans/Groundnuts(n)	5	---	---	4	
Means	383	---	245	---	76
Median	336	---	210	---	81
Stddev	107	---	61	---	27
Rainfed Peas(n)	17	4	14	---	---
Mean	109	55	92	---	---
Median	84	30	85	---	---
Stddev	16	30	16	---	---
Sugarcane(n)	17	---	9	---	---
Mean	139	---	52	---	---
Median	100	---	54	---	---
Stddev	36	---	9	---	---

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.11
Hired Labor (Person-hours) by Crop Enterprise

		Total		Per hectare	
Crop	N[a]	Mean	Std. Dev.	Mean	Std. Dev.
Maize/Beans	42	497	(422)	286	(302)
Maize	6	374	(324)	203	(167)
Maize/Beans/Pigeon Peas	20	407	(470)	385	(397)
Maize/Beans/Gnuts	7	574	(438)	285	(177)
Rainfed Peas	23	147	(107)	73	(64)
Sugarcane	19	203	(291)	101	(103)

a/ N = number of households who actually hired labor for at least one crop production activity

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.12
Use of Fertilizer kg/ha by Crop Enterprise and Size of Farm

	Small	Medium	Large	All
Maize/Beans				
#[1] Applying	8	37	63	108
Mean	119	155	157	154
Std. Dev.	117	103	86	94
Maize				
# Applying	1	5	11	17
Mean	100	108	157	138
Std. Dev.	---	68	133	113
Maize/Beans/P. Peas				
# Applying	4	13	12	29
Mean	175	288	198	235
Std. Dev.	96	445	147	311
Maize/Beans/Gnuts				
# Applying	4	3	8	15
Mean	131	192	188	173
Std. Dev.	63	52	88	76
Cabbage				
# Applying	3	10	6	19
Mean	187	69	54	82
Std. Dev.	271	50	62	113
Chinese Cabbage				
# Applying	9	3	5	10
Mean	44	27	63	48
Std. Dev.	?	22	48	38

[1]/ # = number

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

5.2.4.3 Pesticides Expenses

Many farmers said pests were a major constraint to growing dimba crops. One-third of farmers used pesticides in small quantities on 99 (12.6% of total) crop enterprises. They were applied mostly to dimba crops: cabbage, chinese cabbage, tomato, and rape. The most commonly used pesticides were DDT (43.4%), Actellic (36.45), and Malathion (10%). Other types included Copper, Sevin, Diamethoate 45, and Ripcord. The expenses are shown in current enterprise budgets in Tables in Appendix A.

5.3. Income Generating Activities and Off-Own Farm Employment

Income generating and off-farm employment activities are important sources of income for many smallholder families. In this study they are also important because they can provide competition for irrigated cultivation, with either positive or negative effects. Income generating activities (IGAs) are self employment jobs in trades like commodity trading, brick-making or basket weaving. (In later chapters another term, income earning activities (IEA), is introduced which refers to all non-farm income generating activities including wage employment.)

Farming their own gardens is considered the main occupation[8] by 71.5% of the heads of households. Nearly 6% were employed outside the agricultural sector, 2.2% were agricultural workers, and 6% did some IGAs. Overall, 13.8% said that farming their own gardens was not a primary source of livelihood. IGAs were part of or the only source of livelihood for 11.5% for the households. The Center for Social Research (1990) had similar findings; 72.9% of the heads of households relied on farming. However, a higher proportion, 16%, were in non-agricultural employment.

The importance of off-farm incomes varies inversely with size of land holding. Twice the proportion of households (27%) in the smallest landholding category as in the larger two said farming was not a main occupation. The results tally with findings of other studies

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[8] Occupation was defined as main source of livelihood.

which indicate negative relationship between land holding sizes and non-farm income generating activities.

> A shortage of land is associated with the allocation of men's time to off farm activities. Men in the smallest land holdings (under one hectare) allocate far more of their time to retailing (fish or agricultural products), and wage employment (Peters and Herrera 1989, p. 52).

Peters and Herrera (1989) also reported that on average 40% of their sample households income came from off-farm sources. Chipande (1987) conducted a study in Phalombe, a project adjacent to the one where this study was conducted. He found a greater tendency for men in households with smaller landholding to seek paid employment on estates or the nearby urban centers.

The preponderance of off-farm sources of income in this area reflects the configuration of opportunities available to earn a living. There have been quotas or prohibitions on growing some high value crops such as tobacco. This, together with low gross margins of crops currently grown and proximity to a major urban center of Limbe-Blantyre, have made off-farm sources of income very attractive. This is in contrast to the situation in other parts of Malawi. Farmers' cash-generating activities are mostly selling livestock, selling non-maize crops, and remittances from away household members (Smale 1990, p. 5, Center for Social Research 1988, p. 121).

Thus farmers in the study area could be termed part-time farmers. The principal objective for many of these farmers is to assure a relatively cheap food supply, while generating income from off-farm activities (Smale 1990 p. 6). It may also be the case that farming is underwritten by incoming transfers, either from members of the family working elsewhere on a permanent basis or living in the same household.

Seventy-one percent of household heads said they had some slack months in the agricultural calendar, and during these months 44% of these engaged in some kind of income generating activity. No detailed data was collected on nature of IGAs except incomes made. These ranged from MK8 to MK800 per month, with a mean of MK101. These figures are very high but since they are seasonal, per annum earnings are very low.

Table 5.13
Main Occupation of Household Heads

Main Occupation	Percent
Farming	71.5
Non-Agricultural Employment	5.6
Agricultural Worker	2.2
Income Generating Activities	6.0
Farming and Ganyu	4.5
Farming and Non-Agric. Employment	2.6
Farming and IGAs	5.9
All Occupations	100.0

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.14
Proportion of Farm Households Engaged in Non-Farm Work by Farm Size

	Small	Medium	Large	All Farms
Engaged in IGAs	14%	9.1%	12.6%	11.5%
Off-Own Farm Occupation	27%	12%	14%	16.7%

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

5.4 Maize Production and Food Security

In this section data are presented and discussed with respect to food security situation of households. The emphasis is on strategies to acquire food.

5.4.1 Maize Harvests

Mean total rainfed maize harvests for the four years prior to the survey (1988/89, 1989/90, 1990/91, and 1991/92) are reported in Table 5.15. They were 1,021, 1,031, 928, and 463 kilograms respectively. We would expect these to be generally higher than the harvests in the general smallholder farming population are because most of our sample used fertilizer and have larger land holdings. For example, in 1990, the Center for Social Research estimated mean rainfed maize harvests of 476 kg. The sample had more households with smaller farms. In addition, 1990 was a year of devastating floods. Peters and Herrera (1989) estimated an average maize harvest of 882 kg for 1986/87 cropping season. The size of farms in their study are comparable to this one.

On average the survey households are maize self-sufficient but the drought easily changes this situation. In 1991/92, the maize produced per person was below the level of 200 kg in all the three categories of households. Fertilized maize yielded twice as much unfertilized maize. Female-headed households harvested 615 kg in 1989/91 and 293 in 1990/91 compared to 982 kg and 505 kg for male-headed households in the same years. Thus, female-headed households produced on average 60% of what male-headed households did. The differences in total harvests by land size category and gender of head were statistically significant at the 5% level.

Table 5.15
Mean Rainfed Maize Harvests (Kilograms) by Size of Farm in 1989 - 1992

	1988/89	1989/90	1090/91	1991/92
Small	681 *(180)*[a]	695 *(208)*	630 *(180)*	247 *(69)*
Medium	873 *(265)*	930 *(269)*	866 *(252)*	441 *(139)*
Large	1228 *(296)*	1206 *(274)*	1064 *(238)*	544 *(123)*
All households	1021 *(269)*	1031 *(361)*	928 *(235)*	463 *(122)*

a/ Italicized figures are per capita

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table 5.16
Mean Harvests of Fertilized and Unfertilized Maize (Kilograms)
by Size of Farm in 1991/92

	Small	Medium	Large	Total
Fertilized	256	511	562	508
Maize	*68*	*160*	*123*	*129*
Unfertilized	229	246	330	268
Maize	*69*	*84*	*103*	*85*
All Maize	247	441	544	463
	69	*139*	*123*	*121*

a/ Italicized figures are per capita

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

The food security position of households can be established partly by how long it takes to exhaust their maize harvests. The households were grouped into those who deplete food stocks before harvest and those who do not. The proportion of households whose food stocks lasted from one harvest to another varied in the three years prior to the survey: 0.7% for 1991/92, 11.9% for 1990/91, and 48% for 1989/90. These figure were collected through recall data by farmers and should be treated with caution. However, they bring out the general trend of poor harvests in 1991/92 due to drought.

5.4.2 Food Security and Income Strategies

Only 31% said their food security strategy was to produce all food requirements. Thirty-eight percent grow cash crops in addition to growing food to be food secure. A good 7.4 % of households relied on "ganyu"[9] labor to be food secure, and an additional 5.3% complemented other strategies with ganyu labor. Seven percent did some kind of IGA. Nearly 10% combined own farm production with other strategies (see Table 5.17). The major differences in strategy by farm size are that fewer small and medium size farm households depend only on farm production, and more small farms rely on "ganyu" for food security.

For the forty five percent of those who rely on agricultural cultivation to be food secure, dimba crop production was the major way of managing yield risk in case of rain failure. Trading in agricultural commodities was an important alternative strategy for another 15.5%.

[9] *Ganyu* is piece work wage labor. It is an important survival strategy for going through the hunger months of December to February (Center for Social research 1990), and is also a way of getting seed (Smale 1990).

Table 5.17
Food Security and Income Strategies by Farm Size (Percent of Sample)

	All	Small	Medium	Large
1. Produce All Food	31.1	30.2	37.4	41.4
2. Produce Food and Cash Crops	38.1	30.2	26.3	35.2
3. Own Farm Production + Others	9.6	4.6	6.1	4.0
4. "Ganyu"	7.4	14.0	5.1	7.0
5. Employed Permanently	3.0	4.7	5.1	1.0
6. Income Generating Activities	6.3	9.3	7.1	4.7
7. Others	4.5	10.0	12.1	6.6

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

5.5 Farmers' Willingness to Use Irrigation

Willingness to invest in formal irrigation should be related to perception of constraints to rainfed and dimba farming. For rainfed land, farmers felt that lack of fertilizers (31%) and poor rainfall (27%) were the major constraints. Poor rainfall and water shortage were also important constraints for dimba land cultivation (21% and 14.9% respectively). However, pests and fertilizer were also mentioned frequently (Table 5.18).

Seventy-one percent said they would be willing to participate in irrigation. Sixty-six percent foresaw problems in organization and implementation. Examples of this are disputes among farmers and fear of getting involved in government credit. The crops they frequently mentioned as wanting to grow were maize, tomatoes, and cabbage. The single most important reason for choosing the crops was to generate cash.

Table 5.18
Constraints to Producing More Crops

Constraint	Percent of Farmers Mentioning Constraint	
	Rainfed Land	Dimba Land
Lack of Fertilizer	31	13
Poor Rainfall	27	22
Water Shortage	--	15
Pests	0	15
Others	42	34

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

5.6 Summary

This chapter presented the major descriptive characteristics of the survey households. The number of households surveyed was 270. of which nearly 20% are female headed. Fifty-two percent of heads of households are literate. Median household size is 5. The households are generally better endowed with land than most households in the area, with a mean land holding size of 1.7 ha, of which 1.5 is rainfed and 0.24 ha is dimba land; 16.3% are under 0.7 ha, 36.3% between 0.7 and 1.49, and 47.4% greater than 1.49 ha.

The dominant crop mixtures grown on rainfed gardens are maize/beans, peas, maize, maize/beans/pigeon peas, and maize/beans/groundnuts. On dimba gardens these are sugarcane, maize, cabbage, and tomato.

The households are more likely to use fertilizer than is the case among typical smallholder farmers in Malawi. A large minority hire labor for fertilizer maize-based crop mixtures grown on rainfed land. Pesticides are used on dimba crops of chinese cabbage, cabbage, tomato and rape.

Although all households farm some land, nearly 30% do not consider farming their major occupation. Even in good rainfall years many households do not produce enough maize. The majority, 71%, are willing to participate in irrigation. However, they foresee problems in organization and implementation.

CHAPTER 6: ENTERPRISE BUDGETS AND FORMULATION OF THE TARGET MOTAD MODEL

This chapter describes how the safety-first whole-farm Target MOTAD programming model was formulated, using enterprise budgets and other data. The emphasis is on the sources of data, reasons for including specific activities, and the derivation of co-efficients in the programming matrix.

6.1 Enterprise Budgets

An enterprise budget is prepared by stating income, expenses, and resource needs of the enterprise on a per unit basis (Harsh et al 1981). Crop enterprise budgets in this study are constructed for two reasons: a) to calculate gross margins for each enterprise; and b) to calculate the technical co-efficients needed for the programming matrix presented in section 6.2. Incomes or gross values are derived by multiplying average yields for the enterprises by the price(s) of the output(s) and subtracting variable costs. Technical co-efficients are comprised of the per unit input requirements for the production activities of crops in the enterprises.

The budgets are formulated for currently grown crops, intensive and irrigated crop enterprises to fit the three models that are used. Model I deals with the optimization of the representative farm's returns with current cropping practices. Model II represents the opportunities available for farmers to upgrade their cropping practices to intensive status by using more chemical inputs and the requisite labor. Model III allows representative farms to select crops grown with current or intensive practices on rainfed land, and replaces dimba crops with irrigated ones. Model III has two variations. In Model III(a) the irrigated crops are cereals, while in Model III(b) they are horticultural crops.

Current crop enterprises are those that farmers are practicing in their gardens, as reflected by the survey results. They are of two types: those that use fertilizer and those that do not. Intensive crop enterprises are similar to the fertilized options of current enterprises but the fertilizer and pesticides levels are raised to the recommended levels. Irrigated crop enterprises are those grown by farmers on irrigation projects. They use recommended fertilizer and chemical input levels.

The enterprise budgets are presented in Tables A6.1 to A6.40 in Appendix B. The chapter discusses how they were compiled.

6.1.1. Estimating Yields

Yield data came from the survey results, the Guide to Agricultural Production in Malawi-1992 (GTAPM) and Adaptive Research Unit (ARU) reports. The source of data for each particular enterprise depended on whether it was current, intensive or irrigated.

6.1.1.1 Current Crop Enterprises

Only those crop mixes grown by 10 or more farmers in the sample were considered for enterprise budgets and eventual inclusion in the programming matrix as crop production activities. This was done so that the solution carries crops that reflect dominant farmer practices and facilitates validation of the model. For each crop mixture there were potentially two options: the first option where farmers used no fertilizer and the second option where fertilizer was used. Use of some amount of fertilizer, even if less than the recommended level, was interpreted as use of fertilizer. This was done to capture the production function effect of fertilizer use.

The yield data used are typical values for the cases in the sample. For rainfed enterprises, the mean was used. These values were fairly comparable to other survey results on yields. In the case of dimba crops, it is prudent to use the median yields. Due to the small size of dimba plots and lack of experience of farmers in reporting harvests of dimba crops, the mean could embody serious statistical biases.

Based on the above criterion, fourteen crop mixes were selected from the observed 99. Six are rainfed enterprises and the rest are dimba enterprises. When the fertilized and non-fertilized options are allowed, 15 current enterprise budgets were compiled. These are:

Enterprise Name	Abbreviation
Fertilized Maize/Beans	MzBnF
Non-fertilized Maize/Beans	MzBnN
Fertilized Maize	MzF
Non-fertilized Maize	MzN
Fertilized Maize/Beans/P.peas	MzBPpF
Non-fertilized Maize/Beans/P.peas	MzBPpN
Fertilized Maize/Beans/Gnuts	MzBGnF
Rainfed Peas	Rpeas
Sugarcane	Scane
Dimba Peas	Dpeas
Non-fertilized Cabbage	CabN
Non-fertilized Chinese Cabbage	CcabN
Non-Fertilized Tomato	TomN
Dimba Maize	Dmzn
Dimba Maize/Pumpkin Leaves	DMzPLN

6.1.1.2 Intensive Crop Enterprises

Intensive enterprises differ from current ones in using fertilizer at the higher recommended levels. This leads to higher yields, and consequently, more labor is required for harvesting. These levels are not what the survey farmers use, so other sources of data were used. The first was the ARU for yields of crops. For enterprises on which the ARU does not have yield data, those from the GTAPM were used. The following intensive crop enterprises were included:

Hybrid Maize	HMaize
Hybrid Maize/Beans/Pegion Peas	HMzBP
Maize/Beans	Imzbn
Maize/Beans/P.peas	Imzbpp
Maize/Beans/Groundnuts	Imzbgn
Cabbage	Icab
Chinese Cabbage	Iccab
Tomato	Itom
Maize	IMz

6.1.1.3 Irrigated Crop Enterprises

Only the fertilized option was specified for irrigated crop enterprises. Twenty- two irrigated crop enterprise budgets were compiled, viz:

Tomato	RTom1, RTom2, Rtom3
Beans	RBeans1, RBeans2, RBeans3
Cabbage	RCab1, RCab2, RCab3
Chinese Cabbage	RCcab1, RCcab2, RCcab3
Pumpkin Leaves	RPLvs1, RPLvs2, RPLvs3
Onions	ROn2
Rice	RRice1,RRice2
Hybrid Maize	RHymz1, RHymz2
Wheat	RWheat1, RWheat2

The suffixed figures refer to the seasons in which the crop is grown. An assumption is made that vegetable crops can be grown and harvested in four months. Three seasons are specified for Model III(a): Season 1 is from January to April, Season 2 from May to August and Season 3 from September to December. Consequently, enterprise budgets for irrigated crops are formed with one-third of amortized debt apportioned to each of the three seasons. For Model III(b)--with irrigated cereals--two seasons are specified: September to March, the rainy cropping season; and April to August, the winter cropping season. Half of amortized debt is used.

The yields are calculated using information from discussions with farmers at irrigation projects and reports from Lilongwe ADD for Mchenga and Diamphwe irrigation projects. They are shown in Table 6.1.

Table 6.1
Yields of Irrigated Crop Enterprises

Crop Enterprise	Seasons 1 & 3 Area Planted (ha)[1]	Seasons 1 & 3 Yield (kg)	Season 2 Area Planted (ha)	Season 2 Yield (kg)
Tomato	1.008	2491	0.504	5243
Onion	-----	----	0.504	8008
Beans	1.240	3738	1.008	4754
Chinese Cab.	0.504	3427	0.504	12001
Cabbage	1.008	5110	0.756	24312
Pumpkin Lv.	0.252	1670	-----	-----

1/ Area planted refers the area sown to the crop at Mchenga irrigation project in the respective seasons.
Note: Except for chinese cabbage and cabbage, all the yields are below half of potential.
Source: LADD 1993(b)

6.1.2 Valuing Yields and Inputs

Yields and inputs were valued using prices from the 1990/91 cropping season for two reasons:

a) It is the midpoint between 1989 and 1992 so that assuming constant inflation rate we do not have to deflate/inflate the values; and

b) The yield data available are for 1992. Assuming lagged adaptive expectations, the 1990/91 prices were expected when planting crops in the 1991/92 season. These then were the prices entering the derived demand for inputs in that year. Also important is that this was a year of no drought.

If output is sold, the appropriate price for valuing yields is clearly the sale price. But all farmers in this study consumed some of their output. The consumed output can be valued at its opportunity cost which is the price the output could have been sold at had it not been consumed. This would have to be the average price for the period over which the crop was consumed, assuming constant rate of consumption. However, no data were collected on quantities consumed. Therefore, the prices used were selected from those of the survey and those paid by ADMARC in the 1990/91 cropping season. The approach to off-farm income earning activities is assumed that net returns per hour are equal to the minimum wage rate.

6.1.3 Variable Costs

Variable costs include costs of hired labor, seed, marketing, inputs such as fertilizers and chemical inputs, equipment repairs and maintenance, and operating interest charge. Excluded from this are taxes, depreciation, insurance and overhead labor costs. The approach taken concerning interest charges is to include them as part of investment cost in amortized debt.

6.1.3.1 Seeds

No data were collected through the survey on the seed rate for the enterprises. The data used are from the GTAPM, which specifies different seed rates for different crops depending on the mixtures of crops. The seed rate appears in each enterprise budget under the row title 'seed'. For example, the seed rate for maize is 25 kg per ha.

6.1.3.2 Fertilizer and Chemicals Applied to Crops

The figures used for fertilizer and chemicals applied to current enterprises are averages of quantities used by survey households. For intensive enterprises, GTAPM rates were used, and the same data were applied to irrigated enterprises. For intensive and irrigated enterprises, an assumption was made that pesticides and fungicides are applied twice at the specified rate. Fertilizers are mostly used on maize. The most commonly used types were 20.20.0 (17%), Calcium Ammonium Nitrate (32%), Urea (25%), Double Ammonium Phosphate (4.8%) and 23.21.0 (8.7%). The recommended practice is to apply fertilizers twice, basal and top dressing. Among the surveyed households who used fertilizer on maize, only half followed basal with top dressing. Top dressing was done with mostly CAN and

Urea. Fertilizer costs on average MK1.00 per kg. The quantity of dry fertilizer recommended for the various crops is reflected in the enterprise budgets. For maize, these are 370 kg for hybrid varieties and 160 kg for local maize. Among vegetables, an example can be used of tomatoes. It is recommended to apply every six weeks a total of 80 kg of fertilizer. Chemicals recommended are Carbaryl 85 W.P and Dimethoate 40 W.P for aphids, both applied by spraying solution of 35 g in 14 liters of water.

6.1.3.3 Repairs and Maintenance

No major farm implements are used in this part of Malawi. The major repair and maintenance cost for any of the activities is that of hoes and slashers. The exception is for irrigated enterprises, and this is discussed under Section 6.1.5.

6.1.4 Labor Use and Costs

6.1.4.1 Family Labor

Family labor does not enter the calculation of gross margin as a variable cost but is used to calculate returns per unit of labor and as a constraint in programming. For current enterprises, the median of labor person-hours applied to each enterprise was used. The exception is for land preparation where the median is used for the whole sample of dimba crops, excluding sugarcane. This was done for consistency. Time taken to prepare land should not vary much by enterprise except for sugarcane, which is a perennial crop and has very different planting practices.

For programming purposes, the labor requirements were distributed into the main months in which the activities for the enterprise were done. This is meant to increase the precision of resource constraints in programming. Also, the cost of labor may not be constant over the year. This approach also expedites sensitivity analysis.

In the case of intensive enterprises, the levels of family labor used are derived this way. For the basic activities whose labor requirements do not vary with outputs or inputs (i.e. land preparation, planting, weeding, and irrigation), the labor requirement used is the same as for fertilized current activities. But for fertilizing and harvesting, the figures for current enterprises are increased by the proportionate increase in harvests or inputs due to intensive use of inputs. For irrigated crops, the estimates are done similarly to intensively cultivated crops except that the labor requirements for irrigation are calculated from reports by the Lilongwe ADD for the irrigation projects. Setting up equipment requires at least two people, and it takes 2 to 3 hours to irrigate a hectare of land.

Some of the labor requirements reported by farmers are very high, especially for irrigating dimba crops. Current dimba enterprises require more labor for irrigation than irrigated enterprises because watering is done manually with watering cans. However, there is need for empirical studies to verify these figures.

6.1.4.2 Hired Labor

Hired labor is used in crop production when it is profitable to do so but family labor is limiting. The minimum wage is used as rate of remuneration. This is debatable in the case for "ganyu" labor. The wages are usually in-kind, such as grain, and it is widely believed that these are very low. However, these views may overlook some costs and benefits implicit in the wage. First, when grain markets fail, it is attractive for the "ganyu" workers to earn grain rather than cash because it saves them time and extra money needed to go in search for grain. Second, the wage should reflect the cost to the employing farmer of storing or procuring grain and bringing to close to the "ganyu" workers. In the absence of empirical data, sensitivity analysis is used to assess impact of conjectured wages on returns.

6.1.4.3 Marketing Costs

Marketing costs are calculated as the value of labor used in taking the produce to market and selling it. The figures are based on the researcher's experience and observance of marketing in rural areas of Malawi. People carry produce to the market in the morning and expect to complete selling by mid-day. Considering that the maximum load a person can carry is 50 kg, this works out to about 10 kg per hour. Using the minimum wage of MK0.25 this gives MK0.025 as cost of marketing a kilogram of produce. This figure is multiplied by the quantity harvested[10] of each crop in an enterprise to arrive at marketing costs per enterprise[11]. The exception is sugarcane where it is assumed that each bundle of sugarcane (20 canes) takes two hours to sell. Thus, a bundle costs MK0.50 and a cane MK0.025 to sell.

6.1.5. Irrigation Costs

Irrigation costs vary by type of irrigation technique used. The base model uses the costs for sprinkler irrigation. The costs for the various types of irrigation were calculated as follows:. The estimate is done for five hectares of land because this was the size of the sprinkler and borehole/furrow irrigation projects the Ministry of Agriculture has implemented.

Sprinkler irrigation equipment cost MK90,000 [LADD 1993(a)]. Figures on costs of drilling boreholes and installing pumps for other types of irrigation were available from Ministry of Works, Department of Rural Water Supply. Costs of constructing earthworks were derived from the data that the Department of Irrigation used to evaluate gravity-fed projects. This includes the costs of measuring and constructing headworks, canal structures, road access culverts, bridges, transport, tools, siphons, and payments to surveyors. The costs per hectare for different sites were estimated from MK500 to MK3500 depending on ease of water abstraction and topography. The median, MK2000, is used as an estimate.

Amortized debt is calculated based on 25% interest rate and 15 years of repayment period. This period was chosen to coincide with the useful life time of the equipment or

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[10] Ideally only the quantity sold should be used. For crops that are mostly consumed e.g. maize, the marketing costs are a very small proportion, because of low yields. Thus there should be very little upward bias in the figures.

[11] There are petty traders who continually sell produce at these markets, but they are not producers. They can be considered retailers.

investment. The high interest rate reflects the current commercial rate of about 21% and costs of administration and also reflects risks involved in lending over the long time period.

Five types of irrigation techniques were identified, and Table 6.2 below indicates their costs, amortized costs and annual maintenance costs. The latter are based on 5% of the value of investment. For the gravity-fed irrigation, maintenance costs are only for labor used in keeping the earthworks in good shape.

Table 6.2
Costs of Various Types of Irrigation.

Type of Irrigation Cost	Investment Cost	Amortized Cost	Maintenance
		Malawi Kwachas	
Pump/Sprinkler	18,000	4,664	900
Pump/Furrows	10,000	2,591	500
Bore/Furrows[1]	7,000	1,814	350
Gravity-fed/Furrows	2,000	518	100
Tank/Furrows	6,000	1,554	300

1/ There are two types of boreholes commonly used in Malawi: the Barnaby and Afridev. The costs of the Afridev are used in the budgets.

Source: Departments of Rural Water Supply and Irrigation

6.2 Formulation of the Mathematical Programming Model

The model used to determine optimal income earning activities is the Target MOTAD. It uses Telser's safety first criterion to model farmers' risk avoidance behavior. Safety first goals are specified using two different approaches: minimum maize production and subsistence income requirements. Three versions of the model are used which correspond with the crop production practices that farmers can use, viz current practices, intensive practices and irrigated cultivation.

The method used selects an activity mix which optimizes the choice variable, expected income, while simultaneously enforcing chance constraints up the yearly deviations of income from the expected optimal income. This is done by using a sufficiency constraint that imposes Telser's safety first probablistic criterion in the LP program. The sum of yearly deviations of income from expected income multiplied by the probability of that year's state of nature occurring are summed up. The model then selects a target from which the sum of probability weighted deviations is subtracted, and the difference is greater than the farmer's goal [$t - L^*Q(t) > g$].

This section present the programming tableaus used in the models. For reasons of space the matrix developed is displayed by model showing matrix quadrants with major activity types.

6.2.1 The Objective Function

The objective function maximizes gross margin from farm activities and earnings from off-farm income generating activities subject to constraints on input, market and permissible chance of failing to meet target objectives. The gross margin corresponding to the optimal solution is roughly equivalent to net farm income over fixed costs. In the objective function row are entered the costs or revenues of engaging in a unit of activity (i.e. producing crops, selling crops, hiring labor or selling labor).

6.2.2 Activities in the Model

The activities in the model include crop production, labor hiring and selling, crop selling, deviations and chance counters.

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6.2.2.1 Crop Production Activities

A cropping activity is a single variable representing a given crop enterprise that is cultivated. The unit of account is the hectare. Crop production activities include crop enterprises grown on rainfed land and dimba land for Model I. Model II adds on intensive enterprises. Model III adds on to Model II the crops that are grown with irrigation. In the objective function row is entered the cost of producing one hectare of the crops in the enterprise. These are the variable costs in the enterprise budgets. The input-output co-efficients represent the resource requirements per hectare of the crop activities. The relevant quadrants of crop production activities are displayed in Tables 6.3 to 6.7.

6.2.2.2 Labor Hiring Activities

The model is set up to allow for the hiring of labor if it is profitable to do so. The unit of account is person-hours. The labor hiring activity for each enterprise is disaggregated into months so that the optimal solution hires labor only for the month for which there is a constraint and also because its costs change over the year. Labor hiring activities are labelled JANHL for January hired labor to DECHL for December hired labor.

6.2.2.3 Labor Selling Activities

Due to the seasonality of production, especially when only rainfed and dimba cultivation is practiced, the farm family may have agricultural slack labor in some months of the year. The model allows for off-farm income earning activities (IEAs) in all the 12 months of the year. The official minimum wage rate of MK0.25 per person/hour is used as gross margin. The activities are labelled OFEJAN for off-farm employment in January to OFEDEC for off-farm employment in December. The quadrants for labor hiring and sale activities are displayed in Tables 6.8 and 6.9.

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6.2.2.4 Crop Selling Activities

Crop selling activities together with the yield accounting rows allow for the translating of crop yields into gross margins. The objective function rows carry the relevant prices for the crop. The base prices are those of the 1990/91 cropping season. The following sell activities are included:

Sell Rainfed Maize	SRMZ
Sell Dimba Maize	SDMZ
Sell Rainfed Beans	SBNS
Sell Pigeon Peas	SP/PEA
Sell Groundnuts	SG/NUT
Sell Rainfed Peas	SRPEA
Sell Dimba Peas	SDPEA
Sell Sugarcane	SSCANE
Sell Pumpkin Leaves	SP/LV
Sell Tomato	STOM
Sell Tomato Seasons 1 and 3	STOM1&3
Sell Chinese Cabbage	SCCAB
Sell Cabbage	SCAB
Sell Irrigated Beans	SIRBNS
Sell Onions	SIRON2
Buy Maize	BUYMZ
Sell Wheat	SWHEAT
Sell Rice	SRICE

Crop sale activities quadrant is shown in Table 6.10.

6.2.2.5 Deviations and Chance Counters

Since the model is a Target MOTAD, deviations and chance rows are used in the matrix. Four deviation rows are included to represent the four years of yield data, DYEAR1, DYEAR2, DYEAR3 and DYEAR4; the TQ(t) column sums the deviations, and the t column acts as a counter that selects the target. The chance quadrant is in Table 6.11.

6.2.3 Constraints

The model maximizes gross margin subject to family labor, land and chance constraints. We had intended to use a rotation constraint. Several methods are available to model them (El-Nazer et al 1986, Musser et al 1985). But lack of data on crop yields grown in rotation made this impossible. Also due to lack of data for yields of onions in Season 1 and 3, only Season 2 onions are modelled.

6.2.3.1 Family Labor

The average size of household was used to arrive at the available person-hours. An equivalent of 2 adults available to work full time per household is assumed. They work an average of six hours a day, 25 days in a month. This is the labor available for all economic activities be they farm or non-farm. The family labor available is varied by month to reflect seasonal variation in hours that can be worked due to rains and also disease. In the rainy season the incidence of diarrhoea and malaria is higher. So in November, December, January, and February about 5 work hours per day are specified. This gives 240 hours per household in these months compared to 300 in the other eight months. In the matrix, the monthly labor requirements are labeled JANLAB through DECLAB respectively.

6.2.3.2 Land

Land available for cultivation is limited. The model allows for three size pairs of land holdings for rainfed and dimba land. These are (0.45, 0.13), (1.06, 0.17), and (2.49, 0.33) hectares for small, medium and large farms respectively. In the case of irrigation, the land sizes specified correspond to the current dimba land: 0.13 ha, 0.17 ha and 0.33 ha. Irrigated land available is modelled in seasons for ease of programming crops grown in different seasons. Three seasons are modelled for production of horticultural crops Model III(a), and two seasons for cereal crops Model III(b). The mnemonic names used are:

Rainfed Land	RFLAND
Relay Use of Rainfed Land	RFLD2
Dimba Land	DLAND
Irrigated Land Season 1	IRLDS1
Irrigated Land Season 2	IRLDS2
Irrigated Land Season 3	IRLDS3

Farmers in Malawi use rainfed land to grow field peas or beans or sweet potatoes in relay with maize. Among the survey households the most common relay crop is field peas. They are planted around February and March when maize is beginning to dry.

TABLE 6.3
Model I - Current Rainfed and Dimba Crop Enterprises

	MzBnF	MzBnN	MzF	MzN	MzBPpF	MzBPpN	MzBGnF	RPeas	CabN	Scane	TomN	DMzN	DPeas	CcabN	DMzPLN
RETURN	-191	-55	-151	-27	-220	-72	-238	-41	-168	-220	-183	-80	-54	-71	-77
RFLAND	1	1	1	1	1	1	1								
DLAND									1	1	1	1	1	1	1
JANLAB	111	85	113	85	116	85	114			154		26			132
FEDLAB															
MARLAB								77							
APRLAB	48	27	38	25	68	38	59	125	515		515		515	515	
MAYLAB	48	27	38	25	68	38	59	48	1344		1490		845	296	
JUNLAB									893		747		356	553	
JULAB								28	769		722	515	476	673	515
AUGLAB	151	151	151	151	151	151	151	28	705	274	120	1246	120		1246
SEPLAB	151	151	151	151	151	151	151		240	394	120	693			693
OCTLAB	19	19	19	19	19	19	19			177					
NOVLAB	19	19	19	19	19	19	19			57		120			120
DECLAB	111	85	113	85	116	85	114			154					
Y1INC	246	191	251	226	462	253	366	104	3650	2253	6325	3250	1017	1045	2500
Y2INC	245	174	211	203	581	367	451	133	2696	4394	5405	2959	494	941	2352
Y3INC	225	144	196	134	362	348	430	154	2657	4052	6057	2534	617	925	2127
Y4INC	47	80	-21	42	84	155	128	79	955	4084	4399	2078	506	532	1423
DMAIZE		-89										-2790			-1980
BEANS	-73				-147	-80	-79								
PPEAS					-91	-83									
GNUTS							-141								
RPEAS								-158							
DPEAS													-713		
SCANE										-7795					
PLVS															-391
TOMAT											-5716				
CCAB														-1868	
CAB									-5298						
RFLD2								1							
SUFCON															
Q(t)															
RMAIZE	-1004	-524	-931	-544	-1396	-798	-1116								

TABLE 6.4
Model II - Intensive Crop Enterprises

	IMzBn	IMzBPp	IMzBGn	IMz	HMzBPp	ICcab	ICab	ITom
RETURN	-256	-260	-305	-237	-498	-715	-669	-348.63
RFLAND	1	1	1	1	1			
DLAND						1.	1	1
JANLAB	119	119	125	126	169			
FEDLAB								
MARLAB								
APRLAB	56	94	95	91	140	515	515	
MAYLAB	56	94	95	91	140	1321	1406	515
JUNLAB						578	955	1490
JULAB						673	1725	747
AUGLAB	151	151	151	151	151	730	1661	722
SEPLAB	151	151	151	151	151	240		120
OCTLAB	19	19	19	19	19			120
NOVLAB	19	19	19	19	19			
DECLAB	119	119	125	126	169			
Y1INC	560	679	631	725	812	13762	7453	8853
Y2INC	559	837	731	628	976	12109	10749	9298
Y3INC	518	543	677	593	625	11191	10330	10734
Y4INC	190	156	222	74	80	7761	10334	8184
DMAIZE								
BEANS	-160	-200	-130		-200			
PPEAS		-91			-91			
GNUTS			-141					
RPEAS								
DPEAS								
SCANE								
PLVS								
TOMAT								-9560
CCAB						-23812		
CAB							-20708	
RFLD2								
SUFCON								
Q(t)								
RMAIZE	-1830	-1961	-1887	-2229	-2870			

TABLE 6.5
Model III(a) - Irrigated Horticultural Crops Using Sprinklers - Income Approach

	RCab2	RCab3	RCab1	Plvs2	Plvs3	Plvs1	RTom2	RTom3	RTom1	RCcab2	RCcab3	RCcab1	RBns2	Rbns3	RBns1	ROn2
RETURN	-3379	-2659	-2659	-2698	-2698	-2698	-2727	-2529	-2529	-3128	-2702	-2702	-2790	-2750	-2750	-2928.75
RFLAND																
JANLAB			725			585			801			725			490	
FEBLAB			239			239			239			239			239	
MARLAB			239			334			334			239			359	
APRLAB			660			120			120			504			120	151
MAYLAB	725			585			801			981			490			625
JUNLAB	239			239			239			580			239			239
JULAB	239			334			334			580			239			239
AUGLAB	3381			120			120			516			160			240
SEPLAB		725			585			801			725			690		
OCTLAB		239			239			239			239			239		
NOVLAB		239			334			334			239			359		
DECLAB		660			120	788		120			504			120		
Y1INC	13361	-124	-124	614	614	614	7674	7674	7674	8778	696	696	1911	252	252	12869
Y2INC	13361	-124	-124	614	614	614	7674	7674	7674	8778	696	696	1911	252	252	12869
Y3INC	13361	-124	-124	614	614	614	7674	7674	7674	8778	696	696	1911	252	252	12869
Y4INC	13361	-124	-124	614	614	614	7674	7674	7674	8778	696	696	1911	252	252	12869
DMAIZE																
BEANS																
PPEAS																
GNUTS																
RPEAS																
DPEAS																
SCANE																
PLVS				-6626	-6626	-6626										
TOMAT							-10402									
CCAB										-23812	-6799	-6799				
CAB	-33481	-5069	-5069													
RFLD2																
SUFCON																
Q(t)																
RMAIZE																
SS1LD			1			1			1			1			1	
SS2LD	1			1			1			1			1			
SS3LD		1			1			1			1			1		
RON																
RBNS													-4716	-3014	-3014	
Tom 1&3																

TABLE 6.6
Model III(b) - Irrigated Cereals Using Gravity/Furrows - Maize Production Approach

	RC1GF	RC2GF	WH1GF	WH2GF	MZB1GF	MZB2GF
RETURN	-670	-670	-758	-758	-805	-805
RFLAND						
JANLAB	298		347		280	
FEDLAB						
MARLAB						
APRLAB		151		151		151
MAYLAB		290		282		290
JUNLAB		518		539		308
JULAB		494		377		289
AUGLAB		152		182		280
SEPLAB	151		151		151	
OCTLAB	625		353		290	
NOVLAB	319		319		308	
DECLAB	319		319		289	
Y1CER	3000	3000			3000	3000
Y2CER	3000	3000			3000	3000
Y3CER	3000	3000			3000	3000
Y4CER	3000	3000			3000	3000
DMAIZE						
BEANS					-402	-402
PPEAS						
GNUTS						
RPEAS						
DPEAS						
SCANE						
PLVS						
TOMAT						
CCAB						
CAB						
RFLD2						
SUFCON						
Q(t)						
RMAIZE					-3000	-3000
SS1LD	1		1		1	
SS2LD		1		1		1
RICE	-3000	-3000				
WHEAT			-3500	-3500		

TABLE 6.7
Model III(b) - Irrigated Cereals Using Gravity/Furrows - Income Approach

	RC1GF	RC2GF	WH1GF	WH2GF	MZB1GF	MZB2GF	SWHEAT	SRICE
RETURN	-670	-670	-758	-758	-805	-805	.55	.37
RFLAND								
JANLAB	152		182		298			
FEDLAB								
MARLAB								
APRLAB		151		151		151		
MAYLAB		290		282		339		
JUNLAB		518		539		319		
JULAB		494		377		319		
AUGLAB		152		182		298		
SEPLAB	151		151		151			
OCTLAB	290		282		339			
NOVLAB	518		539		319			
DECLAB	494		377		319			
Y1INC	439	439	1063	1063	441	441		
Y2INC	439	439	1063	1063	441	441		
Y3INC	439	439	1063	1063	441	441		
Y4INC	439	439	1063	1063	441	441		
DMAIZE								
BEANS					-402	-402		
PPEAS								
GNUTS								
RPEAS								
DPEAS								
SCANE								
PLVS								
TOMAT								
CCAB								
CAB								
RFLD2								
SUFCON								
Q(t)								
RMAIZE					-3000	-3000		
SS1LD	1		1		1			
SS2LD		1		1		1		
RICE	-3000	-3000						1
WHEAT			-3500	-3500			1	

TABLE 6.8
Labor Hiring Activities

	janh1	febh1	marh1	aprh1	mayh1	junh1	julh1	augh1	seph1	octh1	novh1	dech1
RETURN	-.25	-.25	-.25	-.25	-.25	-.25	-.25	-.25	-.25	-.25	-.25	-.25
RFLAND												
DLAND												
JANLAB	-1											
FEDLAB		-1										
MARLAB			-1									
APRLAB				-1								
MAYLAB					-1							
JUNLAB						-1						
JULAB							-1					
AUGLAB								-1				
SEPLAB									-1			
OCTLAB										-1		
NOVLAB											-1	
DECLAB												-1

TABLE 6.9
Labor Sale Activities

	OFEAJN	OFEFEB	OFEMAR	OFEAPR	OFEMAY	OFEJUN	OFEJUL	OFEAUG	OFESEP	OFEOCT	OFENOV	OFEDEC
RETURN	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
RFLAND												
DLAND												
JANLAB	1											
FEDLAB		1										
MARLAB			1									
APRLAB				1								
MAYLAB					1							
JUNLAB						1						
JULAB							1					
AUGLAB								1				
SEPLAB									1			
OCTLAB										1		
NOVLAB											1	
DECLAB												1

TABLE 6.10
Crop Sale Activities

	SRMZ	SDMZ	SBEANS	SP/PEA	SG/NUT	SRPEA	SDPEA	SSCANE	SP/LVS	STOMT	STOM 1&3	SC/CAB	SCABB	BUYRMZ	SIRONZ	SIRBNS	SWHEAT
RETURN	.33	1	.65	.40	1.12	1	1	.50	.50	1		.50	.50	-.60			
RFLAND																	
DLAND																	
JANLAB																	
FEDLAB																	
MARLAB																	
APRLAB																	
MAYLAB																	
JUNLAB																	
JULAB																	
AUGLAB																	
SEPLAB																	
OCTLAB																	
NOVLAB																	
DECLAB																	
Y1INC																	
Y2INC																	
Y3INC																	
Y4INC																	
DMAIZE		1															
BEANS			1														
PPEAS				1													
GNUTS					1												
RPEAS						1											
DPEAS							1										
SCANE								1									
PLVS									1								
TOMAT										1							
CCAB												1					
CAB													1				
RFLD2																	
SUFCON																	
Q(t)																	
RMAIZE	1													-1			

TABLE 6.11
Chance Activities

	DYEAR1	DYEAR2	DYEAR3	DYEAR4	TQ(t)	t
RETURN						
Y1INC	1					-1
Y2INC		1				-1
Y3INC			1			-1
Y4INC				1		-1
SUFCON					-4	1
Q(t)	.25	.25	.25	.25	-1	
RMAIZE						

6.2.3.3. Accounting Rows

Accounting rows are introduced for all crops to allow the model to transfer output from the production to the sales or consumption activities. These rows allow modeling production and sales separately. This approach facilitates sensitivity analysis. The accounting rows appear in Tables 6.3 through 6.7 and 6.10; they are:

Dimba Maize	DMAIZE
Beans	BEANS
Rainfed peas	RPEAS
Groundnuts	GNUTS
Pegion Peas	PPEAS
Sugarcane	SCANE
Pumpkin Leaves	PLVS
Tomato	TOMATO
Chinese Cabbage	CCAB
Cabbage	CAB
Rainfed Maize	RMAIZE
Tomatoes Season1&3	TOM1&3
Onions Season 2	RON2
Wheat	WHEAT
Rice	RICE

6.2.3.4 Deviation and Chance Constraint Rows

Income or maize yield constraint rows account for how enterprise risk enters the objective function. These are:

First year incomes or maize yield	Y1INC or Y1MZYD
Second year incomes or maize yield	Y2INC or Y2MZYD
Third year incomes or maize yield	Y3INC or Y3MZYD
Fourth year incomes or maize yield	Y4INC or Y4MZYD

Chance constraints rows are used to make sure the solution meets the probability limit. They are the deviations constraint [Q(t)], and the sufficiency condition (SUFCON). The Q(t) sums up the value of the yearly deviations from a selected target weighted by the probability of the occurrence of that year's income or harvests. In this model the probabilities have been put at 0.25 for each of the four years. The sufficiency condition enforces the requirement that the income achieved is not below the goal in more than the specified proportion of cropping seasons.

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6.3 Summary

This chapter describes the formulation of the model used to determine the optimal mixes of activities. It begins with the description of the compilation of enterprise budgets from which were derived many of the co-efficients that are needed for the programming matrices. For crops that are currently grown, the survey data are used. For intensive and irrigated enterprises sources of data are various government documents. Section 6.2 described the various components of the programming matrices. The activities included are crop production and sale activities, labor hiring and sale activities, and deviation counters. Constraints are family labor, land, accounting rows and chance and deviation rows.

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CHAPTER 7: MODEL I - CURRENT CROPPING PRACTICES

In this chapter the results of Model I using income and maize production goals are presented and discussed, including model validation. Model I deals with optimization of the representative farm's income with current crop packages. It is important to understand whether farmers could be optimally allocating their resources given their present technology and why they might not be doing so if that is the case.

The method used to derive the results presented here is described in detail in sections 3.2 (g) and 3.3; its formulation is documented in section 6.2. It is a Target MOTAD model due to Tauer (1983), which uses Telser's safety first probablistic criterion with Atwood's (1985) lower partial moments (LPM) to model yield or income risk in growing crops. To recapitulate, the algorithm selects the activity mix which optimizes expected income while simultaneously enforcing probablistic constraints upon the deviations of income from this optimal expected income with the least constraining linear lower partial moment stochastic inequality. The constraint is $t - L^*Q(t) > g$, where t is target level of choice variable, L^* is reciprocal of the probability limit, Q(t) is the sum of deviations and g is the goal level of the variable.

The modeler can parametrically change the probability level below which failure to achieve goal is undesirable or change the goal itself. In this analysis exercise this probability pertains to the proportion of cropping seasons above which it is unacceptable to fail to achieve the specified food security goal.

With respect to the goal, the approach in this study is two pronged. There are two main ways of looking at the solutions to the maize insecurity situation. A farmer can try to formulate a plan that allows her to produce all maize, or she can produce some maize and also cash crops to earn income to make up for the deficit. Each of the three models is presented in two variations: the goal in the sufficiency condition is specified in kilograms of maize harvested and also income (gross margins) from all enterprises. In case of maize

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production, the goal is 1,000 kilograms of maize: 200 kg per person per year for a household of five. These estimates are based on government sources [Malawi Government 1993(b)]. Minimum income requirements are calculated to be MK2,500 per household per annum. The following budget was used to arrive at the datum:

Item	Cost(Mk)
Maize (200 Kg @ MK0.60/kg)	120.00
Salt	20.00
Cooking Oil (4 liters @MK10.00/liter[1]	40.00
Sugar (10 Kg @ MK2.00/kg)[1]	20.00
Protein Source (@ MK.50/day)	180.00
Vegetables (@ MK0.05/day)	20.00
Transport/Sundries/Hospital Fees	100.00
Total	500.00

Assuming an average household size of five, the minimum income requirement is MK2500.

Some government/donor documents [Malawi Government 1993(b), World Bank 1990] use a poverty datum of US$40.00 which was MK200 during the time this study was being conducted. This is very low and has neither empirical basis nor description of its derivation. Each specification of the two goal specifications is analyzed for all three farm sizes. The target, t, is endogenously selected by the algorithm but it should be greater than or equal to g.

Sensitivity analysis is done to understand the impact of selected changes in variables on the optimal solutions. It is done using non-marginal changes in values of these variables: values outside optimality or feasibility ranges for optimal solutions. The variables that are parameterized are prices of output, cost of hired labor, yields, and cost of irrigation. When planning investments, the relevant price for valuing output is the one to obtain when the planned production enters the markets. This price may not be discovered in advance; thus, sensitivity analysis evaluates the impact of conjectured price changes. Even with irrigation, yields can vary for the same season in different years and between seasons due to water sour

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source fluctuations, management of crops and natural disasters. There are potentially five different irrigation methods with three cost levels. Sensitivity analysis is intended to capture the difference in costs of these methods. Cost of labor varies by month. In the months of December to January many members of small farm households do "ganyu", work for payment in kind, on larger farms. The wages are believed to be below the minimum wage. In the absence of empirical data on the level of these wages, sensitivity analysis is done for 50% reduction in the minimum wage. It is done for Model III(a) only, because it is in this model that there is significantly higher labor hiring.

The results presented and analyzed include *1)* the level of activities in the optimal solutions, *2)* shadow prices of resources and constraints, *3)* stability of solutions and the cost of forcing excluded activities into the solution, *4)* contributions of various resources to total income and *5)* highest feasible maize production goals.

1) The optimal solutions are of two kinds: non-risk constrained and safety first solutions, where applicable. The results that are discussed extensively are those at the probability limit of 0.25 ($L^* = 4$). These results can be achieved by representative farms in at least 75% of the cropping seasons. However, also presented are results for the 0.33 and 0.40 probability limits for small farms. This is done to illustrate the general nature of solutions and provide supporting evidence for conclusions reached.

2) Shadow prices measure the rate of change in the value of the objective function in response to a small change in the use of a resource or level of constraint. Alternatively they can be seen as the maximum price to pay to get one more unit of a resource or otherwise relax a constraint by one unit. This is true if the resources are not sunk costs. Shadow prices also indicate the productivity or scarcity of resources available to the farm. The more constraining the resource, the higher the shadow price.

3) Two concepts of stability will be used. The first is range of optimality (Anderson et al 1991). This refers to the range of values of the objective function co-efficients

over which the activities in the solution function remain optimal. The second, range of feasibility, indicates the range of the right hand side values of resources/constraints over which the dual value will remain the same. Cost of forcing in excluded activities in the solution reflects the competitiveness of the activities. Competitiveness is defined as the cost to a farmer of forcing in an activity excluded from the optimal solution. The higher the value the less competitive the activity.

4) For all solutions there is a discussion of the contribution of various resources to total income viz, dimba land, rainfed land, irrigated and off-farm income earning activities. These data provide a way of assessing the relative importance of various resources in to achieving food security goals.

5) For each model there is also a presentation of the highest feasible maize production goals and the corresponding optimal maize production levels. The maximum feasible goals show the level of production that a farmer can hope to exceed in 75% of the cropping seasons. They indicate the level of confidence that farmers can have about their potential for maize self-sufficiency.

7.1 Base Solutions

7.1.1 Maize Production Approach and the Non-risk Constrained Solutions

7.1.1.1 Activities in the Solutions

The general pattern of solutions is shown in Table 7.1. The non-risk constrained solution and the maize production approach give the same results because the same activity has the highest gross returns; maize/beans/pigeon peas also has highest maize yield. The level of goals are selected to represent the ends and middle[1] of the feasible but binding region of the sufficiency condition. At all probability levels, the value of the objective function

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[1] In Model I the results do not show a lot of variation in level of optimal crops so that only the ends of the spectrum are presented. Table 7.1 can be compared to Table 8.1 for Model II.

Table 7.1
Model I - Safety First Solutions Using Telser's Probablistic Criterion and Atwood's Lower Partial Moments At Probability Limits 0.25, 0.33 and 0.40
Small Farms

Prob. Limit 1/L*	Goal g (MK)	Mean Income (MK)	Crop Activities (Hectares)					
			MzBPpF	MzBGnN	MzBPpN	RFPeas	Scane	TomN
All	0	1380	0.45	0.0	0.0	0.45	0.13	----
0.25	550[a]	1378	0.45	----	----	0.45	0.129	0.001
	576	1359	0.45	----	----	0.45	0.12	0.01
0.33	562[a]	1379	0.45	----	----	0.45	0.129	
0.001	576	1359	0.45	----	----	0.45	0.13	-----
0.40	570[a]	1377	0.45	----	----	0.45	0.128	-----
0.020	576	1359	0.45	----	----	0.45	0.13	-----

a/ A major difference in the three probability levels is that at tighter limits, e.g. 0.25, the binding region is wider 550-576. This table can be contrasted with Table 8.1 where each probability has a different maximum goal. However, the feasible region is still wider for the more stringent sufficiency condition.

Source: Survey Data 1993/LP88 Results

Model I - Safety Fi

Table 7.2

Table 7.2
Model I - Safety First Solutions with Telser's Probabilistic Criterion and Atwoods Lower Partial Moments At the 0.25 Probability Limit

Level of Activities in Solution

Activity	Small NRCON[a]	Small SFIRST	Medium NRCON	Medium SFIRST	Large NRCON	Large SFIRST
Mean Income(MK)	1,380	1,359	1,657	1,638	2,529	2,471
Goal Income	0	576	0	903	0	1863
Crop Production Activities(Ha)						
MzBPpF	0.45	0.45	1.06	0.24	2.48	tr
MzBPpN	----	----	----	----	----	----
MzBGnF	----	----	----	0.82	----	2.48
Rainfed Peas	0.45	0.45	0.45	0.45	0.45	0.45
Sugarcane	0.13	0.12	0.17	0.17	0.33	0.33
TomN	----	0.01	----	----	----	----
Off-Farm IGAs (Person-hours)						
January	167	169	90	92	---	---
February	240	240	240	240	240	240
March	205	205	158	158	48	48
April	213	----	95	102	---	---
May	247	240	177	184	11	34
June	300	292	300	300	300	300
July	287	267	270	270	230	230
August	183	177	63	64	---	---
September	166	157	54	55	---	---
October	254	250	231	231	158	158
November	284	284	270	270	234	234
December	167	169	90	92	---	---

Cont'd/....

Table 7.2 Cont'd

Selling Activities (Kilograms)						
Rainfed Maize	668	310	1480	1251	3476	2779
Beans	66	25	118	100	276	196
Pigeon Peas	40	16	76	21	179	tr
Groundnuts	---	---	----	115	---	350
Rainfed Peas	71	71	167	----	393	393
Tomatoes	----	36	----	----	----	----
Sugarcane	1013	923	1325	1325	2572	2572
Hired Labor Activities (Person-hours)						
January	--	--	--	--	97	94
April	--	--	--	--	180	158
May	--	--	--	--	115	---
July labor	--	--	--	--	266	---
August Labor	--	--	--	--	236	236
September labor	--	--	--	--	241	241
December	--	--	--	--	95	95

a/ NRCON: The Non-Risk Constrained Solutions are same as Maize Production Approach Solutions
b/ SFIRST = Safety First Solutions

Source: Survey Data 1993/LP88 Results

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when the sufficiency condition is non-binding (due to a zero level goal) is the same, MK1,380. In this particular case it also happens that the maximum feasible income goal (MK576) is the same at all the selected probability levels. Due to the narrow band of the feasible but binding region, the solutions do not reflect much difference in crop combinations and values of the objective function. This is due to the tightness of the risk situation as represented by the sufficiency condition.

The results of the base scenario at the 0.25 probability limit are shown in Table 7.2. The configuration of yearly yields and output prices leads to the same solution for the safety first maize production approach and the non-risk constrained solution. This is due to the mean-minimum dominance of the fertilized maize/beans/pigeon peas enterprise among rainfed crops. It has the highest minimum yields and the highest mean income. Since the maize production approach optimizes expected income subject to a safety first constraint on yield deviation, maize/beans/pigeon peas is selected. Sugarcane is optimal for dimba land and a relay crop of field peas. The level of activities in solution--production and selling--varies with available resources for the three farm sizes. (It is assumed that the farmers will sell what they produce over consumption requirements.)

The maximum mean returns are MK1,380, MK1,657 and MK2,529 respectively for the small, medium, and large farm sizes. The representative small and medium farms meet only 52% and 66% of their subsistence income requirement of MK2,500. These results corroborate the findings of other research studies on levels of malnutrition and poor health as cited earlier.

Small and medium farms have surplus labor which they can sell or use in income earning activities (IEAs), every month. Large farms have surplus family labor in February, March, May, July, October and November. However, they need to hire labor in January, April, June, August, September and December.

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7.1.1.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The shadow prices of rainfed land and dimba and relay use of rainfed land are MK196 and MK3,338 and MK41 respectively. Thus, under the base scenario enterprise price and yield permutation, dimba land can generate MK3,338. This dual value of land is feasible over a range of 0 to 0.46 ha, 0.17 to 0.23 ha, and 0.32 to 0.55 ha with respect to the three farm sizes. Sugarcane is optimal until prices drop below MK0.28/cane. Sensitivity analysis is thus done at MK0.25/cane.

On dimba land there are no crops that compete well with those in the optimal solution on small and medium farms. Introducing any dimba crop not already in the solution can completely wipe out the gross returns. Fertilized maize/beans/groundnuts is the most competitive on rainfed land at zero cost of being forced into solution.

7.1.1.3 Contribution of Dimba Crops to Income

Dimba crops contribute 31%, 38%, and 47% to the optimal income of small, medium and large households respectively. Rainfed land is most important to large farms, contributing 41% of their income (See Table 7.3). This result is important. From the small portions of dimba land, the small representative farms can generate more income than from their rainfed land. For the representative medium farm a 0.17 hectare plot of dimba land can provides the same income as 1 hectare of rainfed piece of land. These results have two implications. First, dimba land is very important to providing livelihoods especially for small farms when compared to the other farm sizes. Second, small increases in availability of dimba land can have significant positive impact on household incomes. A conclusion can be made that when favorable market conditions exist, upgrading small portions of rainfed land to irrigated status has the potential to significantly improve the incomes of households, and their food security status.

Farmers can generate a substantial portion of their income from non-farm IEAs: 49%, 31% and 12% for small, medium and large farms. Small farms can thus derive nearly half of their total income from use of agricultural slack labor in either IEAs or employment. This study did not focus on off-farm IEAs. A good specification of the off-farm IEAs is important to draw specific conclusions. However, the finding is in line with the descriptive results as presented in Chapter 5--that small farms tend to be engaged more in off-farm IEAs than large farm operators. Studies conducted in other countries also have similar findings: Flanders (1977), Priebprom (1982) in Thailand, and Reddy and Finders (1988) in USA.

This finding indicates that if farmers with very small holdings are not able to practice intensive agriculture, then government needs to focus attention on off-farm sources of income either to make them more remunerative or easier to establish.

Table 7.3

Model I - Base Scenario

Contribution of Dimba Land, Rainfed Land and Off-farm IEAs to Income

	Size of Farm		
	Small	Medium	Large
Rainfed Land	20%	31%	41%
Dimba Land	31%	38%	47%
Off-Farm IEAS	49%	31%	12%
Total Income (MK)	1380	1657	2529

Source: Survey Data 1993/LP88 Results

7.1.1.4 Maximum Feasible Maize Production

While the non-risk constrained solution does not change with probability limits, the level of achievable maize goals do change. These are indicated in Table 7.4. At the 0.25 probability limit, the feasible maize production goals are 300 kg and 708 kg, for small and medium farms. The corresponding expected production levels are 668 kg and 1,480 kg. Thus, small farms can be sure that the expected maize production of 668 kg will be more than 300 kg in 75% of the cropping seasons. In other words there is certainty that small farms can provide adequate maize for 1.5 persons in three quarters of the cropping season. Large farms can meet the safety first goal of 1,000 kg without being constrained. When the proportion of cropping seasons permissable to fail to meet the goal is raised to 40%, the medium farms still fail to reach a mean of 1,000 kg.

Table 7.4
Model I - Maximum Feasible Maize Production (kg) Goals
by Allowable Probability of Failure

	Size of Farm		
Probability Limit	Small	Medium	Large
0.25	300	708	1,663
0.33	331	780	1,834
0.40	405	954	2,401

Note: The minimum maize requirements are estimated at 1,000 Kilograms per household

7.1.2 Safety First Solutions

In this section the results of the safety first solutions at the 0.25 probability limit are discussed. These were shown in Table 7.2.

7.1.2.1 Activities in the Solutions

The crop mixtures vary by farm size. Small farms have fertilized maize/beans/ pigeon peas on rainfed land and sugarcane and a small amount of tomato on dimba gardens. Medium farms have fertilized maize/beans/groundnuts on rainfed land and a small portion of fertilized maize/beans/pigeon peas. Large farms have fertilized maize/beans/groundnuts. Sugarcane is the sole crop on dimba land for both medium and large farms. The differences in solutions are due to the resource endowments of the three farm sizes. When safety first goals are specified in income and land is very limiting, activities with very high means returns remain in solution, i.e. maize/beans/pigeon peas and tomatoes for small farms. On large and medium farms, maize/beans/groundnuts dominates.

The highest feasible income goals are MK576, MK903 and MK1,863 at the 0.25 probability limit, for the three farm sizes. They correspond to incomes of MK1,359, MK1,638 and MK2,471 with respect to farm size. None of the three representative farm sizes can achieve incomes that are higher than the minimum income requirements of MK2,500 in 75% of the cropping seasons.

Only the large farms need to hire labor to support their crop activities. This is in the months of January, April, August, September, and December. The medium and small farms can sell family labor in every month because the sizes of their gardens are too small to absorb it all.

A slightly different version of Model I was analyzed with hybrid maize/beans/pigeon peas. This model corresponds to the past extension practice of offering credit for only hybrid maize. When farmers are risk averse, this enterprise does not appear in optimal solution.

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7.1.2.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

From the non-risk to the risk constrained solutions, the dual values of land change, rising from MK196 to MK524 for rainfed land; MK3,338 to MK4,943 for dimba land; and from MK41 to MK115 for relay use of rainfed land (MK82 for small farms) (see Table 7.5). The dual values of land are very high compared to rental or sale rates, even though these are not well established empirically. The dual values are derived as the net return to the optimal activity grown on the land. They, thus, represent the income the farmer loses when not using the land, or income to be had from using one more unit of land.

The differences in the dual values of land in the non-risk constrained solution and the risk constrained solution is the safety first premium of land. It measures the contribution of one more unit of land to manage risk as measured by the yield/income variability and perceived by the farmer. The latter is reflected in the sufficiency condition (goal and probability level).

The range of optimality is narrower under the risk constrained solutions than the non-risk constrained solutions or maize production approach. Thus, risk averse farmers may watch price changes more carefully because they will impact their safety first goals. The dual of the sufficiency condition of 0.54 shows that the expected value of the objective function can increase by MK0.54 if the goal is relaxed by MK1.00. (The value of the dual of the sufficiency condition changes with probability levels, the value being lower at higher probability levels. Thus, at higher probability limits (1/L), there is less trade off between income safety first goals and returns.)

The most competitive alternative crops vary by farm size. For small farms these are cabbage at zero cost per hectare on dimba land. On rainfed land there is no competition from any crop. On medium and large farms, the dimba crop of sugarcane has no competition. In case of rainfed land, non-fertilized maize/beans/pigeon peas could be forced in solution at cost of MK23 per hectare on both medium and large farms, and fertilized maize/beans/pigeon peas on large farms at zero cost per hectare.

7.1.2.3 Contribution of Dimba Crops to Income

The configuration of sources of income from dimba, rainfed and labor are similar to the non-risk constrained solution.

7.1.2.4 Maximum Feasible Maize Production

The maize yields obtainable when income safety first goals are binding are 628 kg, 1,251 kg and 2,779 kg for small, medium and large farm sizes. They are lower than in the case of no risk aversion or maize approach because the criteria for selecting optimal activities is now based primarily on income variability rather than mean returns. The activities with less income variability yield less maize per hectare.

7.2 Sensitivity Analysis

Sensitivity analysis is done for three cases. The first, Scenario A, allows the price of the dominant dimba crop in the base solution, sugarcane, to drop by 50% from MK0.50 to MK0.25. Scenario B assesses the impact of mean yields of the tomato enterprise at the price of MK1.00 on expected returns and optimal crop mixtures. (The base scenario has median yields of tomato). Scenario C reduces the price of tomatoes in scenario B by 50%. This last scenario corresponds to the situation where high yields of tomatoes can glut the market or to account for high perishability of tomatoes. The results of sensitivity analysis for small farms only are shown in Table 7.6. (Results for medium and large farms are similar with respect to combinations.)

Table 7.5
Model I - Shadow Prices of Resource and Constraints

Resource/Constraint	SFIRST[a]		NRCON[b]
Small Farms	Medium/Large Farms		All Farms
Land (MK/Ha)			
Rainfed Land	524	241	195
Relay Rainfed Land	115	83	41
Dimba Land	5,526	4,943	3,338
Labor All months (MK/Person-hour)	0.25	02.5	0.25
Sufficiency Condition	-0.71	-0.54	0

a/ Safety First Solutions
b/ Non-risk Constrained Solutions

Source: Survey Data 1993/LP88 Results

Table 7.6

Table 7.6
Model I - Sensitivity Analysis Results - Small Farms

	Scenario A[b]		Scenario B[c]		Scenario C[d]	
	NRCON	SFIRST	NRCON	SFIRST[e]	NRCON	SFIRST
Expected Income	1,158	1,118	1,482	1,455	1,380	1,348
Crop Activities						
MzBPpF	0.45	----	0.45	----	0.45	0.45
MzBPpN	----	0.44	----	0.44	----	----
MzbGnF	----	tr	----	tr	----	----
Rpeas	0.45	0.45	0.45	0.45	0.45	0.45
CabN	----	----	----	----	----	tr
Sugarcane	----	----	----	----	0.13	0.11
Tomato	----	----	0.13	0.13	----	----
Dmzn	0.13	0.13	----	----	----	0.02
Dual Value						
RFLand	195	348	195	348	195.00	2,296.00
Dimba Land	1,632	4,481	1,421	10,151	3,338.00	18,330.00
Relay Land	41	149	41	149	41.00	591.00
SUFCON	-1.37	0	-1.37	0.00	-5.60	0.00

a/ Base Scenario: Price of sugarcane MK0.50/cane, median tomato yields, and price of tomato MK1.00/kg
b/ Scenario A: Price of sugarcane MK0.25/cane, median tomato yields, and price of tomato MK1.00/kg
c/ Scenario B: Price of sugarcane MK0.25/cane, mean tomato yields, and price of tomato MK1.00/kg
d/ Scenario C: price of sugarcane MK0.50/cane, mean tomato yields, and price of tomato MK0.50/kg
e/ SFIRST: Safety first solutions; NRCON: Non-risk Constrained Solutions

Source: Survey Data 1993/LP88 Results

7.2.1 The Non-risk Constrained Solutions

7.2.1.1 Activities in Solutions

In all the three scenarios, fertilized maize/beans/pigeon peas is dominant on rainfed land in the non-risk constrained solutions. On dimba land, maize is dominant in Scenario A, tomatoes in Scenario B and sugarcane in Scenario C. The maximum mean returns for these three cases are MK1,158, MK1,482 and MK1,380. The base solution has an expected income of MK1,380.

7.2.1.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The shadow price of dimba land has gone down from MK3,338 in base scenario to MK1,632 and MK1,421 in Scenarios A and B respectively. This is due to the low profitability of dimba maize and tomato at the prices and yields in these scenarios. Values of the sufficiency condition are higher for Scenario A and B, reflecting that its relaxing it by one unit would add more to the expected value of the objective function than in the base or Scenario C.

Under Scenario A, sugarcane competes with dimba maize at zero cost per hectare on small farms; tomatoes at cost of MK37 per hectare on medium farms; and sugarcane and tomato both at zero cost per hectare on large farms. These results show that the kinds of crop mixes grown by farmers can be varied among dimba maize, tomato and sugarcane when the price of sugarcane is low. When it is high, as in the base solution, sugarcane is dominant. On rainfed land, maize/beans/groundnuts can be exchanged with fertilized maize/beans/pigeon peas at a cost of MK24/ha. The optimal crop mixtures are: maize/beans/pigeon peas, rainfed peas for rainfed land in all scenarios; on dimba land maize for Scenario A; tomato for Scenario B or sugarcane for Scenario C. Thus, fertilized maize/beans/pigeon peas is dominant under all scenarios with no risk aversion. But each scenario has a unique dimba crop.

7.2.1.3 Contribution of Dimba Crops to Income

The proportional contribution of dimba crops to income under the three scenarios is shown in Table 7.7. The base scenario has a sugarcane price of MK0.50 and median tomato yields at MK1.00. Scenario A has a MK0.25 sugarcane price and median yields of tomato at a price of MK1.00. The contribution of dimba land falls from 35% in the base solution to 30% in Scenario A. Rainfed land contributes only 19% and off-farm IEAs 51% in Scenario A.

In Scenario B, the price of sugarcane is at MK0.25 and mean tomato yield at MK1.00. Tomatoes are in the optimal solution. The contribution of dimba land is 48% and that of rainfed land 15%. It is thus demonstrated that the contribution of dimba land to income is dependent on the price of what is grown on it. However, under each scenario the contribution of dimba crops to income is considerable.

Table 7.7

Model I - Contribution of Dimba, and Rainfed Land Crops

and Off-Farm IEAs to Total Income Under Three Scenarios

Small Farms [a]

	Base Solution	Scenario A	Scenario B	Scenario C
Expected Income (MK)	138	1158	1482	1380
Rainfed Land	16%	19%	15%	16%
Dimba Land	35%	30%	48%	35%
Off-farm IEAs	49%	51%	36%	49%

a/ The figures are for the NRCON Solutions. The difference in proportions between the NRCON and Safety First solutions is mostly 1 to 2 percent.

Source: Survey Data 1993

7.2.2 Safety First Solutions

7.2.2.1 Activities in Solutions at the 0.25 Probability Limit

Scenarios A and B have non-fertilized maize/beans/pigeon peas on rainfed land. Scenario A has maize and Scenario B has tomato on dimba gardens. Maize/beans/pigeon peas is sill optimal on rainfed land in Scenario C and sugarcane dominates in dimba land. There is a small amount of cabbage and dimba maize. These crop combinations generate incomes of MK1,118, MK1,455 and MK1,348 for the small farms with respect to the scenarios.

7.2.2.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The shadow prices of rainfed land are MK348 for Scenarios A and B, and MK2,296 in Scenario C. The much higher dual value in Scenario C is due to fertilized maize. For dimba land, these are MK4,481, MK10,151 and MK18,330. The difference is due to the profit that optimal crops in each scenario can generate. In Scenario A, tomatoes, sugarcane and cabbage can substitute each other depending on which crop is in the optimal solution. In Scenario B only cabbage competes with tomatoes at zero cost per hectare. Under Scenario C there in no competition to the sugarcane optimal solution on dimba land.

7.2.2.3 The Contribution of Dimba Crops to Income

The pattern here is the same as that for non-risk constrained solutions. The level of contribution depends on the prices and yields assumed. Scenario B has highest contribution from dimba crops (48%).

7.3 Lessons from Model I

The foremost lesson from Model I is the contrast between the results of the maize production and income approaches. The first contrast is the level of incomes. Those of the income approach are lower when the sufficiency condition is binding. The second difference is the optimal crop mixes. The non-risk constrained solutions have fertilized maize/beans/pigeon peas, whereas when safety first goals are constraining the non-fertilized maize/beans/pegion peas is optimal.

With respect to cropping patterns, it was shown that when farmers are risk averse, stable and higher incomes from dimba crops can make fertilizing maize optimal. In the base scenario and also in Scenario C, the higher value of sugarcane, a very yield stable crop, enables fertilized maize to be optimal. However, under this model only local maize is optimal, not hybrid varieties. This may explain the disappointing past experience of non-adoption of hybrid varieties. Credit was made available only for hybrid maize and other rainfed crops. This did not solve the basic problem of income risk due to yield risk because all crops for which credit was available are subject to yield risk and have very low gross margins in bad years. Efforts to increase incomes from dimba cultivation can have the desired impact of making farmers adopt fertilizer on maize. Therefore, credit and extension programs need not be maize centered to encourage fertilizing for maize.

Under current cropping practices, when *a)* farmers are very risk averse, or *b)* they base their safety goals on income (i.e. perceive fertilized maize as a cash crop), and have unstable and low non-rainfed land sources of income, they should not fertilize rainfed maize. The fact that a large proportion of farmers do fertilize their maize indicates that they have other sources of income to manage the risk of fertilizing maize or else they perceive fertilized maize as a food producing activity. Both of these factors are at work in this area. The analysis has shown dimba land can provide higher incomes. This plus the proximity of the large urban area of Limbe-Blantyre provides a reliable market for dimba crops for farmers from this area. Wage employment may also be a factor in the stabilizing incomes.

The contribution of dimba crops to income varies from 35% to 48% depending on size of farm. It also depends on the value of crops grown. Small sized farms could derive half of their income from off-farm IGAs.

7.4 Validating the Model

Model I represents the current situation of farmers. The results of the model indicate that it performs reasonably well when compared to the descriptive results reported in Chapter 5. First, the activities in the solutions as well as the most competitive crops are dominant in farmers' cropping patterns. These are maize based crop mixtures and relay peas on rainfed land, and with sugarcane, tomatoes, dimba maize, and cabbage in dimba gardens. The solutions to the base scenario and sensitivity analysis show that the model farms adjust to grow different crops depending on price relations. This implies that careful market studies should be done to assess the market and effective prices for crops in order to ascertain the optimal crop mixtures farmers should grow in different areas and at different times. It also implies that some method of managing supply is needed given the thin vegetable markets and related price volatility.

The labor hired depends on the cropping mix in the optimal solution. Growing tomatoes or dimba maize calls for more hired labor than growing sugarcane. The LP results prescribe hiring labor only for large farms. In the survey results, all farm sizes hire labor, but the frequency is higher among larger farms. The difference between the LP and survey results may be explained by the observation that more adults from small sized farms households tend to work off-farm. In these households, hiring labor is used to substitute for the working persons.

Another plausible explanation concerns the estimation of labor available. In this analysis, it was assumed that the equivalent of two adults are available to work 5 hours a day during rainy season and 6 hours in the dry season, 25 days in a month. These figures apply to all farm sizes. Some survey results indicate that small farms have less labor. For example, the 1984/85 annual survey of agriculture showed than the labor available varies from 510 to 1,548 person hours with respect to farm size (Malawi Government 1985). What is not clear in these reports is how the labor available was assessed. Assuming that only one adult is available to work the whole year, for only 3 hours a day gives about 1,000 person hours. It appears that the hours reported as available are hours actually worked. In the LP results, small farms have so much agricultural slack labor that even if the amount available is reduced to half, they would not need to hire labor. This suggests that small farms may be using more than half of their available labor time on IEAs and, thus, need to hire labor to meet the requirements of cropping activities. In this part of Blantyre ADD farms take up seasonal wage labor in factories like those that process tobacco.

Optimal solutions always include intercropped enterprises on rainfed land. This is a dominant practice in the area. Risk averse behavior favors diversification, and crops with high minimum returns which, in many cases, have low average gross margins. These are most likely to be enterprises that do not use fertilizer.

To sum up, except for the case of hiring labor, the model tracks very well what the farmers are currently doing. It provides a rationale for the variety of cropping patterns that are observed. The variety of cropping mixes can be explained by difference in the level of safety first goals and crop yields and their prices.

CHAPTER 8: MODEL II - CURRENT AND INTENSIVE CROPPING PRACTICES

In this chapter the results of Model II are presented, discussed and compared to those of Model I. Model II supplements Model I with the opportunities for farmers to upgrade their cropping practices from current to intensive status by using more chemicals, e.g. Copper Oxychloride, D.D.T., Sevin and Ripcord and fertilizers such as 20:20:0, Calcium Ammonium Nitrate, Double Ammonium Nitrate and Sulphate of Ammonium. They also use more labor on intensive enterprises. This is done without irrigation. Results of Model II should throw light on whether intensive cropping practices are optimal vis-a-vis current practices given that they require more expenditures on inputs and use of more labor. They also provide a base for measuring the worth of irrigation investments. Hybrid maize is included as an intensive activity intercropped with beans and pigeon peas.

8.1.1 Non-Risk Constrained Solutions and the Maize Production Approach

8.1.1.1 Activities in Solutions

The general pattern of solutions at the three probability levels is shown in Table 8.1 for small farms only. The non-risk constrained solution and the maize production approach give the same results as in Model I. Hybrid maize has the highest maize yields and the highest gross returns on rainfed land.

It is clear that hybrid maize combinations are optimal only at low levels of risk aversion (low safety goals or low probability limits). When risk aversion increases, intensive maize/beans/groundnuts is optimal on rainfed land. Hybrid maize is not optimal because of very low returns in years of drought. On dimba land, mixtures of the two crops, cabbage and chinese cabbage, vary depending on the goal and probability levels. Cabbage enters the solution in small amounts at high level of risk aversion because it has high yields in year 1 when chinese cabbage has low yields. Such crop diversification helps to manage risk.

The results pertaining to the 0.25 probability limit are in Table 8.2. When risk aversion is low, the farmers meet maximum feasible income goals with intensive maize/beans/pigeon peas and chinese cabbage. The maximum mean returns are MK2,261, MK2,898 and MK5,019 for the small, medium and large farms respectively.

Table 8.1
Model II - Safety First Solutions Using Telser's Probabilistic Criterion and Atwood's Lower Partial Moments At Probability Limits 0.25, 0.33 and 0.40 - Small Farms

Prob. Limit 1/L*	Goal g (MK)	Expected Income (MK)	Crop Activities				
			HMzBPp	IMzBGn	RFPeas	ICcab	ICab
All	0[b]	2,261	0.45	----	0.45	0.13	----
0.25	1,120	2,258	0.17	0.28	0.45	0.13	----
	1,240	2,207	----	0.45	0.45	0.09	0.04
	1,426[a]	2,112	----	0.45	0.45	0.02	0.11
0.33	1,270	2,260	0.38	0.07	0.45	0.13	----
	1,290	2,223	----	0.45	0.45	0.12	0.01
	1,426[a]	2,112	----	0.45	0.45	0.02	0.11
0.40	1,380	2,258	0.19	0.26	0.45	0.13	----
	1,480	2,226	----	0.45	0.45	0.11	sm
	1,469[a]	2,186	----	0.45	0.45	0.08	0.05

a/ Maximum feasible goal is at the probability limit.
b/ This corresponds to situation of no risk aversion.
sm: very small amounts

Source: Survey Data 1993/LP88 Results

Table 8.2
MODEL II - Safety First Solutions with Telser's Probabilistic Criterion and Atwoods Lower Partial Moments At the 0.25 Probability Limit

Level of Activities in Solutions

Activity	Small NRCON[a]	Small SFIRST[b]	Medium NRCON	Medium SFIRST	Large NRCON	Large SFIRST**
Expected Income (MK)	2,261	2,112	2,898	2,668	5,019	5,019
Goal Income (MK)	0	1,423	0	2,067	0	2,500
Crop Production Activities (Ha)						
Imzbppf	0.45	----	1.06	----	2.49	
Imzbgnf	----	0.45	----	1.06	----	2.49
Rainfed Peas	0.45	0.45	1.06	1.06	2.49	2.49
Iccab	0.13	0.02	0.17	0.01	0.33	---
Icab	----	0.11	----	0.16	----	0.33
Off-Farm IGAs (Person-Hours)						
January	163	183	60	106	---	240
February	240	240	240	240	240	---
March	205	205	158	158	48	48
April	70	128	---	95	---	---
May	---	42	---	---	11	---
June	41	154	---	134	300	---
July	180	81	130	---	230	---
August	134	23	---	---	---	---
September	147	218	29	137	---	---
October	291	291	279	279	158	252
November	291	291	279	279	234	252
December	163	183	60	106	---	---

Cont'd/...

Table 8.2 (Cont'd)

Selling Activities (Kilograms)						
Rainfed Maize	1292	849	3042	2000	3476	4898
Beans	90	59	212	137	276	323
Pigeon Peas	41	---	96	---	179	---
Groundnuts	---	---	----	149	---	351
Rainfed Peas	71	71	167	167	393	393
Chinese Cabbage	3099	481	----	81	----	---
Cabbage	---	2273	4053	3449	2572	6833
Hired Labor Activities (Person Hours)						
January	--	--	--	--	97	73
April	--	--	126	18	180	407
May	43	--	237	88	115	510
June	--	--	38	--		15
July	--	--	--	19	266	338
August	--	--	1	168		693
September	--	--	--	--	241	75
December	--	--	--	--	95	73

a/ Non-risk Constrained Solutions - are the same as for Maize Production approach solutions
b/ SFIRST Solutions
**/ The safety first solution for large farms is not constrained by risk aversion. Thus, the goal of MK2,500 at the 0.25 probability limit does not present a risk problem for large farms.

Source: Survey Data 1993/LP88 Results

With this result, only the representative large farms may achieve returns that are higher than the minimum income requirement of MK2,500 in 75% of cropping seasons.

8.1.1.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The shadow prices of land are MK384, MK9,463 and MK41 for rainfed land, dimba and relay rainfed land respectively (Table 8.3). The shadow prices of land have shot up in Model II by 97% for rainfed land and 183% for dimba land. The dual value for relay use of rainfed land stays the same because the field peas crop does not have recommended intensive practices. These values show a dramatic increase in the value of land if intensive cropping practices are followed.

On rainfed land, intensive maize/beans/groundnuts competes with hybrid maize/beans/pigeon peas at zero cost of forcing into solution, except on medium farms where it would cost a meager MK11/ha. This shows that even when farmers are not risk averse, hybrid maize has serious competition from fertilized local maize based crop mixtures. This is due to low on-farm yields of these hybrid maize varieties. On dimba land, tomato competes with chinese cabbage on small farms and medium farms; and on large farms, cabbage and tomato compete with chinese cabbage--all of these at zero cost per hectare.

Table 8.3

Model II - Shadow Prices of Resource and Constraints

Resource/Constraint	SFIRST[a]	NRCON[b]
Land (MK/Ha)		
Rainfed Land	485.00	384.00
Relay Rainfed Land	88.00	41.00
Dimba Land	1,342.00	9,463.00
Labor All Months (MK/Person-hour)	0.25	0.25
Sufficiency Condition	-0.51	0

a/ SFIRST = Safety First Solutions
b/ NRCON = Non-risk Constrained Solution

Source: Farm Survey 1993/LP88 Results

8.1.1.3 Contribution of Dimba Crops to Income

In Model II, dimba crops contribute more to total income than in Model I. The results are displayed in Table 8.4. First, income increases by 64%, 75% and 98% respectively for the three farm sizes. Most of the increase is due to dimba crops. However, income from dimba crops increases by 202% for small farms, 195% for medium farms and 186% for large farms. The average proportion of dimba income in total income has changed from 38% in Model I to 64% in Model II. These results highlight the importance of the dimba land resource and the potential of intensive dimba cultivation to significantly increase incomes.

The flip side of this result is that most labor is now absorbed in intensive cultivation so that there is enough slack labor to generate only 21% of the total income from off-farm IGAs compared to 49% in Model I on small farms. The increase in total income is not enough to make up for the increase in labor use so that average returns to a person hour of

Table 8.4
Model II - Contribution of Dimba and Rainfed Land and Off-Farm IEAs to Total Income in Non-risk Constrained Solution

	Size of Farm		
	Small	Medium	Large
Rainfed Land	15%	25%	28%
Dimba Land	64%	64%	67%
Off-farm IGAS	21%	11%	5%
Total Income (MK)	2,261	2,898	5,019

Source: Survey Data 1993/LP88 Results

labor used on farm work falls from MK2.21 in Model I to MK1.56 in Model II. Selling labor or IEAs as modelled here are not risky activities and should thus dominate the results. However, the returns to labor from farm production are significantly higher than the mimum wage of MK0.25, so that the use of labor on risky enterprises is optimal.

8.1.1.4 Maximum Feasible Maize Production

The non-risk constrained solution coincides with the maximum goal solution using the maize production approach. The reason is the same as in Model I - Fertilized maize/beans/pigeon peas is mean-minimum dominant among the rainfed maize producing enterprises. The maximum feasible maize production goals for small and medium farms are 617 kg and 788 kg at the 0.25 probability limit (see Table 8.5). They correspond to expected maize production levels of 1,291 kg, 3,042 kg. Large farms can achieve their maize consumption requirements with no risk constraint. Therefore, when intensive cultivation is practiced, small and medium farms cannot expect to achieve their minimum maize consumption of 1,000 kg in 75% of the cropping seasons.

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Table 8.5
Model II - Maximum Feasible Maize Production Goals
by Allowable Probability of Failure

Probability Limit	Small	Medium	Large
0.25	617	788	NB
0.30	800	NB	NB
0.40	895	NB	NB

NB = Not Binding, the 1,000 kg maize requirement can be met and does not constrain solution.

Source: Survey Data 1993/LP88 Results

8.1.2 Safety First Solutions

8.1.2.1 Activities in the Solutions

The optimal crop activities were shown in Table 8.2. They are fertilized maize/beans/groundnuts and cabbage with a small portion of chinese cabbage on dimba land for small and medium farms. Cabbage is the sole crop for large farms. The optimal returns are MK2,112, MK2,668 and MK5,019. They correspond to income goals of MK1,423, MK2,067, and MK2,500. The solution for large farms is not constrained by risk. Small and medium farms cannot hope to achieve their minimum income requirements. They can only assure that the optimal incomes are not less than MK1,423 and MK2,067 in three quarters of the cropping seasons.

8.1.2.2. Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The shadow prices of rainfed and dimba land are MK485 and MK13,420 respectively (Table 8.3). The safety first premium of dimba land is thus MK3,957 and that for rainfed land MK101. These figures compare with MK1,605 and MK328 for Model I. *In Model I* *rainfed land has a higher safety first premium than in Model II. This shows that intensive farming practices on dimba land helps in managing risk.* If the farmer is very risk averse, she should be willing to pay this risk premium over the value of crops to be produced from the land. This value can be used in appraising irrigation investments for cases where risk is structured as defined by yield variability in this study and farmers are as risk averse as specified by the goals and probability levels in this model. The dual of the sufficiency condition is -0.51.

When safety first income goals are at their maximum feasible for small and medium farms, hybrid maize does not present any competition to intensive maize/beans/groundnuts. On large farms, some of the current dimba enterprises, sugarcane, maize and maize/pumpkin leaves can be introduced at no cost. Intensive tomatoes and chinese cabbage would also cost nothing to introduce into the optimal solution.

8.1.2.3 Contribution of Dimba Crops to Total Income

The structure of results for the contribution of various resources to income are the same as under the non-risk constrained solutions. Dimba land contributes 60% of total income.

8.1.2.4 The Maximum Feasible Maize Production

The expected maize production levels when there is income risk aversion are 849 kg, 2,000 kg and 4,698 kg. These are lower than in the case of no risk aversion because now farmers need to grow those crops that maximize income while minimizing risk.

8.3 Lessons from Model II

The first lesson from Model II is that intensive cultivation can make fertilizer use optimal even at high levels of risk aversion. This is due to the increased yields that can be achieved with intensive use of fertilizer. Second, when the income approach is used, dimba land has a higher safety first premium than in Model I, indicating the value of this land to the farmer in managing risk. The third lesson is that higher yields and incomes are still not enough to make hybrid maize optimal. Thus, even when intensive dimba cultivation is practiced farmers may find fertilized hybrid maize still too risky to adopt on rainfed land.

CHAPTER 9: MODEL III - CURRENT, INTENSIVE AND IRRIGATED CROPPING PRACTICES

Model III allows representative farms to select crops grown with current or intensive practices on rainfed land, and replaces dimba crops with irrigated ones. In Model III(a) dimba crops have been replaced by irrigated horticultural crops. In Model III(b) the irrigated crops are cereals--maize, rice and wheat. The area of irrigated land is limited to that of dimba land. This is done to facilitate comparison between the models.

The discussion is based on a base scenario which assumes the costs of sprinkler irrigation and the prices that farmers attempted to get for their produce at the Mchenga and Diamphwe projects. Sensitivity analysis is done to demonstrate the impact of lower costs and prices on incomes.

9.1 Base Solutions

9.1.1 Model III(a): Irrigated Vegetables

9.1.1.1. Activities in Solutions

The results for Model III(a) at the three probability levels for small farms are shown in Table 9.1. With irrigation available, yields become sufficiently stable so that differences between risk and safety first solutions are negligible. An important difference from Model II is that now hybrid maize can linger in the optimal solutions until the very end of the binding but feasible region, when intensive maize/beans/groundnuts takes over completely. The outcomes are not very different for the risk and non-risk constrained solutions: The optimal returns differ by a few Malawi Kwachas. The major difference is in the crops on rainfed land. The safety first constrained solution has intensive maize/beans/groundnuts while the non-risk solution has hybrid maize/beans/pigeon peas. The safety first goal at the level of minimum income requirement is binding only for small sized farms. For this reason and also because the non-risk constrained solutions coincide with solutions to the maize production approach, in most of the following discussion, reference is made only to the non-risk constrained solutions. *It is important to note that with irrigation, farmers who set their safety goals using the maize production approach will behave in almost the same way as those who use the income approach.*

The results for the 0.25 probability limit are shown in Table 9.2. Tomatoes in seasons 1 and 3, and cabbage in season 2 are optimal on dimba land. On rainfed land hybrid maize/beans/pigeon peas is optimal. The maximum expected incomes are MK3,066, MK3,947 and MK7,041 for the three farm sizes. Small farms hire labor, 220 person hours, only in August. Medium farms hire a total of 789 person hours in six months. Large farms hire 3,387 person hours in eight months. The level of crop selling and off-farm IEAs are displayed in Table 9.2.

9.1.1.2 Shadow Prices, Stability of Solutions and Competitiveness of Enterprises

The dual values of land are shown in Table 9.3. The value is MK384 for rainfed land under non-risk constrained solution, and MK390 under the safety first solutions. For irrigated land the values increase from MK1,665 to MK1,795 due to risk in seasons 1 and 3, and from MK12,225 to MK13,296 in season 2.

The safety first premiums of various types of land are also displayed in Table 9.3 for the three models. The magnitude of the safety first premium is dependent on the value of crops grown and the dual of the sufficiency condition. Rainfed land has less safety first premium as the risk of failure to meet the safety first goal decreases from Model I through to Model III. Despite the comparatively high value of irrigated crops in season 2, the safety first premium is lower than under intensive dimba cultivation because production risk is lower with irrigation. Put differently, the incomes in Model III are high and stable enough that additional units of irrigated land do not have as high a value in satisfying safety first goals as dimba land has in Models I and II.

Table 9.1
Model III(a) - Safety First Solutions Using Telser's Probablistic Criterion and Atwood's Lower Partial Moments Using the Income Approach At Probability Limits 0.25, 0.33 and 0.40 - Small Farms

			Crop Activities					
Prob. Limit 1/L*	Goal g (MK)	Expected Income (MK)	HMzBPp	IMzBGn	RFPeas	RTomS1	RTomS3	RCabS2
All	0	3066	0.45	----	0.45	0.13	0.13	0.13
0.25	2437	3066	0.448	0.002	0.45	0.13	0.13	0.13
	2467	3063	0.440	0.006	0.45	0.13	0.13	0.13
	2500	3061	----	0.450	0.45	0.13	0.13	0.13
0.33	2506	3065	0.438	0.013	0.45	0.13	0.13	0.13
	2540	3063	0.156	0.294	0.45	0.13	0.13	0.13
	2551	3061	-----	0.450	0.45	0.13	0.13	0.13
0.40	2542	3066	0.448	0.310	0.45	0.13	0.13	0.13
	2551	3065	0.180	0.264	0.45	0.13	0.13	0.13
	2572	3061	-----	0.450	0.45	0.13	0.13	0.13

Source: Survey Data 1993/LP88 Results

Table 9.2
Model III(a) - Safety First Solutions with Telser's Probablistic Criterion and Atwood's Lower Partial Moments Using the Income Approach At the 0.25 Probability Limit

Level of Activities in Solutions

Activity	Small NRCON[a]	Small SFIRST[b]	Medium NRCON/SFIRST	Large NRCON/SFIRST
Expected Income (MK)	3,066	3,061	3,947	7,041
Crop Production Activities (Ha)				
HMBPp	0.45	----	1.06	2.49
IMzBGn	----	0.45	----	----
Rainfed Peas	0.45	0.45	1.06	2.49
RCabS2	0.13	0.13	0.17	0.33
TomS1	0.13	0.13	0.17	0.33
TomS3	0.13	0.13	0.17	0.33
Off-farm IEAs (Person hours)				
January	47	66	---	---
February	181	181	163	91
March	156	156	75	---
April	71	93	---	---
May	121	142	---	---
June	268	268	259	221
July	256	258	229	151
August	---	---	---	---
September	115	115	---	---
October	232	238	203	103
November	182	182	136	---
December	58	77	---	---

Cont'd/...

Table 9.2 (Cont'd)

Table 9.2 (Cont'd)

Selling Activities (Kilograms)				
Rainfed Maize	1,291	853	3,042	7,146
Beans	90	58	212	498
Pigeon Peas	40	---	96	226
Groundnuts	---	63	---	---
Rainfed Peas	71	71	167	393
TomS2	---	---	---	---
TomS1&3	642	642	840	11,048
CabbageS2	4,352	4,352	5,691	1,630
Hired Labor Activities (Person-hours)				
January	---	---	91	476
March	---	---	---	169
April	---	---	123	637
May	---	---	23	407
July	---	---	---	266
August	220	220	464	1,261
September	---	---	12	371
November	---	---	---	23
December	---	---	78	449

a/ NRCON - Non-Risk Constrained Solutions - are same as Maize Production approach solutions
b/ SFIRST - Safety First Solutions

Source: Survey Data 1993/LP88 Results

Table 9.3
Safety First Premium of Rainfed, Dimba and Irrigated Land in Models I, II and III

	Model I		Model II		Model III	
	DV NRCON	SF Prem	DV NRCON	SF Prem	DV NRCON	SF Prem
Rainfed Land	192	328	384	101	384	6
Dimba Land	1,632	1,605	13,420	3,957	na	na
IRLDS1	na	na	na	na	1,665	194
IRLDS2	na	na	na	na	12,225	1,071
IRLDS3	na	na	na	na	1,665	194

na = not applicable
DV NRCON = Dual Value for Non-risk Constrained Solution
SF Prem = Safety First Premium, the difference between dual value of non-risk constrained solution and safety first solution
IRLDS1, IRLDS2, IRLDS3 = irrigated land seasons 1, 2 AND 3
Source: Survey Data/LP88 Results

The dual value of the sufficiency condition under Model III is very low, -0.08, because the condition is not very constraining. Reducing the goal by MK1.00 will increase the returns by only 8 tambala. Put differently, safety first behavior is barely necessary when farmers use some formal irrigation. A caveat in this regard is that yields used in the analysis do vary by season but not by year. If yearly variation of seasonal yields is allowed the 'safety first' premium would be higher.[2] Some crops compete at low cost with those in solution: intensive maize/beans/groundnuts competes with hybrid maize/beans/pigeon peas on rainfed land at cost of MK11/ha; and onions compete with cabbage in season 2 at a cost of (MK0.5)/ha. In season 1 and 3 there is no competition with tomatoes.

[2] A needed qualification is that sometimes other kinds of risk are introduced by participating in irrigation. Production becomes dependent on inputs whose supply may be unreliable.

Price stability analysis shows that pumpkin leaves would enter solution if its price rose to MK0.67/ kg, in seasons 1 and 3. However, it is unlikely that in season 3 prices would go up because markets for pumpkin leaves do glut. The price of beans would have to go up 50% to MK1.57 for that enterprise to enter solution, and the same for tomatoes in season 2. The case for tomatoes is more likely. Thus, farmers can split their plots between tomatoes and cabbage in season 2 if the cabbage price is anywhere near Mk1.50/kg, making three possible crops with onions as shown above. In season 1, both pumpkin leaves and tomatoes can be planted. In season 3, tomatoes are dominant. This is a season of extreme scarcity of tomatoes due to pests and diseases. Careful management to ensure high yields can lead to very high returns. Reports from irrigation projects indicate that extension staff and farmers have been slow in responding to some tomato diseases [Lilongwe ADD 1993(a)].

9.1.1.3 Contribution of Irrigated Crops to Total Income

The contribution of irrigated crops to income is shown in Table 9.4. On average it is 76%. *Noticeable is that the possible contribution of off-farm IEAs goes down to 14% from 49% in Model I for small farms, 31% to 8% for medium farms and 12 % to 2% in the case of large farms. This is evidence that irrigation can absorb a lot of labor.* Our approach to off-farm IEAs is to assume alternative use of agricultural slack labor at MK0.25. The opportunity to use it may not exist, and in that instance irrigation provides a way of assuring that there is less under- or unemployment.

Table 9.4
Model III(a) - Contribution of Irrigated and Rainfed Land and Off-Farm IEAs to Total Income

	Size of Farm		
	Small	Medium	Large
Rainfed Land	10%	17%	20%
Irrigated Land	76%	75%	78%
Off-Farm IEAs	14%	8%	2%
Total Income (MK)	3,066	3,947	7,041

Source: Survey Data 1993/LP88 Results

As in the cases of Models I and II, the contribution of land depends on the profitability of the enterprises grown on it. In Model III an important determinant of profitability is the cost of irrigation. The lower the cost of irrigation the higher the contribution of irrigated land to income. In particular, gravity fed/furrows irrigation can lead to farms generating up to 81% of income from their irrigated land.

9.1.1.4 Maximum Feasible Maize Production

The maximum feasible maize yields are the same as under Model II; the reason being that the same optimal activity hybrid maize/beans/pigeon peas will give these yields. However the total income possible does change and is the same as in the non-risk constrained solutions for Model III.

9.1.2. Sensitivity Analysis for Model III(a)

9.1.2.1 Sensitivity to Changes in Cost of Irrigation

The results of expected income by type of irrigation are presented in Table 9.5 and provide some important insights. First, the returns to farmers for the four types of irrigation show the profit that farmers can generate if government were to subsidize sprinkler irrigation.

Second, even seemingly high cost sprinkler irrigation has the potential to give returns above the costs of capital and operations. This is in spite of low yields for some seasons.

Table 9.5
Model III - Returns Under Various Types of Irrigation for Small Farms

	Costs (MK)[1]	Costs Relative Pump/Sprinkler System	Returns (MK)
Pump/Sprinkler	7,379	100%	3,066
Pump/Furrows	4,776	34%	3,386
Borehole/Furrows	2,166	70%	3,726
Tank/Furrows	1,852	74%	3,767
Gravity/Furrows	621	91%	3,927

1/ Costs include amortized debt, maintenance and operating costs

Source: Department of Irrigation, Lilongwe ADD & LP Analysis

9.1.2.2 Sensitivity to Changes in Prices of Output (With Sprinkler Irrigation)

Sensitivity analysis for the price of tomatoes, and chinese cabbage. The prices of these two crops vary much by season and they are the most difficult to sell because of high perishability. When the price of tomato in seasons 1 and 3 is reduced from MK2.00 to MK1.00, the returns drop to MK2,691 for small farms, and chinese cabbage comes into solution in both seasons. The dual values of irrigated land in seasons 1 and 3 fall accordingly to MK216. Then pumpkin leaves show strong competition. The price increase necessary for pumpkin leaves to enter solution is only MK0.04. The same is true for beans, at MK0.10. Tomatoes could go back into solution at MK1.41. Therefore, if farmers cannot get a good price for tomatoes in seasons 1 and 3 (i.e.> MK1.41) they can also plant pumpkin leaves and beans.

Holding the above scenario constant, and adding a lower price of chinese cabbage leads to a lower income still, MK2635, since no activity can substitute the two chinese cabbage crops and the land should be left fallow. This result is of special concern since leafy vegetables are difficult to market (LADD 1993). Farmers may have to reckon with low prices and it may be optimal to not grow crops in some seasons. However, they can grow crops if less costly irrigation is used. Cabbage still remains in solution under this scenario. However, farmers will need to use earnings from growing cabbage to pay the whole year's debt. Since the debt is split into MK313 for every season, MK626 will be subtracted farther from MK2,635 to give MK2,009. In this case, it is still possible for farmers to make a positive yearly income. They are at almost the same level as in Model II (MK2112)[3]. If irrigation is done by farmers without dimba land and with only 0.45 hectare of rainfed land, this income represents a significant improvement since dimba land small sized farms can expect an income of only MK946. This income improves the situation of small sized farms with dimba land from MK1,380 in Model I to MK2,009 in Model III(a).

9.1.2.3 Sensitivity to Changes in Wages

The minimum wage of MK0.25 is reduced by 50% for both labor selling and labor hiring activities. The results show that small farms' expected returns fall by MK30 and for large farms they increase by MK103 to MK7144. Medium farms are not affected because they sell as much labor as they hire.

9.1.3 Model III(b): Irrigation of Cereals

Model III(b) deals with growing cereal crops of maize, rice and wheat using gravity fed irrigation in addition to rainfed crops. Two cropping seasons with irrigation are modelled in addition to the normal rainfed cultivation practices. Enterprise budgeting showed gravity fed irrigation to be the most financially robust way to irrigate cereals. (See Tables A6.8 and A6.9, and A6.16-A6.19 in Appendix A for gross returns to growing cereals with the different

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[3] This is the return at maximum goal in Model II. Since irrigation practically removes risk, it is fair to compare the two figures.

irrigation methods.) Wheat and maize have not been grown extensively using irrigation. Enterprise budget analysis shows that when maize is grown intercropped with beans it may be more profitable than growing rice monocropped. The emphasis on irrigating rice has been justified by its stronger foreign exchange earning ability compared to maize. Irrigating wheat may increase production and thereby save foreign exchange since wheat is mostly imported. The demand for wheat is ever-increasing, with increased urbanization and demand for fast foods. The government of Malawi has expressed need to encourage growing of wheat with irrigation [Malawi Government 1992(c)].

9.1.3.1. Activities in Solution

When the representative farms are operated with no risk aversion, it is optimal to grow hybrid maize, with beans and pigeon peas, and relay field peas on rainfed land. Wheat is optimal in both seasons on irrigated land. The gross returns are MK1,223, MK1,536 and MK2,361 with respect to farm size. These figures are lower than for those for Model I. The shadow price of MK681 for the two irrigation seasons is the returns to growing wheat. Those of rainfed land remain at MK381 and MK41.

9.1.3.2. Shadow Prices, Price Stability and Competitiveness of Solutions

Under the maize production approach, the dual values for land are MK390, MK47, and MK766 for rainfed, relay rainfed and the two irrigation seasons respectively.
Price stability analysis shows that wheat will remain in solution unless its price drops to MK0.39. Intensive maize/beans/groundnuts competes with hybrid maize/beans on rainfed land. On irrigated land there is no competition to wheat from rice or maize. Forcing them into solution would cost MK643 and MK569 respectively.

In this model, the maize safety first goals are not binding, except for small farms. Thus, small farms can now meet cereal consumption requirements but are still constrained by risk aversion behavior. With the income approach, intensive maize/beans and groundnuts are optimal on rainfed land and wheat in the two irrigation seasons. Hybrid maize is optimal at moderately high levels of risk aversion. Large, medium and small farms can assure that the expected returns of MK2,333, MK1,524 and MK1,218 are above goal levels of MK411, MK680 and MK1451 in 75% of the cropping seasons.

9.2. Lessons from Model III

With irrigation, farmers can meet their minimum income requirements in 75% of the cropping seasons especially if lower cost irrigation is used. Model small farms may not be self-sufficient in maize production if all the irrigated land is used for horticultural crops, but they can earn enough income to meet their subsistence needs in 75% of cropping seasons.

The representative households may now be able to use almost all their labor on their farms. This can help to control rural-urban migration. In addition, the returns to labor used on the farm are higher than minimum wage of MK0.25.

Farmers without dimba land can benefit from irrigation, even the costly sprinkler system. This is the case even with low yields and prices of crops in some seasons. It is necessary that they get good yields and prices in at least one season to profitably use the system.

Sensitivity analysis results show that even when prices of some horticultural crops are lowered, the optimal solutions do not include unfertilized maize crops, as was the case in Model I. Thus, irrigated cultivation may enable adoption of fertilizer on rainfed maize. In Model II, hybrid maize is optimal at low levels of safety goals. As soon as the sufficiency condition becomes binding it is forced out of solution because it aggravates the risk already existent with dimba cultivation. In Model III, even at moderately high safety goals, hybrid maize remains in solution because the stable yields of irrigated crops make it less risky to grow hybrid maize. This is good for both food and income security since hybrid maize increases returns to rainfed land.

Irrigation may be considered superior to intensive dimba cultivation in that it can encourage the adoption of fertilized hybrid maize varieties on rainfed land by farmers with moderately high risk aversion, even when they view it as cash crop (i.e. income approach). This is important because the growing of maize using most irrigation methods may be unprofitable; therefore, other sources of stable income may be needed to cushion against the risk of growing it under rainfed conditions. This can have a very significant positive impact on food security if the hybrids are of types preferred by farmers and can also improve returns to rainfed land.

Model III(b) has an important lesson. Although it leads to lower gross returns than Models I and III and III(a), it has potential to assure representative farms of all sizes of their cereal requirements in 75% of the cropping seasons. In Models I, II and III(a) only large farms could hope to achieve cereal self-sufficiency in 75% of the cropping seasons. In situations where markets for cereals do not function well and markets for horticultural crops are uncertain, this may be the most attractive way of dealing with food insecurity in households. In this case, rather than just growing only rice, households should be helped to adopt mixed cropping with irrigation.

CHAPTER 10: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

10.1 Summary of Objectives and Research Methodology

The Government of Malawi places considerable emphasis on ensuring that all people have a timely, reliable and nutritionally adequate food supply. Yet food insecurity is still a major problem among rural smallholder households. Under existing agricultural polices, the chances of most households attaining food security are dismal owing to the risky nature of rainfed, low-input crop farming.

The goal of this study was to investigate the potential of intensive dimba cultivation and small scale irrigation to improve the food security position of smallholder households. The specific objectives were:

1) to understand the current pattern of land use of both dimba land and rainfed land for agricultural production in the Chiradzulu North Extension Planing Area (EPA);
2) to compile enterprise budgets for farm activities congruent with land and labor use as determined above;
3) to estimate the contributions of dimba crops to household food income and food security;
4) to identify technically feasible crop/irrigation technology packages that can be used to increase production of crops;
5) to estimate the possible contributions of irrigated crops to household income and food security;
6) to select crop/irrigation technology packages that contribute most to improving food security;
7) to make policy and research recommendations based on the findings of the study to appropriate institutions.

To achieve these objectives, a field study was conducted during November 1992 to February 1993 among smallholder farming households in Chiradzulu North Extension

Planning Area of Blantyre ADD. Sampling of households was done purposively to get enough households with dimba land. Three questionnaires (one for households, one for enterprises, and one for garden measurement) were used to obtain data consistent with the objectives. Secondary data sources were used to supplement survey data to get yields on irrigated crops and the kind of techniques that can be used for irrigation, as well as farmers' experience with irrigation.

The data are used to describe land and labor use patterns in the area and to compile enterprise budgets to supply technical co-efficients that are used to implement a safety first Target MOTAD programming model. The use of this model assumes that farmers are risk averse and practice safety first behavior when deciding what crop production or IEAs to engage in. The safety first behavior is modeled using Telser's probabilistic criterion. The criterion is imposed in Target MOTAD with a sufficiency condition that uses Atwood's (1985) lower partial moments approach. The algorithm selects the activity mix which optimizes expected income while simultaneously enforcing probabilistic constraints upon negative deviations of specified goal variables from a target level using the least constraining linear lower partial moment stochastic inequality. Two different probablistic constraint approaches are specified, one using maize production and the other using income.

To implement the Target MOTAD, a programming tableau of activities and resources constraints was formulated. The activities included were crop production and selling activities, labor hiring and selling activities, and deviation counters. Constraints were family labor, land, accounting rows, and chance and deviation rows. The technical co-efficients were derived from enterprise budgets of current, intensive and irrigated crops.

10.2 Summary of Farm Survey Results

The sample size was 270 of which nearly 20% were female headed households. Fifty- two percent of the household heads were literate. Median household size was 5. Small farms (less than 0.7 ha), medium farms (< 0.7 up to 1.5 ha), and large farms (1.5 or more ha) made up 16.3%, 36.3% and 47.4% of the sample respectively. Due to selection of households possessing dimba land, the households in the survey were generally better endowed with land than most in the area with a mean land holding of 1.7 hectares. (The average in the area is estimated at 0.8 ha.) On average, 1.5 ha was rainfed land and 0.24 ha dimba land. Small farms had an average of 0.45 ha of rainfed land and 0.13 ha dimba land; for medium farms the respective figures were 1.06 ha and 0.17 ha, and for large farms 2.49 ha and 0.33 ha.

The dominant crop mixtures grown on rainfed land were maize/beans, peas, maize alone, maize/beans/pigeon peas, and maize/beans/groundnuts. For dimba land they were sugarcane, maize, cabbage and tomato.

The survey households were more likely to use fertilizer than is the case among typical smallholder households in Malawi. A large minority hired labor for fertilized maize-based crop mixtures grown on rainfed land. Pesticides were used on dimba crops of chinese cabbage, cabbage, tomato and rape.

Although all households farmed some land, nearly 30% of heads of households do not consider farming their main occupation. They generally produce enough maize when rainfall comes in good amounts. The majority, 71%, are willing to use and invest in irrigation. However, they foresee problems in organization and implementation.

10.3 Summary of Mathematical Programming Results

10.3.1 Cropping Activities

The results of Model I for base scenario and sensitivity analysis show that in the farmers' current situations, some risky crops (e.g. fertilized maize/beans/pigeon peas) are optimal when sources of income from dimba crops are high and stable, e.g. from sugarcane, or when safety first goals are based on maize production. Not fertilizing maize-based crop mixtures can be optimal when risk avoidance behavior is very conservative (i.e. safety first goals are very high and/or allowable probability of failure is low) and income from dimba crops is unstable and very low in drought years.

This result indicates that to encourage farmers to use fertilizer on maize, maize yields must be stabilized (as by irrigation) or farmers need to have other non-rainfed-land stable sources of income to manage maize production risk. This is borne out by observance that it is farmers who have collateral or other sources of income that usually participate in credit programs for maize (Center for Social Research 1988, Ngwira 1988).

The results of Model II show that medium intensity levels of fertilizer use, as in intensive local maize/beans/groundnuts, may be optimal even at high levels of risk aversion. This is made possible by the higher incomes from intensive dimba cultivation. However, the high level of fertilizer use as on hybrid maize is still too risky for farmers to adopt.

With irrigation in Model III(a), hybrid maize is optimal on rainfed land with no risk aversion in both versions. With risk aversion, stable incomes from irrigated crops make intensive maize/beans /groundnuts optimal at the highest levels of risk aversion; and hybrid maize is optimal at moderately high levels of risk aversion.

In Model III(b), hybrid maize is also optimal at moderately high levels of risk aversion. Wheat is optimal in season one, and maize/beans in season two. The results of Model III supports the conclusion that both stable and high incomes from non-rainfed land cultivation should encourage the use of fertilizer on maize based crop mixtures.

10.3.2. Expected Income and Contribution of Dimba Crops to Total Income

The results from the three models are summarized in Table 10.1. They include expected income, maximum feasible goals and optimal levels of maize production.

10.3.2.1. Current Cropping Practices

The returns to production on representative farms in the current situation are very low: MK1,380, MK1,657 and MK2,529 for small, medium and large farms. With them, small and medium farms achieve 55%, and 66% of the minimum income requirements of MK2,500. Only large farm households can be certain of achieving these minimum income requirements in 75% of the cropping seasons. With risk aversion, the expected incomes drop to MK1,359, MK1,638 and MK2,471, and these incomes can be greater than the income goal levels of MK576, MK903 and MK1,863 in 75% of cropping seasons. These results suggest that many households in the small and medium size categories are affected by poverty resulting in malnutrition, morbidity and mortality.

Dimba land contributes significantly to the income: 35%, 38% and 47% of total income on small, medium and large farms in the base scenario. Thus, under current cropping practices, dimba land can be of equal or greater importance compared to rainfed land for providing livelihoods to households depending on the size of land holdings. The level of contribution will also depend on the value of crops grown which in turn depends on costs and prices of input and output. However, under most scenarios of low prices, dimba land still contributes a significant portion of total income. This is important given the small sizes of these dimba plots. It is evident that creating small tracts of irrigated land has the potential to significantly change the food security situation of households through providing higher incomes.

Under current circumstances, model farms can generate a good portion of their income from off-farm income earning activities (IEAs) especially in the small farm category where 49% of income can be so derived. These figures are 31% and 12% for the medium and large farms. The model small farms have underemployed agricultural labor in almost all months, totalling 2,704 person hours which can be used in off-farm IEAs. Medium sized farms have 2,055 person hours. The large farms need to hire labor in some months (totalling 855 person-hours) and have 1,220 person hours to put to IEAs or employment at other times.

10.3.2.2 Intensive Cropping Practices

When enterprises that use intensive fertilizer and chemical input levels are considered, potential expected incomes increase significantly. For farmers indifferent to risk, incomes for small farms increase from MK1,380 in Model I to MK2,261 in Model II, for medium farms from MK1,657 to MK2,898, and for large farms from MK2,529 to MK5,019, meeting 62% and 80% of the requirements of small and medium farms. However, small and medium farms can not be certain of achieving incomes higher than subsistence requirements in 75% of cropping seasons. Given the land resources, intensive crop practices without irrigation may not solve the food security problems of small and medium farm families.

What changes significantly when intensive enterprises are considered is that dimba crops can contribute much more to income than rainfed crops because of the very high yields that can be achieved. The portion of income that can be derived from dimba crops increases from 35% in Model I to 64% in Model II for small farms; from 38% to 64% for medium farms and from 47% to 67% for large farms.

Due to the high labor demand of intensive crops, slack labor available for off-farm IEAs drops. Consequently, income that can be generated from IEAs falls from 49% in Model I to 21% in Model II for small farms. For medium farms it falls from 31% to 11%, and for large farms the drop is from 12% to 5%.

10.3.2.3 Irrigated Crop Practices

With sprinkler irrigation for horticultural crops, potential incomes increase to MK3,066, MK3,947 and MK7,041 respectively for small, medium, and large farms. However, it is possible to get MK3,927, MK5,072 and MK9,225 when gravity-fed irrigation is used for horticultural crops. Thus, it is possible for all farm sizes to meet minimum income requirements with irrigation for horticultural crops. Irrigated land can contribute from 75% to 81% of expected returns depending on the type of irrigation that is used.

With sprinkler irrigation for horticultural crops, all the representative farm sizes need to hire labor--220, 789 and 3,387 person-hours with respect to small, medium, and large farm sizes respectively. The proportion of income that comes from off-farm IEAS is 14%, 8% and 2% respectively. This is a significant drop from 49%, 31% and 12% in Model I. Thus, irrigation has the capacity to absorb slack labor and provide higher returns to labor than minimum wage employment.

When gravity fed irrigation is used for cereals, income are lower--MK1,223, MK1,536 and MK2,361 with respect to small, medium and large farms.

Table 10.1
Comparison of Expected Returns, Maximum Feasible Goals and Maize Production
Models I, II and III

	NRCON	SAFETY FIRST	
	Exp.Income[1] (MK)	Exp.Income(MK) **(Goal-MK)**[2] Maize Prod. (Kg)	Exp.Income(MK) **(Goal-Maize Kg)**[2] Maize Prod. (Kg)
Model I			
Small Farms	1380	1359 **(576)** 310	1380 **(300)** 668
Medium Farms	1657	1638 **(903)** 1251	1657 **(708)** 1480
Large Farms	2529	2471 **(1864)** 2779	2429 **(1000)** 3476
Model II			
Small Farms	2261	2112 **(1423)** 849	2261 **(617)** 1292
Medium Farms	2898	2668 **(2067)** 2000	2898 **(788)** 3042
Large Farms	5019	5019 **(2500)** 2898	5019 **(1000)** 3478
Model III(a)			
Small Farms	3066	3061 **(2500)** 853	3066 **(617)** 1292
Medium Farms	3947	3847 **(2500)** 3042	3947 **(788)** 3042
Large Farms	7041	7041 **(2500)** 7146	7041 **(1000)** 7146
Model III(b)			
Small Farms	1223 1291	1218 **(411)** 855	1150 **(1000)** 1675
Medium Farms	1536	1524 **(680)** 2004	1536 **(1000)** 3042
Large Farms	2361	2333 **(1451)** 4699	2361 **(1000)** 7146

1/ Maize produced under non risk constrained solution is same as under maize production approach except for small farms in Model III(b). The goal for NRCON solutions is zero.
2/ The expected income can be achieved while meeting the goal in 75% of cropping seasons.
3/ Model I-Current Crop Practices; Model II-Intensive Crop Practices; Model III(a) Sprinkler Irrigation for Horticultural Crops; Model III(b) - Gravity-fed Irrigation for Cereals.

NRCON: Non-risk constrained solutions
Safety first: Safety first solutions

10.3.4. Shadow Prices of Resources and Constraints

Under Model I, dimba land has a higher safety first premium than that of irrigated land in season 2 when the dual value is many times higher. This reflects the high value of land to meeting the sufficiency condition in Model I when income safety goals are very high. Put differently, under current crop production practices farmers would greatly benefit from acquiring more irrigated land to enable them to achieve safety first income goals as specified in this model.

10.3.5. Maximum Feasible Maize Production

Under current crop production practices, only large model farms can meet the specified minimum maize requirement of 1,000 kilograms per household in at least 75% of the cropping seasons from own production. Medium farms can be self-sufficient in maize in at least 67% of the cropping seasons with intensive cultivation practices. Small farms cannot expect to be self-sufficient in maize at the probability constraints used here even with irrigation, if irrigated land is not used to grow cereals for food. However, they can generate enough income to meet their subsistence income requirements.

10.4. Lessons from Analysis of Programming Results

1) Current and intensive crop farming may not lead to returns or maize yields that solve the food security problems of small and medium farms. Irrigated crop farming has potential to increase income of small farms or help them attain maize self-sufficiency. This finding indicates that for farms without dimba land, food insecurity can be dealt with by irrigating either horticultural or cereal crops depending on market conditions for horticultural crops.

2) Intensive dimba cultivation generates high enough incomes to cushion farmers from the risk of fertilizing local maize varieties or using fertilizer at medium intensity. It may thus be concluded that if employment and IEAs are limited, and irrigation is not

feasible, intensifying dimba cultivation is not just an alternative but should be part of the strategy to improve food security.

3) When income safety goals are high, hybrid maize is not optimal and cannot compete with other maize based crop mixtures. This result has been supported by other studies which show that it is not worthwhile to grow hybrid maize in bad years (Smale 1991). However, this study goes further by showing that as long as farmers are very risk averse (i.e. want to meet income subsistence needs in 75% of cropping seasons), and bad years come as frequently as once every four years, farmers should not grow hybrid maize. However, if they have irrigation, they may grow hybrids or use fertilizer intensively even when they have moderately high risk aversion.

4) All four models do not include hybrid maize at the highest feasible income safety goals. Thus, as long as farmers *a)* view hybrids as cash crops and not a source of household food consumption requirements, and *b)* are very risk averse, they may not grow hybrid maize unless its price or on-farm yield increases significantly. This finding supports the view that varietal change in breeding and extension should encourage the new trend which emphasizes semi-flint varieties, e.g. MH18 if farmers are to adopt hybrids. Although growing hybrids does not generate the same income as dimba crops, it increases the income returns to rainfed land by 96%, and also assures higher minimum maize production. Both of these contribute positively to food security.

5) The LP solutions based on the maize production approach have maize-based crop mixtures using fertilizer. If farmers set their safety first goals using the maize production approach, failure of to use fertilizer may be construed as lack of access to fertilizer.

6) When gravity fed irrigation is used for cereals, model farms achieve lower incomes, but their cereal consumption requirements can be met. Thus, if it is not possible to establish marketing arrangements that make growing vegetables profitable, gravity fed

irrigation should be used to grow cereals. This should be the case for most rural areas that are far from urban centers. When farmers in the small and medium landholdings set their safety first goals using the income approach, irrigating cereals is not attractive because the expected incomes cannot meet their subsistence requirements.

7) Most of the risk-constrained solutions show the need for diversification. Different crops do well in different years. Diversification is shown to be important to optimize income in situations of risk aversion and also to assure food security. It is important that credit and extension which is currently centered on maize be diversified.

10.5 Recommendations for Dimba Cultivation and Irrigation

Having found that *1)* smallholder farmers should not grow hybrid maize if they are very risk averse and income oriented in their safety goals, *2)* moderately risk averse farmers can grow hybrid maize with gravity-fed irrigation, *3)* small farms will not meet their goals of achieving maize consumption requirements in 75% of the cropping seasons unless they irrigate cereals, and *4)* intensive dimba cultivation and irrigation has significant potential to increase income it is recommended that:

1) ***smallholder farmers with dimba land should be targeted with credit and extension for dimba crops, rather than rainfed maize, particularly those in the smallest size category.***

2) ***farmers without dimba land should be assisted in establishing and investing in irrigation for either horticultural or cereal crops, depending on the market situation.***

The government recognizes that small farms can not produce their food requirements from their gardens or meet minimum income requirements. The results of this study indicate that irrigation can enable households with small farms to generate enough income to purchase food. Irrigation can have the double-edged role in food security of increasing self-sufficiency in maize and generating adequate income to purchase food.

Having found that as long as farmers are risk averse and view hybrid maize as a cash crops (i.e. income approach), and not a source of household food consumption requirements, they may not grow it unless its price or on-farm yield increases significantly, it is recommended that:

3) ***maize breeding research and extension should encourage the new trend which emphasizes semi-flint varieties.***

These semi-flint varieties have storage and processing characteristics preferred by farmers for own consumption maize. Although growing hybrids does not generate as much income as dimba crops, it increases the income returns to rainfed land by 96% and assures a higher minimum maize production.

Having shown that when farmers set their safety goals using a maize production approach, the failure to use fertilizer can be construed as lack of access to fertilizer, and cognizant of evidence that many smallholder farmers do not use fertilizer, it is recommended that:

4) ***the credit and extension program should allow wider access to inputs.***

This may include detaching credit from government extension programs and encouraging formation agricultural credit associations.

Since safety first solutions show the need for diversification and since diversification spreads income risk, and enhances food security, it is recommended that:

5) ***the credit and extension which are currently centered on maize be diversified to put more emphasis on other crops.***

This should help to make it less risky to fertilize maize.

10.6 Recommendations for Future Research

For future research, it is recommended:

6) ***more farm production studies of horticultural crops be done to enhance the quality of input-output data.***

This would certainly improve the reliability of subsequent studies validating the results presented here.

7) ***marketing studies be conducted on horticultural crops.***

This is necessary in order to improve understanding of vegetable markets and the possible ways to improve their efficiency and assess the price to be expected with additional products from different levels of irrigated land. As optimal crop/technology packages depend on marketing and pricing arrangements, these studies can help in refining decisions on crops that should be grown on dimba in each season and on rainfed land. This will have implications for government infrastructural investments.

8) ***community and institutional organization studies be conducted for local management and financing of irrigation projects.***

The information would help increase the chance of successfully implementing irrigation projects.

All in all, this study provides ample evidence that intensive dimba cultivation and small scale irrigation can have a two-fold enhancing effect on household food security by both encouraging adoption of fertilized maize and generating significantly higher incomes with which to purchase food.

APPENDIX A

EXPLANATORY NOTES FOR ABBREVIATIONS USED IN ENTERPRISE BUDGETS

tin	=	tin containing seed and volume of 300 ml
kg	=	kilogram
cup	=	measuring cup with volume of 50 ml
MK	=	Malawi Kwacha (at time of study US$1 = MK4.20)
p/h	=	person hours of labor
pkt	=	packet, the packet for chemicals applied to tomato and cabbage weighs 200 g
maint. of farm equip.	=	maintenance of farm equipment
inv. in irrig. equip.	=	investment in irrigation equipment
l/prep.	=	land preparation
irrig.	=	irrigate
fert.	=	fertilize
harv.	=	harvest

Table A6.1
Enterprise Budget for 1 Hectare of Current Non-Fertilized Local Maize

	Quantity	Price (MK)	Value (MK)
Output (kg)	448.00	0.33	161.50
Variable Costs			
Seed (kg)	25.00	0.33	8.25
Fertilizer (kg)	0.00	0.00	0.00
Marketing (p/h)	488.00	0.03	12.20
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			27.00
Gross Margin			134.50

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85				85
February							0
March							0
April						25	25
May						25	25
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85				85
TOTAL	302	38	170			50	560

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.2
Enterprise Budget for 1 Hectare of Current Fertilized Local Maize

	Quantity	Price (MK)	Value (MK)
Output (kg)	1,051.00	0.33	346.83
Variable Costs			
Seed (kg)	25.00	0.33	8.25
Fertilizer (kg)	110.00	1.00	110.00
Marketing (p/h)	1,051.00	0.03	26.28
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			151.00
Gross Margin			195.83

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		28		113
February							0
March							0
April						38	38
May						38	38
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		28		113
TOTAL	302	38	170		56	76	642

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.3
Enterprise Budget for 1 Hectare of Intensive Local Maize

	Quantity	Price (MK)	Value (MK)
Output (kg)	2,561.00	0.33	830.50
Variable Costs			
Seed (kg)	25.00	0.33	8.25
Fertilizer (kg)	160.00	1.00	160.00
Marketing (p/h)	2,516.00	0.03	62.90
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			237.70
Gross Margin			592.80

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		41		126
February							0
March							0
April						91	91
May						91	91
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		41		126
TOTAL	302	38	170		82	182	774

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.4
Enterprise Budget for 1 Hectare of Hybrid Maize

	Quantity	Price (MK)	Value (MK)
Output (kg)	3,652.00	0.33	1,205.16
Variable Costs			
Seed (kg)	25.00	0.33	8.25
Fertilizer (kg)	370.00	1.00	370.00
Marketing (p/h)	3,652.00	0.03	74.98
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			459.78
Gross Margin			745.38

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		41		126
February							0
March							0
April						91	91
May						91	91
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		41		126
TOTAL	302	38	170		82	182	774

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.5
Enterprise Budget for 1 Hectare of Current Non-Fertilized Maize/Beans

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	514.00	0.33	169.62
Beans	45.00	0.65	29.50
Gross Value			415.77
Variable Costs			
Seed (kg)			
Maize	25.00	0.33	8.25
Beans	40.00	0.65	26.00
Marketing (p/h)	559.00	0.03	13.97
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			54.77
Gross Margin			361.00

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85				85
February							0
March							0
April						27	27
May						27	27
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85				85
TOTAL	302	38	170	0	0	54	564

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.6
Enterprise Budget for 1 Hectare of Fertilized Local Maize/Beans

		Quantity	Price (MK)	Value (MK)
	Output (kg)			
	Maize	1,124.00	0.33	
370.62	Beans	69.00	0.65	44.80
	Gross Value (MK)			415.42
	Variable Costs			
	Seed (kg)			
	Maize	25.00	0.33	
8.25	Beans	40.00	0.65	26.00
	Fertilizer (kg)	120.00	1.00	120.00
	Marketing (p/h)	1,193.00	0.03	29.83
	Maint. of Farm Equip.	0.33	19.85	6.55
	Total Variable Costs			190.63
	Gross Margin			224.79

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		26		111
February							0
March							0
April						48	48
May						48	48
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		26		111
TOTAL	302	38	170	0	52	96	658

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.7
Enterprise Budget for 1 Hectare of Intensive Fertilized Maize/Beans

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	2,049.00	0.33	676.17
Beans	151.00	0.65	98.15
Gross Value (MK)			774.32
Variable Costs			
Seed			
Maize (kg)	25.00	0.33	8.25
Beans	40.00	0.65	26.00
Fertilizer	160.00	1.00	160.00
Marketing (p/h)	2,200.00	0.03	55.00
Maint. of Farm Equip.	0.33	19.85	6.55
Total Variable Costs			255.86
Gross Margin			518.45

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		34		119
February							0
March							0
April						56	56
May						56	56
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		34		119
TOTAL	302	38	170	0	68	112	690

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.8
Enterprise Budget for 1 Hectare of Hybrid Maize/Beans Irrigated Using Gravity/Furrows

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	2,999.00	0.33	989.76
Beans	402.00	0.65	261.30
Gross value			1,250.97
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
Fertilizer (kg)	370.00	1.000	370.00
Marketing (p/h)	3,401.00	0.025	85.03
Maint. of Farm Equip.	0.33	19.850	6.55
Maint. of Irrig. Equip.			50.00
Investment in Irrig. Equip.			259.00
Total Variable Costs			804.83
Gross Margin			446.14

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	38		150			339
June			85	150	84		319
July			85	150	84		319
August						298	298
September							
October							
November							
December							
TOTAL	302	38	170	450	168	298	1,426

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.9
Enterprise Budget for 1 Hectare of Hybrid Maize/Beans Irrigated Using Pump/Sprinklers

	Quantity	Price (MK)	Value (MK)
Output			
Maize (kg)	2,999.00	0.33	989.76
Beans (kg)	402.00	0.65	261.30
Gross value			1,250.97
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
Fertilizer (kg)	370.00	1.000	370.00
Marketing (p/h)	3,401.00	0.025	85.03
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			450.00
Inv. in Irrig. Equip			2,332.00
Total Variable Costs			3,835.83
Gross Margin			-2,584.86

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	38		150			339
June			85	150	84		319
July			85	150	84		319
August						298	298
September							
October							
November							
December							
TOTAL	302	38	170	450	168	298	1,426

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.10
Enterprise Budget for 1 Hectare of Current Non-Fertilized Local Maize/Beans/ Pigeon Peas

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	989.00	0.330	326.37
Beans	97.00	0.650	63.05
Pigeon Peas	76.00	0.400	30.40
Gross value			419.82
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
P/Peas	6.00	0.400	2.40
Marketing (p/h)	1,162.00	0.025	29.05
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			72.25
Gross Margin			347.57

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85				85
February							0
March							0
April						38	38
May						38	38
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85				85
TOTAL	302	38	170	0	0	76	586

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.11
Enterprise Budget for 1 hectare of Current Fertilized Local Maize/Beans/Pigeon Peas

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	1,459.00	0.330	481.47
Beans	111.00	0.650	72.15
Pigeon Peas	72.00	0.400	28.80
Gross value			582.42
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
P/Peas	6.00	0.400	2.40
Fertilizer (kg)	136.00	1.000	136.00
Marketing (p/h)	1,642.00	0.025	41.05
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			220.25
Gross Margin			362.17

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		31		116
February							0
March							0
April						68	68
May						68	68
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		31		116
TOTAL	302	38	170	0	62	136	708

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.12
Enterprise Budget for 1 Hectare of Intensive Local Maize/Beans/Pigeon Peas

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	2,049.00	0.330	676.17
Beans	151.00	0.650	98.15
P/Peas	72.00	0.400	28.80
Gross value			803.12
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
P/Peas	6.00	0.400	2.40
Fertilizer (kg)	160.00	1.000	160.00
Chemicals	1.00	13.000	13.00
Marketing (p/h)	2,272.00	0.025	56.80
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			260.00
Gross Margin			543.12

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		34		119
February							0
March							0
April						94	94
May						94	94
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		34		119
TOTAL	302	38	170	0	68	188	766

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.13
Enterprise Budget for 1 Hectare of Hybrid Maize/Beans/Pigeon Peas

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	2,999.00	0.330	989.67
Beans	402.00	0.650	261.30
P/Peas	72.00	0.400	28.80
Gross value			1,279.77
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
P/Peas	6.00	0.400	2.40
Fertilizer (kg)	370.00	1.000	370.00
Chemicals	1.00	13.000	13.00
Marketing	3,401.00	0.025	85.03
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			498.30
Gross Margin			781.49

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		84		169
February							0
March							0
April						140	140
May						140	140
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		84		169
TOTAL	302	38	170	0	168	280	958

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.14
Enterprise Budget for 1 Hectare of Current Fertilized Local Maize/Beans/Groundnuts

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	1,212.00	0.330	399.17
Beans	92.00	0.650	59.80
Groundnuts	186.00	1.120	208.32
Gross value			664.29
Variable Costs			
Seed			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
Groundnuts	40.00	1.120	44.80
Fertilizer	115.00	1.000	115.00
Marketing	1,490.00	0.030	37.25
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			237.85
Gross Margin			426.44

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		29		114
February							0
March							0
April						59	59
May						59	59
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		29		114
TOTAL	302	38	170	0	58	118	686

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.15
Enterprise Budget for 1 Hectare of Intensive Local Maize/Beans/Groundnuts

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	2,049.00	0.330	676.17
Beans	151.00	0.650	98.15
Groundnuts	186.00	1.120	208.32
Gross value			982.64
Variable Costs			
Seed (kg)			
Maize	25.00	0.330	8.25
Beans	40.00	0.650	26.00
Groundnuts	40.00	1.120	44.80
Fertilizer (kg)	160.00	1.000	160.00
Marketing (p/h)	2,386.00	0.025	59.65
Maint. of Farm Eqiup.	0.33	19.850	6.55
Total Variable Costs			305.25
Gross Margin			665.46

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January			85		40		125
February							0
March							0
April						95	59
May						95	59
June							0
July							0
August	151						151
September	151						151
October		19					19
November		19					19
December			85		40		125
TOTAL	302	38	170	0	80	190	780

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.16
Enterprise Budget for 1 Hectare of Rice Irrigated Using Gravity/Furrows

	Quantity	Price (MK)	Value (MK)
Output (kg)	3,000.00	0.370	1,110.00
Variable Costs			
Seed (kg)	75.00	0.500	37.50
Fertilizer (kg)	230.00	1.000	230.00
Chemicals	1.00	12.000	12.00
Marketing (p/h)	3,300.00	0.025	75.00
Maint. of Farm Equip.	0.33	19.850	6.55
Maint. of Irrig. Equip.			50.00
Inv. in Irrig. Equip.			259.00
Total Variable Costs			670.05
Gross Margin			439.95

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	324		150			625
June			85	150	84		319
July			85	150	84		319
August						298	298
September							
October							
November							
December							
TOTAL	302	324	170	450	168	298	1,712

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.17
Enterprise Budget for 1 Hectare of Rice Irrigated Using Pump/Sprinklers

	Quantity	Price (MK)	Value (MK)
Output (kg)	3,000.00	0.370	1,110.00
Variable Costs			
Seed (kg)	75.00	0.500	37.50
Fertilizer (kg)	230.00	1.000	230.00
Chemicals	1.00	12.000	12.00
Marketing (p/h)	3,300.00	0.025	75.00
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip			450.00
Inv. in Irrig. Equip.			2,332.00
Total Variable Costs			3,701.05
Gross Margin			-2,591.05

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	324		150			625
June			85	150	84		319
July			85	150	84		319
August					298	298	
September							
October							
November							
December							
TOTAL	302	324	170	450	168	298	1,712

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.18
Enterprise Budget for 1 Hectare of Wheat Irrigated Using Gravity/Furrows

	Quantity	Price (MK)	Value (MK)
Output (kg)	3,500.00	0.550	1,925.00
Variable Costs			
Seed (kg)	100.00	0.550	55.00
Fertilizer (kg)	300.00	1.000	300.00
Marketing (p/h)	3,500.00	0.025	87.50
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			0.00
Maint. of Irrig. Equip.			50.00
Inv. in Irrig. Equip.			259.00
Total Variable Costs			758.05
Gross Margin			-1,166.95

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	52		150			353
June			85	150	84		319
July			85	150	84		319
August						347	347
September							
October							
November							
December							
TOTAL	302	52	170	450	168	347	1,489

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.19
Enterprise Budget for 1 Hectare of Wheat Irrigated Using Pump/Sprinklers

	Quantity	Price	Value
Output (kg)	3,500.00	0.550	1,925.00
Variable Costs			
Seed (kg)	100.00	0.550	55.00
Fertilizer (kg)	300.00	1.000	300.00
Marketing (p/h)	3,500.00	0.025	87.50
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			450.00
Inv. in Irrig. Equip.			2,332.00
Total Variable Costs			3,789.05
Gross Margin			-1,864.05

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April	151						151
May	151	52		150			353
June			85	150	84		292
July			85	150	84		292
August						347	347
September							
October							
November							
December							
TOTAL	302	52	170	450	168	347	1,489

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.20
Enterprise Budget for 1 Hectare of Current Relay Rainfed Field Peas

	Quantity	Price	Value
Output (kg)	195.00	1.000	195.00
Variable Costs			
Seed (kg)	75.00	0.400	30.00
Fertilizer (kg)	0.00	0.00	0.00
Marketing	195.00	0.025	4.88
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			41.43
Gross Margin			153.57

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March	58	19					77
April	58	19	48				125
May			48				48
June							0
July						28	28
August						28	28
September							0
October							0
November							0
December							0
TOTAL	116	38	96	0	0	56	306

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.21
Enterprise Budget for 1 Hectare of Current Dimba Field Peas

	Quantity	Price (MK)	Value (MK)
Output (kg)	670.00	1.000	670.00
Variable Costs			
Seed (kg)	75.00	0.400	30.00
Fertilizer (kg)	0.00	0.000	0.00
Marketing	670.00	0.025	16.75
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			53.30
Gross Margin			616.70

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March	515						515
April	515	38		292			845
May			64	292			356
June			64	292		120	476
July						120	120
August							0
September							0
October							0
November							0
December							0
TOTAL	1,018	38	128	876	0	240	2,312

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.22
Enterprise Budget for 1 Hectare of Sugarcane

	Quantity	Price (MK)	Value (MK)
Value of Output	8,546.00	0.500	4,173.00
Variable Costs*			
Marketing (p/h)	8,546.00	0.025	213.65
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			220.20
Gross Margin			4,052.80

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May							0
June							0
July							0
August	274						274
September	274					120	394
October		57				120	177
November		57					57
December			154				154
TOTAL	548	114	154	0	0	240	1,051

* Cuttings are used for propagation and the cost is assumed to be zero.
Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.23
Enterprise Budget for 1 Hectare of Current Non-Fertilized Cabbage

	Quantity	Price (MK)	Value (MK)
Output (kg)	5,650.00	0.500	2,825
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	0.00	0.000	0.00
Marketing (p/h)	5,650.00	0.025	141.25
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			167.80
Gross Margin			2,657.20

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515		124		705		1,344
June		124	64	705			893
July			64	705			769
August				705			705
September						240	240
October							0
November							57
December							0
TOTAL	1,018	248	128	2,820	0	240	4,466

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.24
Enterprise Budget for 1 Hectare of Intensive Cabbage

	Quantity	Price (MK)	Value (MK)
Output	22,000.00	0.500	2,825
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	80.00	0.000	80.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	22,000.00	0.025	550.00
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			669.55
Gross Margin			2,155.45

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515		124		705	25	1,369
June		124	64	705	25		918
July			64	705	25		799
August				705	25		730
September						240	240
October							0
November							0
December							0
TOTAL	1,018	148	128	2,820	100	240	4,566

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.25
Enterprise Budget for 1 Hectare of Cabbage Irrigated Using Pump/Sprinklers-Seasons 2

	Quantity	Price	Value
Output (kg)	33,481.00	0.500	16,740.50
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	80.00	1.000	80.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	33,841.00	0.025	846.03
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Variable Costs			3,378.55
Gross Margin			13,361.45

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April							
May	302	248		150	25		725
June			64	150	25		239
July			64	150	25		239
August				150		120	270
September							
October							
November							
December							
TOTAL	302	248	128	600	75	120	1,473

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.26
Enterprise Budget for 1 Hectare of Cabbage Irrigated Using Pump/Sprinklers-Seasons 1and3

	Quantity	Price	Value
Output (kg)	5,069.00	0.500	2,534.50
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	80.00	1.000	80.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	5,069.00	0.025	126.73
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Variable Costs			2,659.28
Gross Margin			-124.78

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							
February							
March							
April							
May	302	248		150	25		725
June			64	150	25		239
July			64	150	25		239
August				150	25	329	504
September							
October							
November							
December							
TOTAL	302	248	128	600	100	329	1,707

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.27
Enterprise Budget for 1 Hectare of Current Non-Fertilized Tomato

	Quantity	Price (MK)	Value (MK)
Output	6,240.00	1.000	6,240.00
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	6,240.00	0.025	156.00
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			182.55
Gross Margin			6,057.45

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515			658	25		1,490
June			64	658	25		747
July		292	64	658	25		722
August						120	120
September						120	120
October							0
November							0
December							0
TOTAL	1,030	292	128	1,974	75	120	3,714

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.28
Enterprise Budget for 1 Hectare of Intensive Tomato

	Quantity	Price (MK)	Value (MK)
Output (kg)	11,083.00	1.000	11,083.00
Variable Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	15.00	0.000	15.00
Chemicals (pkt)	1.00	12.800	12.80
Marketing (p/h)	11,803.00	0.025	295.08
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			348.63
Gross Margin			10,734.37

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515			658	25		1,490
June			64	658	25		747
July		292	64	658	25		722
August						120	120
September							0
October							0
November							0
December							0
TOTAL	1,030	292	128	1,974	75	120	3,714

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.29
Enterprise Budget for 1 Hectare of Irrigated Tomato Using Pump/Sprinklers-Season 2

	Quantity	Price (MK)	Value (MK)
Output (kg)	10,402.00	1.000	10,402.00
Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	15.00	0.000	15.00
Chemicals (pkt)	1.00	12.800	12.80
Marketing (p/h)	10,402.00	0.025	260.05
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,727.40
Gross Margin			7,674.60

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	292		150			769
June			64	150	25		239
July			64	150	25		239
August						120	120
September							0
October							0
November							0
December							0
TOTAL	302	292	128	450	50	120	1,367

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.30
Enterprise Budget for 1 Hectare of Irrigated Tomato Using Pump/Sprinklers-Seasons 1 and 3

	Quantity	Price (MK)	Value (MK)
Output (kg)	2,471.00	1.000	2,471.00
Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	15.00	0.000	15.00
Chemicals (pkt)	1.00	12.800	12.80
Marketing (p/h)	2,471.00	0.025	61.78
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,529.13
Gross Margin			-58.13

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	292		150			769
June			64	150	25		239
July			64	150	25		239
August						120	120
September							0
October							0
November							0
December							0
TOTAL	302	292	128	450	50	120	1,367

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.31
Enterprise Budget for 1 Hectare of Current Chinese Cabbage

	Quantity	Price (MK)	Value (MK)
Output (kg)	2,004.00	0.500	1,002.00
Variable Costs			
Seed (tin)	1.00	20.00	20.00
Marketing (p/h)	2,004.00	0.025	50.10
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			76.65
Gross Margin			925.35

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515	292		489			1,296
June			64	489			553
July			64	489		120	673
August							0
September							0
October							0
November							0
December							0
TOTAL	1,030	292	128	1,467	50	120	120

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.32
Enterprise Budget for 1 Hectare of Intensive Chinese Cabbage

	Quantity	Price	Value
Output (kg)	23,812.00	0.500	11,906.00
Variable Costs			
Seed (tin)	1.00	20.00	20.00
Fertilizer (kg)	80.00	1.000	80.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	23,812.00	0.025	595.30
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			714.85
Gross Margin			11,191.15

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	515						515
May	515	292		489	25		1,321
June			64	489	25	120	578
July			64	489		120	673
August							0
September							0
October							0
November							0
December							0
TOTAL	1,030	292	128	1,467	50	120	3,087

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.33
Enterprise Budget for 1 Hectare of Irrigated Chinese Cabbage Using Pump/Sprinklers-Season 2

	Quantity	Price (MK)	Value (MK)
Output (kg)	23,812.00	0.500	11,906.00
Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	80.00	0.000	80.00
Chemicals (pkt)	1.00	13.000	13.00
Marketing (p/h)	23,812.00	0.025	595.30
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			3,127.13
Gross Margin			8,778.15

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	324		150			801
June			64	150	25		239
July			64	150	25	120	359
August						120	120
September							
October							0
November							0
December							0
TOTAL	302	324	128	450	50	240	1,494

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.34
Enterprise Budget for 1 Hectare of Irrigated Chinese Cabbage Using Pump/Sprinklers-Seasons 1 and 3

	Quantity	Price (MK)	Value (MK)
Output (kg)	6,799.00	0.500	3,399.00
Costs			
Seed (tin)	1.00	20.000	20.00
Fertilizer (kg)	80.00	0.000	80.00
Chemicals	1.00	13.000	13.00
Marketing (p/h)	6,799.00	0.025	170.00
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,702.53
Gross Margin			696.97

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	324		150			801
June			64	150	25		239
July			64	150	25	120	334
August						120	120
September							0
October							0
November							0
December							0
TOTAL	302	324	128	450	50	240	1,494

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.35
Enterprise Budget for 1 Hectare of Non-fertilized Dimba Maize

	Quantity	Price (MK)	Value (MK)
Output (kg)	2,614.00	0.500	2,614.00
Variable Costs			
Seed (kg)	25.00	0.330	8.25
Marketing	2,614.00	0.025	65.35
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			80.15
Gross Margin			2,533.85

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May							0
June							0
July	515						515
August	515	38	85	608			1,246
September			85	608			693
October							0
November						120	120
December							0
TOTAL	1,030	38	128	1,218	50	120	2,474

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.36
Enterprise Budget for 1 Hectare of Current Non-fertilized Dimba Maize/Pumpkin Leaves

	Quantity	Price (MK)	Value (MK)
Output (kg)			
Maize	1,961.00	1.000	1,961.00
Pumpkin Leaves	486.00	0.500	243.00
Gross value			2,204.00
Variable Costs			
Seed (kg)			
Maize (kg)	25.00	0.330	8.25
P/Lvs (cup)	1.00	1.000	1.00
Marketing	2,447.00	0.025	61.18
Maint. of Farm Equip.	0.33	19.850	6.55
Total Variable Costs			76.98
Gross Margin			2,127.02

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							5
May							5
June							5
July	515						515
August	515	38	85	608			1,246
September			85	608			693
October							0
November						120	120
December							0
TOTAL	1,030	38	128	1,216	50	240	2,574

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.37
Enterprise Budget for 1 Hectare of Irrigated Green Beans Using Pump/Sprinklers-Season 2

	Quantity	Price	Value
Output	4,716.00	1.000	4,716.00
Variable Costs			
Seed (kg)	40.00	1.000	40.00
Fertilizer (kg)	200.00	1.000	200.00
Chemicals	1.00	13.000	13.00
Marketing	4,716.00	0.025	117.90
Maint. of farm Impl.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig Equip.			1,555.00
Total Costs			2,790.45
Gross Margin			1,925.55

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	38		150	25		441
June			49	150	25		237
July			49	150		160	378
August						160	160
September							0
October							0
November							0
December							0
TOTAL	302	38	128	450	50	320	1,198

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.38
Enterprise Budget for 1 Hectare of Irrigated Green Beans Using Pump/Sprinklers-Seasons 1 and 3

	Quantity	Price (MK)	Value (MK)
Output (kg)	3,014.00	1.000	3,014.00
Variable Costs			
Seed (kg)	40.00	1.000	40.00
Fertilizer (kg)	200.00	1.000	200.00
Chemicals	1.00	13.000	13.00
Marketing (p/h)	3,014.00	0.025	90.42
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,747.90
Gross Margin			266.10

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	38		150	25		490
June			64	150	25		239
July			64	150		120	359
August						120	120
September							0
October							0
November							0
December							0
TOTAL	302	38	128	450	50	240	1,208

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.39
Enterprise Budget for 1 Hectare of Irrigated Onions Using Pump/Sprinklers-Season 2

	Quantity	Price (MK)	Value (MK)
Output (kg)	15,888.00	1.00	15,888.00
Variable Costs			
Seed (tin)	1.00	20.00	20.00
Fertilizer (kg)	79.00	1.00	79.00
Chemicals	1.00	13.00	13.00
Marketing (p/h)	15,888.00	0.03	397.20
Maint. of Farm Equip.	0.33	19.85	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,928.75
Gross Margin			12,959.25

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April	151						151
May	151	324		150	25		625
June			64	150	25		239
July			64	150			239
August						240	240
September							0
October							0
November							0
December							0
TOTAL	1,030	38	128		50	240	1,494

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

Table A6.40
Enterprise Budget for 1 Hectare of Pumpkin Leaves
Irrigated Using Pump/Sprinklers-All Seasons

	Quantity	Price (MK)	Value (MK)
Output (kg)	6,626.00	0.500	3,313.00
Variable Costs			
Seed (cup)	1.00	20.000	20.00
Fertilizer (kg)	79.00	1.000	79.00
Marketing (p/h)	6,626.00	0.025	165.65
Maint. of Farm Equip.	0.33	19.850	6.55
Fuel and Oil			558.00
Maint. of Irrig. Equip.			300.00
Inv. in Irrig. Equip.			1,555.00
Total Costs			2,684.20
Gross Margin			628.80

Labor Input (Median) Person-hours

Month	L/Prep	Plant	Weed	Irrig	Fert	Harv	Total
January							0
February							0
March							0
April							0
May	302	19		150	25		585
June			64	150	25		239
July			64	150		120	334
August						120	120
September							0
October							0
November							0
December							0
TOTAL	1,030	19	128	450	50	240	1,278

Source: Survey Data 1993/Guide to Agricultural Production in Malawi 1992

APPENDIX B

THE ROLE OF DIMBA LAND AND SMALL SCALE IRRIGATION IN IMPROVING HOUSEHOLD FOOD SECURITY IN SOUTHERN MALAWI

Farmer Survey

Name of Enumerator____

Date of Interview__________________________

I. Identification

Household Code___________

Section Code______________

EPA Code________________

District Code______________

Name of Respondent___________________________

Name of Enumerator____________________ Name of Respondent____________________
Date of Interview______________________

II. Labor Availability

Q1. How many people are in this household? _____

Q2. Which of these members are available to work on your parcels of land during the year? (Ask for days in a week, hours in a day.)

Person name											
Sex											
Age											
Relation to Head											
September	H/D										
	D/W										
October	H/D										
	D/W										
November	H/D										
	D/W										
December	H/D										
	D/W										
January	H/D										
	D/W										
February	H/D										
	D/W										
March	H/D										
	D/W										
April	H/D										
	D/W										
May	H/D										
	D/W										
June	H/D										
	D/W										
July	H/D										
	D/W										
August	H/D										
	D/W										

Note: H/D = Hours per day
D/W = Days per week

Sex
Male = 1
Female = 2

Age
0-10 = 1
>10-55 = 2
>55 = 3

Relation to Head
Head = 0
Wife = 1
Relative/child = 2
Other = 3

III. Socio-Economic Characteristics of Household Heads

Q3. Marital Status *1 = Married 3 = Divorced* *2 = Widowed 4 = Separated 5 = Single*	
Q4. Household Type *1 = male head 2 = female head*	
Q5. Occupation of Head *1 = Farming 2 = Employment outside agriculture* *3 = Agriculture laborer* *4 = Own business 5 = Unemployed 6 = Other*	
Q6. Education of Head *1 = No Schooling 2 = Std.I-III 3 = Std. IV-VII 4 = Higher* *5 = Unknown*	

IV. Patterns of Land Use

Q7. How many parcels of land do you have? *(Put number in code box)*	
Q8(a). Are any of these dimba gardens? *(Put number in code box. No = 0.)*	
Q8(b). Are any of them potentially irrigable? (i.e. within 200 meters of a reliable water source. No = 0.)	
Q9. How did you acquire the dimba land? *1 = Inherited from parents* *2 = Given by chief* *3 = Bought it (price _______)*	
Q10. What type of land is it? (Enumerator to verify.) *1 = Close to water source, high water table, well drained* *2 = Close to water source, low water table, dries out in dry season* *3 = Swampy, poor drainage* *4 = Other*	
Q11(a). Does it flood during the rain season? *Yes = 1 No = 2*	
Q11(b). Is it waterlogged between April and June? *Yes = 1 No = 2*	

MAP

(Draw a map indicating the position of the parcels in relation to household, and for each parcel of land get details as indicated below to help you fill out tables A, B & C.)

Parcel 1

Land type______________ Acres_______

Crop Mixture________________________

(Description of planting)______________

____

No. of Parcel sheets to complete______

Parcel 2

Land Type_______________ Acres_______

Crop Mixture_________________________

(Description of planting)________________

____

No. of Parcel sheets to complete_______

Parcel 3

Land type______________ Acres_______

Crop Mixture________________________

(Description of planting)______________

____

No. of Parcel sheets to complete______

Parcel 4

Land Type_______________ Acres_______

Crop Mixture_________________________

(Description of planting)________________

____

No. of Parcel sheets to complete_______

Q12(a). Labor Use (1991/1992)

Parcel No. ____________ Acres for Enterprise ____________

Type of Land ____________ Crop Mixture ____________

Enterprise ____________ Months ____________

Input/Activity		Family Labor	Hired Labor	Months
Land Prep	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Planting	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Weeding	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Fertilizer	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Irrigation	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Harvest	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			
Other	days			
	h/d			
	Pric	xxxxxxxxxxxxxxx		
	Peop			

Q12(b). Input Use (1991/1992)

Parcel No. ____________________ Acres for Enterprise only ______________

Type of Land __________________ Crop Mixture ______________________

Enterprise ____________________ Months __________________________

Input	Type	Unit	Quantity	Price/Unit
Chemicals				
Fertilizer	1.			
	2.			
Manure				
Irrigation				

Q12(c). Harvest and Sales

Parcel No. ____________________ Acres for Enterprise only ______________

Type of Land __________________ Crop Mixture ______________________

Enterprise ____________________ Months __________________________

Crop Code	Year	Total Harvest		Sales		
		Unit	Quantity	Unit	Quantity	Price/Unit
	1992					
	1991					
	1990					
	1989					
	1992					
	1991					
	1990					
	1989					

Q13. What are the major constraint to producing more of dimba crops? *1 = Water shortage (because the dimba garden normally dries out fast, not due to drought)* *2 = Lack of fertilizer* *3 = Inadequate/unreliable rainfall* *4 = Pests and predators* *5 = Other (specify)________________*	
Q14. What are the major obstacles to producing more of rainfed crops? *2 = Lack of fertilizer* *3 = Inadequate/unreliable rainfall* *4 = Pests and predators* *5 = Other (specify)*	

V. Non-Farm Income Generating Activities

Q15. What agricultural activity did you engage in between April and September? *1 = Cultivate a second crop on rainfed land* *2 = Cultivate dimba land* *3 = Other (specify)________________*	
Q16. Are there some months in the calendar year when you do little or no agricultural activities? *N/A = 999 (Put in code box; otherwise tick months)* |Jan|Feb|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec|	
Q17(a). Do you use the time to do some income generating activities? *N/A (no free months) = 999* *No = 0* *Farm IGAs = 1* *Other (specify)________________* = 2	

Name of Enumerator____________________ Name of Respondent____________________

Date of Interview______________________

Q17(b). What is the income per week/month from this activity? N/A = 999 *Record figure per month* *(Convert per day/week to per month)*	
Q17(c). What are the prerequisites to engage in the activity? N/A = 999 *(Open ended) If it is a trade list training or apprenticeship required or amount of investment/type of equipment required.* ______________________________ ______________________________	
Q17(d). How many days a month do you engage in the activity? *(Put No. of Days)* N/A = 999	

VI. Willingness to Use and Invest in Irrigation

Q18(a). Would you be willling to invest in irrigation technology? *1 = Yes 2 = No*	
Q18(b). Suppose you were to invest in irrigation technology of __________ which cost ________ for a quarter of an acre (both capital and interest) and a repayment period of two years. Your installments would be MK200 every three months. Would you be willing to make the investment? ____________ What if your net income from using the one quarter of an acre were: MK200.00. Would you be willing to make the investment? ___________ MK500.00? ____________	
Q18(c). If 'no', why? *(Open ended)* ____ ____	

Q19. If you invest in irrigation which crops would you want to grow on your dimba? When and why? (Give names of two most important crops.)

Season 1. October - March Crop (mixture)____________________ Why___________________________	
Season 2. April - June Crop (mixture) Why___________________________	
Season 3. July - September Crop (mixture) ____________________ Why___________________________	

Codes for why

1 = Water will be available
2 = For food
3 = For cash
4 = Suitable for soils
5 = Other (specify)________________

Q20. [If yes to Q8(b)] If you invested in irrigation what crops would you like to grow on this piece of land that can be irrigated? (Note that the land can then be cropped from April to September.)

Season 1. October - March Crop (mixture)______________________ Why____________________________	
Season 2. April - June Crop (mixture) Why____________________________	
Season 3. July - September Crop (mixture) ______________________ Why____________________________	

Q21(a). Is your dimba parcel of land contiguous with other farmers' dimba gardens? *1 = yes 2 = No*	
Q21(b). Would you be willing to participate in a communal irrigation project? *1 = Yes 2 = No*	
Q21(c). Do you foresee any problems in setting up and organizing communal irrigation projects? (Open ended) ____ ____	

VII. Use of Extension and Credit Services

Q22(a). In the last 3 years have you received credit from any source?

(If no credit was taken put 999 all through)

Year	Source	Use	Amount	Repayment Condition	
				Interest	Duration
1991/92					
1990/91					
1989/90					

Q23(a). In the past 3 years have you been in contact with any agriculture/irrigation extension agent?

(If no contact in one or all years put 999 all through)

When (year)	Which agent	For what crop/activity	How frequent
		Dimba = 1 Rainfed = 2	
1991/92			
1990/91			
1989/90			

Q23(b). If no, why not? (Open ended)

____

VIII. Food Production Strategies and Security

Q24(a). What are your strategies for making sure the household has enough food all year through? (Compare with Q5.) 0 = Produce some food/grow cash crops 1 = Produce all food requirements 2 = Do ganyu labor (where______________________) 3 = Member(s) of family permanently employed 4 = IGAs or business (specify____________________) 5 = Other (specify)____________________________	
Q24(b). If you rely on agricultural production (codes 0 and 1), what do you do when rain fails to come in good time/amounts? N/A = 999, i.e. does not rely on agricultural production 1 = Rely on dimba productions 2 = Trading in an agricultural commodity 3 = Practicing a trade (specify)______________________ 4 = Other (specify)_______________________________ 5 = Selling labor (specify)__________________________	
Q25. How many months did your food production last in the past three years? *(Put the no. of months in the code boxes.)* <u>Year</u> <u>Months lasted</u> 1991/92 1990/91 1989/90	

GARDEN MEASUREMENT

Name of Enumerator . . . .
Name of Assistant . . . .
Name of Respondent . . . .

Date . . . .
Section Code . . . .
Household Code . . . .

	Crop Name	Crop Code	Description of Planting

TOTAL AREA _________ ha _________ acres

Perimeter _________ meters

Plot 1: Area ________ ha ________ acres
Perimeter _________ meters
N/S error _________
EW error _________
% gap error _________

Plot 2: Area ________ ha ________ acres
Perimeter _________ meters
N/S error _________
EW error _________
% gap error _________

Plot 3: Area ________ ha ________ acres
Perimeter _________ meters
N/S error _________
EW error _________
% gap error _________

Garden Stations From - To	Forward Bearing	Length of Side	Backward Bearing	Plot No.	Plot Stations From - To	Forward Bearing	Length of Side	Cumulative Length of Sides	Backward Bearing
A - B									
B - C									
C - D									
D - E									
E - F									
F - G									
G - H									
H - I									
I - J									
J - K									
K - L									
L - M									
M - N									
N - O									
O - P									
P - Q									
Q - R									
R - S									
S - T									
T - U									
U - V									
V - W									
W - X									
X - Y									
Y - Z									

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