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Determination of optimal crop combinations on Zambian farms: incorporation of certainty and risk considerations in mathematical programming models

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Determination of optimal crop combinations on Zambian farms:
Incorporation of certainty and risk considerations in
mathematical programming models

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by

Judith Nanyangwe Lufumpa

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE

Department: Economics
Major: Agricultural Economics

Signatures have been redacted for privacy

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa

1991

DEDICATION

DEDICATED TO THE MEMORY OF MY FATHER

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CHAPTER I
INTRODUCTION

As part of the overall strategy to diversify the Zambian economy and reduce its heavy dependence on the mining industry for foreign exchange earnings, agricultural development was more emphasized by the Zambian government during the 1980s.

In the years before the 1970s, revenues from the copper mining industry provided Zambia with huge foreign exchange reserves which made Zambia one of the wealthiest countries in Sub-Saharan Africa. As a result, Zambia developed an intricate economic system that was heavily dependent on imports. However, since the early 1970s, a combination of high oil prices and low copper prices resulted in a reduction of Zambia's foreign exchange earning capacity.

This prolonged situation resulted in a continuous depletion of Zambia's foreign exchange reserves. Eventually, the present situation culminated, in which foreign debt became the principal source of capital inflow for the Zambian economy.

Most of the blame for this state of affairs has been placed on events in the world economy and on the mono structure of the Zambian economy.

As of 1990, Zambia's foreign debt stood at 8 billion dollars⁽¹⁾. The main sources of foreign debt are the International Monetary Fund (IMF), World Bank and international private banks.

Concerted efforts are being made to reduce the debt. However, the capacity of the Zambian economy to service foreign debts, has continued to decrease.

There are three possible ways in which Zambia's foreign debt could be reduced. One way is outright debt forgiveness by the creditors. This is a politically controversial method. However, there have been discussions in international forums on the issue of outright forgiveness of some of the debts of developing countries.

Another way of reducing the foreign debt is to increase the capacity of the Zambian economy to produce goods for export, and, therefore, earn more foreign exchange to service the debt. Alternatively, dependence on imports could be reduced so that more foreign exchange is available for debt servicing.

However, the answers to Zambia's debt problems are not as obvious as indicated. Since the 1930s, when intensive mining in Zambia began, the economy has been heavily dependent on the mining industry for most of the foreign exchange. Copper mining alone accounted for 92 percent⁽²⁾ of all foreign

exchange earnings and 45 percent⁽²⁾ of the Gross Domestic Product (GDP) in 1964. Table 1.1 below shows the percentage contribution of the copper industry to GDP and exports over the 16 year period, 1964 to 1979. The copper industry continued to account for over 90 percent of the total exports in the Zambian economy for the first 12 years after

Table 1.1: Percentage contribution of the copper industry to gross domestic product and exports

YEAR	Percent Contribution to GDP	Percent Contribution to exports
1964	45	91
1965	40	91
1966	44	94
1967	39	93
1968	38	95
1969	48	96
1970	23	94
1971	23	94
1972	24	92
1973	32	95
1974	32	95
1975	13	91
1976	17	92
1977	11	91
1978	12	88
1979	18	86

Source: Compiled by author from Zambia Mining Yearbooks and Monthly Digest of Statistics.

independence in 1964. However, in 1978 and 1979 the percentage contribution on exports declined slightly to 88 percent and 86 percent, respectively. This decline came about as a result of the precipitous fall of copper prices on the world market. The percentage contribution of the copper industry to the Gross Domestic Product (GDP) has been declining over the 16 year period. In the first seven years, the contribution of the copper industry to GDP averaged 40 percent. This declined to an average of 20 percent for the remainder of the period leading up to 1979.

During the 1980s, therefore, the Zambian government attempted to implement austerity measures in an effort to diversify the economy. The main focus was placed on agricultural development because of the sector's huge untapped potential for domestic and export production. Agriculture has great potential to contribute to future economic growth and export diversification for Zambia. Within the agricultural sector, the large group of traditional farmers was targeted as the pivotal group for agricultural development in Zambia.

Agricultural Production in Zambia

Zambian farmers can be broadly divided into four categories, namely, large-scale commercial farmers, small-

scale commercial farmers, traditional farmers, and peasant farmers.

Large-scale commercial farmers are highly mechanized and cultivate more than 40 hectares of land using cash inputs (fertilizer and agro-chemicals). This category of farmers relies heavily on hired labor for their farm operations. They employ both permanent and part-time farm labor in their operations. Crops commonly grown by large-scale commercial farmers are maize, wheat, soybeans, tobacco, fruits, and vegetables. Most of these farmers have mixed farm enterprises where they engage in both crop and livestock production. Some commercial farmers also grow sunflower, groundnuts and cotton.

Small-scale commercial farmers cultivate between 10 and 40 hectares of land. Like the large-scale commercial farmers, they are also mechanized though not to the same extent. Oxen and tractors are the main forms of traction used by this category of farmers. Farm labor for the small-scale commercial farm enterprise consists of family and hired labor. They produce mainly for the market, though some of the produce is retained for home consumption. This category of farmers also engages in mixed farming. The main crops grown are maize, cotton, sunflower, and tobacco.

A traditional farmer, on the other hand, is a farmer cultivating between one and ten hectares of land. These

farmers grow their own food for consumption with the surplus or a cash crop for sale. They use cash inputs, too, but in low amounts.

Oxen are the main form of traction used. Occasionally, traditional farmers hire tractors for use in their operations. Farm labor for this category of farmers consists mainly of family and hired labor. This group of farmers mainly grows maize, sunflower, cotton, groundnuts, rice, sorghum, millet, and cassava.

The major source of income for traditional farmers is from the sale of the cash crops and some of their surplus food production. A large percentage of the maize, sorghum, millet, and cassava grown on the farms are retained for consumption, while all cotton and sunflower and almost all of the rice and groundnuts are grown for sale.

The fourth category of farmers are peasant farmers who are mainly subsistence producers. They produce mainly for on-farm consumption with occasional surpluses for the market. The size of their production is less than five hectares, usually one or two hectares. They use hand hoes for cultivation, and only family labor is utilized on the farm.

Peasant farmers do not use any external inputs in their operations. The crops grown by this group of farmers are maize and the traditional crops of sorghum, millet, and

cassava. Their source of income is from occasional sale of surpluses, fruits, vegetables, fish, and locally brewed beer.

According to a survey done during the period April to August 1986, in which 56 commercial farmers were interviewed, most of the land on the large-scale commercial farms is allocated to maize and soybean production, in that order. Irrigated wheat ranked third and rainfed wheat fourth. The remainder of the cropland is used for the production of other crops. The allocation of land to crops on large commercial farms is tabulated in Table 1.2. The combination of crops presented in Table 1.2 is not typical of all commercial farmers in Zambia. However, the commercial farmers surveyed allocated land in this manner on average.

During August 1986, another survey was carried out in which 28 small-scale commercial farmers were interviewed. Like in the case of large-scale commercial farmers, most of the land is allocated to maize production. Sunflower and cotton growing ranked second and third, respectively. The pattern of land use on these farms is presented in Table 1.3 below.

Table 1.2: Land use by large-scale commercial farmers

Land use	Hectares/Farm
Maize	139.20
Wheat:	
Irrigated	44.00
Rainfed	7.90
Soybeans	82.70
Other Crops	42.80
Idle crop land	112.10
Total crop land	368.00
Improved pastures	107.40
Unimproved land	793.50
Lots, roads, waste	31.80
Total Land in operation	1,300.70

Source: Ministry of Agriculture and Water Development, Estimated Cost of Production of Major Crops in Zambia, December, 1987, p.2.

Table 1.3: Land use on small-scale commercial Farms

Land use	Hectares/Farm	Range in hectares
Maize	23.3	3.2 - 121.50
Sunflower	1.8	1.2 - 16.20
Cotton	1.3	1.0 - 5.30
Other crops	2.2	0.6 - 25.00
Idle crop land	27.8	0.0 - 180.10
Total Cropland	56.3	7.4 - 202.40
Total land	100.8	20.4 - 280.00

Source: Ministry of Agriculture and Water Development, Estimated Cost of Production of Major Crops in Zambia, December, 1987, p.27.

Another survey was carried out during the 1985-86 agricultural planting season. This survey covered the whole of Zambia and over a hundred peasant and traditional farmers. Approximately 100 farmers who used oxen as a source of power in their farm operations were interviewed. 72 of the farms producing maize and using oxen were used to determine land use on traditional farms. On average, most of the land on traditional farms is put under maize, cotton, sorghum, sunflower, and groundnuts production, in that order. The results of the survey are tabulated in Table 1.4 below.

Table 1.4: Land use on traditional farms

Land use	Hectares/Farm	Range in hectares
Maize	3.26	1.00 - 16.00
Sunflower	1.10	0.20 - 4.00
Cotton	1.17	0.25 - 2.40
Sorghum	1.11	0.40 - 2.43
Groundnuts	0.65	0.15 - 2.50

Source: Compiled by author from the Ministry of Agriculture and Water Development, Estimated Cost of Production of Major Crops in Zambia, December, 1987.

Zambia has about 30 million hectares of arable land of which 2.2 million (7.3%)⁽³⁾ is under cultivation. There are 827,873 rural households,⁽⁴⁾ with an average household size of five. Most of these households are not consistent surplus producers. Therefore, government strategy has been to provide this group of farmers with assistance that can allow them to become surplus producers on a consistent basis.

A wide range of crops are grown in Zambia. These include maize, sorghum, millet, wheat, rice, soybeans, sunflower, groundnuts, cotton, tobacco, cassava, barley, sugarbeans, tea, kenaf, coffee, sugar cane, and a variety of fruits and vegetables.

Of the crops listed above there are some which are grown predominantly by certain categories of farmers; for example, irrigated wheat is grown by large-scale commercial farmers, while sorghum, millet, and cassava are grown by traditional farmers mostly for home consumption with occasional surpluses for sale.

Maize is by far the most important cereal crop in Zambia. It is Zambia's staple food and is consumed by over 90 percent of the population⁽⁵⁾. Maize is grown by all categories of farmers in Zambia. However, the traditional farmers produce over 70 percent⁽⁶⁾ of the total marketed maize.

Maize production dates back to the 1890s. During the colonial period, maize was mostly grown by the European settler farmers. Maize was mainly used as a source of low-cost food for mine workers in the urban areas. However, as more and more people migrated to urban areas in search of work, the demand for maize grew. It was this increase in the demand for maize that resulted in the promotion of maize production among African farmers in certain restricted areas (Eastern, Southern, and Central provinces).

After independence farmers in all regions of the country were encouraged to produce more maize. A complex system of subsidies for the maize sub-sector was developed to facilitate maize production around the country. As a result of this encouragement, food patterns changed to maize consumption even in places where the staple food had previously not been maize, thus making maize Zambia's staple food.

Almost all the maize grown in Zambia is rainfed. The maize sub-sector tends to be self-sufficient in times of good rains. Marketed maize production has been increasing since 1964 except during periods of drought. Marketed maize production figures are presented in Appendix III. Figure 1.0 below presents marketed production of some crops.

However, bad weather is not the only factor adversely affecting maize production in periods of low production

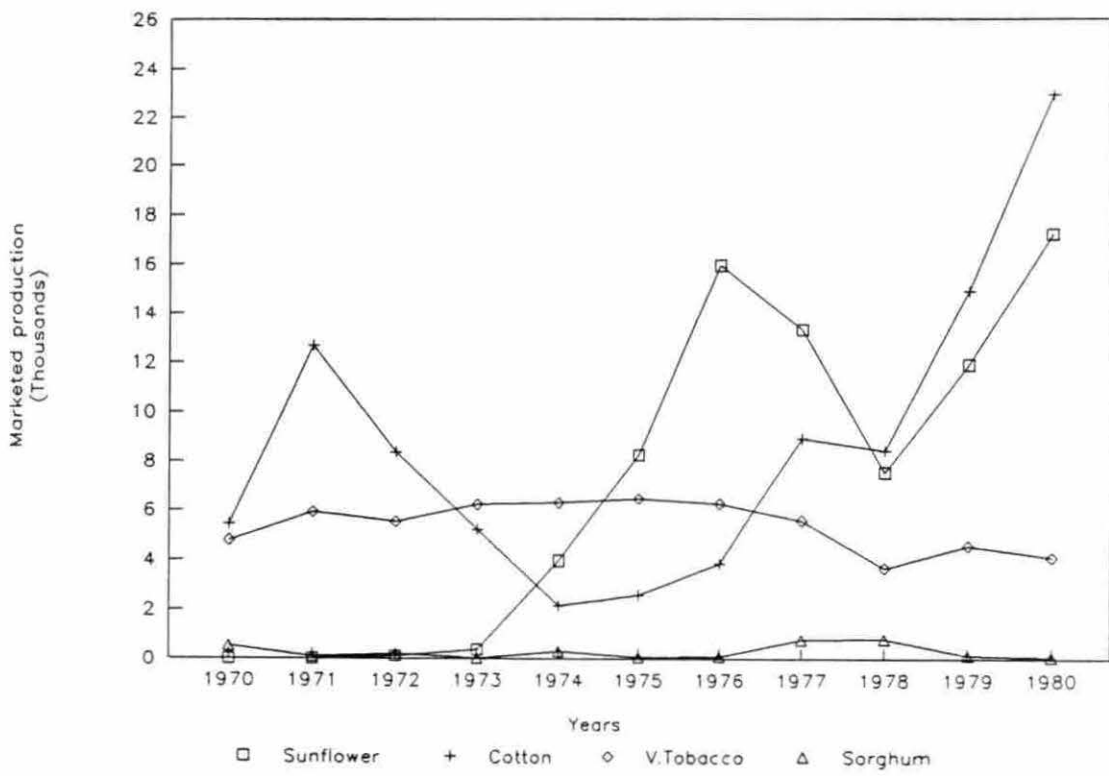


Figure 1.0 Marketed production of some agricultural crops

levels. Maize production is also affected by the untimely supply of inputs, especially fertilizers which are a major input in maize production. Poor marketing arrangements have also resulted in substantial crop losses in the marketing system.

The increase in maize production could be largely attributed to the increase in hectarage put under maize. Land area has increased from 266,000 hectares in 1965 to 904,900 hectares in 1989. Marketed maize production also has increased from 257,804 metric tons in 1965 to 639,589 metric tons in 1989. Over the same period, there were upward and downward fluctuations in both land area under maize and marketed maize production. The maize hectarage of 904,900 hectares in 1989 was the highest ever attained in Zambian maize production history.

Soybeans and sunflower are grown primarily for edible oil production. Soybeans are also used in stockfeed production. Soybean production in Zambia does not date very far back. The crop came into large-scale production only in the last ten years. Marketed soybean production was recorded at 37 metric tons in 1974. Over the years production increased, reaching the level of 21,200 metric tons in 1989.

The increase in both land area under soybeans and in the level of production is attributed to the introduction of the

soybean breeding program in the agricultural research stations. This started with the introduction of soybeans on the Zambian farms.

Initially soybeans were mainly grown by large-scale commercial farmers. Recently, traditional farmers have been picking up soybean production on their farms. A lot of emphasis is being put on soybean production because of its nutritional benefits. Soybean is a relatively cheaper source of protein. Soybean meals incorporated in the human diet would help reduce malnutrition, especially for the low-income group in Zambia.

Sunflower is grown mostly by traditional farmers and small-scale commercial farmers. Sunflower is mainly used for processing into cooking oil.

Sunflower production has declined over the years. This decline in sunflower production has been caused by a number of factors, some of which relate to marketing problems, shortage of new hybrid seed, and the pricing policy for sunflower. For a long time the price of sunflower was very low relative to the soybeans price. Recently, the price of sunflower has been changed to a level that is now comparable to the soybeans price.

Groundnuts is the other oilseed crop grown in Zambia, though they are mostly used for confectionery purposes. They

are grown mainly by traditional farmers for on-farm use, with the surplus put up for sale.

Cotton production in Zambia has grown from 2,098 metric tons in 1965 to 52,688 metric tons in 1989. Cotton is produced by both small-scale commercial farmers and traditional farmers. All the cotton grown is sold. Most of the cotton is produced in four provinces, namely Southern, Eastern, Central, and Lusaka.

Almost all field crops grown in Zambia are rainfed except for irrigated wheat and barley. Rainfed wheat is also grown in Zambia. Irrigated wheat requires huge initial capital investments. It is, therefore, grown entirely by large-scale commercial farmers who have invested in the irrigation equipment.

Wheat production in Zambia began in the 1940s. During that time, its production was only for the small urban population. With the rural-urban migration which followed the introduction of mining in the Copperbelt province, the urban population started to grow. This increased the demand for wheat.

However, this increase in the demand for wheat outmatched the increases in wheat production. As a result, Zambia was forced to start importing wheat to meet the local demand. As mentioned earlier, Zambia's foreign exchange earning capacity

had significantly declined by the late 1970s, thus adversely affecting imports. This included wheat imports. Most of the wheat coming into Zambia after 1985 came in as food aid or was imported at concessional rates. The food aid and concessional rate imports depressed the local production of wheat for some time, since the import parity price was always lower than the local cost of production of wheat.

Nevertheless, the Zambian government has been encouraging wheat production. Two wheat projects, Mpongwe Development Project and Zambia Canada Wheat Project, were introduced to boost wheat research and production. As a result of some of these efforts, wheat production has increased from 934 metric tons in 1975 to 33,9000 metric tons in 1988. However, the per capita consumption of wheat has increased from 6.7 in 1960 to 18.8 kilograms⁽⁷⁾ in 1980. The level of self-sufficiency in wheat has also increased from two percent to thirteen percent⁽⁷⁾ over the same time period.

Barley is another crop which has just been reintroduced amongst commercial farmers. During the 1989/90 crop season, 814 hectares⁽⁷⁾ were cultivated.

Rice is predominantly grown by traditional farmers. It is mainly grown in Western and Southern provinces. In 1989, 12,587 hectares were put under production. The output level for the crop season was 13,500 metric tons.

Sorghum, millet, and cassava are traditional crops which are grown mainly by traditional farmers. These crops are produced mostly for home consumption, with some surplus for sale. For a long time the marketing and pricing arrangements for these commodities discouraged surplus production for the market. However, with the change in the marketing and pricing policy (discussed later in this chapter), the situation is expected to change.

Sorghum production has doubled over the five-year period (1974-1989) to a production level of 36,680 metric tons in 1989⁽⁸⁾. With this increase in sorghum surplus production, it is likely that sorghum sales will increase.

Millet production has also increased by 40 percent⁽⁸⁾ over the same five-year period. Production in 1989 was 26,400 metric tons. Like is the case for most other crops, this increase in production has been due to the increase in hectarage.

Cassava is another important food crop for a large percentage of the rural population. In 1989, 100,800 hectares were allocated to cassava production, and 72,000 metric tons of cassava were harvested.

Burley tobacco and Virginia tobacco are produced for the domestic market as well as for export. Virginia tobacco is mostly grown by commercial farmers, while burley tobacco is

grown by the small-scale commercial farmers and the traditional farmers.

The marketed production figures for all agricultural crops in Zambia are tabulated in Appendix III.

Marketing and Pricing of Agricultural Commodities

The marketing of agricultural commodities in Zambia is currently done through the government controlled parastatals, Zambia Cooperative Federation and the Cooperative unions.

Previously the marketing of all field crops was dominated by NAMBoard (National Agricultural Marketing Board). All field crops, except tobacco, soybeans, and sunflower, were marketed by NAMBoard. Tobacco was marketed by TBZ (Tobacco Board of Zambia) and soybeans and sunflower by Refined Oil Products (ROP).

During the colonial days two marketing organizations, the Grain Marketing Board (GSB), which catered to the commercial farmers, and the Agricultural Rural Marketing Board (ARMB), which catered to the rural areas, were responsible for the marketing of both agricultural inputs and produce.

However, in 1969, the two boards merged to form the National Agricultural Marketing Board which took over the role of agricultural input and produce marketing. By the 1970s,

NAMBoard had grown so large that inefficiency set in. In order to rectify this problem, the government assigned some of NAMBoard's duties to other institutions. The role of cotton growing and marketing was transferred to the Lint Company of Zambia. The marketing of fruits and vegetables was taken over by the Zambia Horticultural Products Company (ZAMHORT). Furthermore, in 1982 more responsibilities were withdrawn from NAMBoard, leaving it only the responsibility for importing or exporting maize, and for importing grain-bags and chemical fertilizers. NAMBoard also continued to shoulder the responsibility of inter-provincial maize transfers.

With the liberalization of maize marketing in 1986, NAMBoard's functions were further reduced. In 1989, NAMBoard was finally dissolved. Maize marketing functions were now put in the hands of the Zambia Cooperative Federation (ZCF). Fertilizer production and marketing were the responsibilities of the Nitrogen Chemicals of Zambia (NCZ). As of the 1989/90 agricultural marketing season, the Zambia Cooperative Federation monopolized the handling of both agricultural inputs and agricultural produce.

The procurement and distribution of livestock and poultry are done by the Cold Storage Board of Zambia (CSB), Zambia Pork Products (ZAPP), and the Dairy Produce Board of Zambia (DPBZ). CSB buys cattle from farmers, slaughters them, and

distributes beef to customers. Similarly, ZAPP does the same with pork and pork products. DPBZ is responsible for buying milk from farmers and processing it. DPBZ also makes other milk products, which are later sold directly to customers or through other marketing agencies. ZAPP and CSB operate in competition with private traders in the livestock markets.

For a long time, the pricing of agricultural crops has been under the control of the Ministry of Agriculture. The Ministry sets floor prices for all agricultural crops except for maize, which is still a controlled product.

The price of maize is a fixed price but the prices of the other crops can be higher than the floor price. This allows for negotiations between buyers and sellers. For example, in the case of wheat the floor price was lower than the actual selling price.

This was a result of negotiations between the sellers (farmers) and the buyer (National Milling Company). Wheat is one of the few crops where farmers have been able to negotiate for a higher price than the recommended floor price. This is because wheat is mainly grown by large-scale commercial farmers who are a powerful lobbying structure. Table 1.5 below shows floor prices for wheat and the price paid by the buyer, NMC, over a five-year period.

Table 1.5: Floor prices and National Milling prices for wheat. (in Zambian Kwacha)

	1983	1984	1985	1986	1987
Floor price	35.75	42.50	45.20	86.40	111.00
NMC price	45.00	60.00	85.00	135.00	190.00

Source: Compiled by author from Agricultural Statistics Bulletins.

Agricultural imports and exports

In an attempt to diversify the economy, Zambia has been promoting exports and encouraging local production of currently imported goods. Zambia is a net importer of agricultural commodities. For a long time, the agricultural sector has accounted for no more than 2.2 percent of Zambia's total exports. Since 1975, the agricultural sector's contribution to total exports averaged about two percent⁽⁹⁾. Zambia's agricultural exports include maize, tobacco, cotton lint, sugar, confectionery groundnuts, tea, coffee, fruits and vegetables. Maize is only exported during periods of bumper harvest. Agricultural imports include wheat, maize and edible vegetable oils.

Review of Agricultural Policies in the National Development Plans Since Zambia's Independence

In the First National Development Plan (FNDP 1966-70), only 12% of the total investment was allocated to crop and livestock development even though two-thirds of the population lived in the rural areas (Dodge, 1977 p.55).

In the First National Development Plan, the objectives for the agricultural sector were to reduce the imbalances between the rural and urban areas, increase rural incomes through increased agricultural production, and help to diversify the economy.

However, during this plan period very few of these objectives were met. Most of the data on marketed production indicated shortfalls from the targets. The only crop which actually exceeded the production target was sugar cane.

The Second National Development Plan (1972-76) had the following objectives: 1) improving rural standards of living, 2) creating rural employment opportunities in rural areas in order to discourage rural-urban migration, 3) increasing the contribution of the agricultural sector to GDP, and 4) developing self-sufficiency in staple foods.

During the Second National Development Plan, an annual rate of increase of 5-6 percent for agriculture's contribution

to GDP was registered. Overall, the agricultural sector's contribution to GDP increased slightly from 13.7 percent between 1966-70 to 14.2 percent in 1976. The SNDP was able to meet and exceed marketed production targets for maize, sugar-cane, and poultry products.

The Third National Development Plan (1979-83) had the following objectives for the agricultural sector:

- (a) balanced development, i.e., having regard to linkages among industry, agriculture and other sectors of the economy.
- (b) diversify the economy by promoting agriculture and reducing the dependency on copper.
- (c) expand the production base in the agricultural sector not only to meet self-sufficiency but also for promoting exports.
- (d) adoption of investment and production programs and creation of credit marketing and extension facilities which will directly benefit subsistence producers and traditional farmers.

However, most of the objectives of the Third National Development Plan were not achieved because the assumptions on which most of the objectives were based never materialized. During this period, the agricultural sector's contribution to GDP was 16 percent, and only two percent of the total exports

for Zambia.

The overall objectives of the agricultural sector during the Fourth National Development Plan (FNDP 1989-93) were to increase production and productivity, to streamline the marketing of both products and inputs, as well as contribute to improved living conditions of the rural population (NCDP, 1989).

Some of the agricultural sector's main objectives as listed in the FNDP are:

- (a) achieve a satisfactory level of self-sufficiency at household, community, and national levels in the production of staple foods.
- (b) expand the production of agricultural exports.
- (c) balance agricultural production targets with changes in the size and growth rate of the nation's population, so as to achieve the desired self-sufficiency in food production.
- (d) increase the import substitution and replacement of agricultural products and inputs.

As reported in the economic report for 1990, the preliminary production figures for crops like maize and rice exceeded the targeted levels in the first year of the plan.

Objectives of the Study

The main objective of the study is to analyze resource allocation by Zambian farmers under both certainty and risk considerations. Specifically, three categories of farmers, large-scale commercial, small-scale commercial, and traditional, are considered.

The specific objectives are:

- a) to derive an optimal combination of crops for the three categories of farmers under both certainty and risk considerations, using linear programming models. The risk programming model used is the Minimization of Total Absolute Deviations (MOTAD).
- b) to analyze the results and compare the certainty and the risk results for each category of farmer.
- c) to compare the results with the current practices of the farmers. The study results will also be compared with the results from the 1986 surveys of farm production in Zambia.
- d) to do some sensitivity analysis in order to determine the changes in the optimal enterprise combinations and the objective function value due to changes in some of the variables involved in the production process.

e) to make policy recommendations arising from the discussion.

Sources of Data for the Programming Models

The data used in this study were collected as secondary data and through personal interviews with personnel in the Ministries, parastatal organizations, and other agricultural-related institutions in Zambia. Most of the data were, however, collected from the Ministry of Agriculture during the author's trip to Zambia in February, 1991.

Endnotes

- 1 Zambia Daily Mail and Times of Zambia, February 28, 1991.
- 2 International Labor Office, Basic Needs in an Economy under Pressure, United Printers, Addis-Ababa, Ethiopia, 1981, p. 201.
- 3 Ministry of Agriculture, Evaluation of the Performance of Zambia's Maize Sub-sector, August 1990, p. 34.
- 4 Ibid p.1
- 5 Ministry of Agriculture, Press Release, 1989, p. 1.
- 6 Central Statistics Office, Agricultural and Pastoral Production, Comprehensive Agricultural Survey (phase I), 1986/87 Agricultural Season, August 1990, p. 31.
- 7 Planning Division, Ministry of Agriculture and Cooperatives, Crop Production in Zambia: Past Trends and Future Prospects as Related to Fertilizer Usage, October 1989, p 8.
- 8 Ibid p. 10.
- 9 Pervis, W.D., Domestic and Foreign Currency Costs of Agricultural Production and Their Implications for Economic Policy, Lusaka, Zambia, 1987. p.3.

CHAPTER II
LITERATURE REVIEW

Programming models have been used extensively in production economics to determine optimal farm plans. They have also been used in empirical studies to recommend new production plans.

Hazell (1971) developed the techniques of Minimization of Total Absolute Deviations (MOTAD) as a criterion for portfolio selection. MOTAD is an alternative to mean-variance analysis. It is a linear risk programming model which can be solved by parametric linear programming algorithms.

MOTAD is most applicable when the variance of farm income is measured using time-series sample data. The variance estimates are based on sample mean absolute deviations. MOTAD provides an efficient set of farm plans that are very similar to results obtained by quadratic programming. Risk in the MOTAD model is measured by linear deviations from the mean. Some of the advantages of MOTAD over quadratic programming outlined in the literature on MOTAD are:⁽¹⁾

- (a) MOTAD is easier to compute than quadratic programming.

- (b) MOTAD requires only the standard linear programming algorithm.
- (c) While quadratic programming does provide dual information on marginal value of constraints and activities, these values do not hold for any specified intervals. The MOTAD model is, therefore, adapted to post optimality analysis.

Anderson et al. (1977) used a simple three-crop model to illustrate the MOTAD model and then compared the results to the quadratic programming results. There were some broad similarities between the two models, with no considerable differences. Their conclusions were similar to those drawn by Hazell in 1971. They concluded that MOTAD techniques can be used as a substitute for quadratic programming in risk programming models.

Katongo (1986) developed a certainty linear programming model to analyze the decision making behavior of traditional farming households in Zambia. The study indicated that current farming practices amongst traditional farmers did not utilize the resources optimally. There were low returns on resources. Katongo's study also pointed out that on-farm consumption was preferred to market purchases. The results of the study also indicated that the farming households provided most of the labor used on the farms. The study further

indicated that land allocation for each crop was greatly influenced by the consumption requirements of the households.

However, Katongo did not incorporate risk in his model. Usually models which do not incorporate risk give farm plans which do not reflect the farmer's farm practices. The inclusion of risk in the analysis may have brought about a different conclusion about the optimality of current traditional farm practices.

Herr (1989) used linear programming under certainty and risk considerations to select optimal farm enterprize combinations for representative farms in Southern Iowa. Risk was incorporated in the model through the use of a target MOTAD model, which was introduced by Tauer in 1983.

One of the considerations in Herr's study was the possibility of combining off-farm employment with crops and livestock enterprises. The optimal solution of the model included seasonal part-time farm jobs for the husband and full-time off-farm jobs for the wife. The part-time farm job included crop activities, feeding cattle, and hogs enterprises. The solutions for the target MOTAD varied with the level of risk aversion. The risk neutral target MOTAD solution was similar to the solution for the certainty model.

Kaaria (1990) developed a linear risk programming model to evaluate the economic potential of incorporating high-fat

oats in the farm plans for Northeast Iowa. The results indicated that high-fat oats is a viable crop which can be included in the farm plans in Northeast Iowa. The characteristics of the sociological model of technology transfer also indicated that high-fat oats may be readily adopted by farmers in Northeast Iowa.

Dodge (1977), in her book on agricultural policy and performance in Zambia, states that the performance of the agricultural sector was not satisfactory during the first twelve years after independence. Dodge asserts that some of the factors contributing to the poor performance of the agricultural sector are the low priority that was given to the agricultural sector in the First National Development Plan (FNDP), crop pricing, and crop marketing policies.

Ulrich et al. (1989) used economic and financial analysis to determine the profitability of Zambian crops. The crops included in their study were wheat, maize, sunflower, cotton, rice, groundnuts, soybeans, sorghum, millet, and barley.

According to Ulrich and his colleagues, in general, for small-scale commercial and traditional farmers, wheat gave the highest financial return on labor and the highest financial net margin per hectare. On the other hand, irrigated wheat gave the highest financial net margin per hectare, while

irrigated soybeans had the highest financial return on labor for the large-scale commercial farmers. The authors further assert that in relation to commercial farmers, if the Zambian agricultural sector were to be less regulated, irrigated wheat would be the most profitable both on a per hectare basis as well as a per labor basis. They also state that if this reduced regulation were to take place, irrigated barley would be the most unprofitable crop to grow.

The Ministry of Finance and National Commission for Development planning (1989), in their study on traditional crops promotion, analyzed the opportunities for using sorghum, millet, and cassava in the baking, brewing, and stockfeed industries. In this study much emphasis was put on sorghum as a potential substitute for wheat, barley, and maize because the processing and production techniques for sorghum are well-developed and are readily available.

The study indicates that production and processing technologies for cassava and millet are not that well-developed. They also state that there are many uses for these traditional crops which have not been exploited in Zambia. For example, sorghum, cassava, and millet can be substituted for maize in opaque beer, and also as an energy source in livestock feed production. Sorghum could also be utilized in combination with wheat in the baking industry.

Suba (1985) used the Nerlove model of agricultural supply response to determine the supply response of maize in Zambia. Maize prices and rainfall are some of the factors outlined in this study as affecting the maize supply response in Zambia.

Some of the policy implications of the Government's maize policy drawn from Suba's study were that an effective instrument of increasing maize production would be an appropriate pricing policy. This would have to be integrated with the other non-price factors that are important in influencing maize production levels.

Suba also pointed out that weather variability, especially rainfall, is an important non-price factor. He recommends that the development of drought-resistant varieties could help overcome this rainfall problem. Suba concludes that the production of drought-resistant crops like sorghum, cassava and millet in drought-prone areas could help alleviate the problems arising from fluctuations in maize supplies.

Mendamenda (1987) used a Nerlovian model to study the response of Zambian commercial farmers to changes in the producer price of maize. The results of this study indicate that land allocation for maize depends on a number of variables. These variables included economic, environmental, technological and sociological factors. In the policy implications of the study, Mendamenda cautions policy makers

not to focus only on prices when considering supply responses, but also to consider the other factors outlined above.

Mwiinga (1989) in his study on resolving the contradictions in state policy for agricultural development in Zambia, addresses the question of why, after 25 years of independence, the objectives of agricultural and rural development are still far from being achieved. He asserts that the Government continues to pursue the same policies that have failed to bear positive results.

Mwiinga suggests that the bias against the rural sector and traditional producers and the problems of inefficiency and poor management should be addressed by the Zambian Government. He further suggests that the Government will have to increase resource allocation to the agricultural sector for significant development to occur in that sector.

Mwiinga also proposes ways in which current contradictions in the state of the agricultural sector can be resolved. The important propositions relate to the need for the country to increase food production and attain food self-sufficiency and provide raw materials for the industries.

Lufumpa (1989) outlined a policy model for maize marketing operations in Zambia. A multi-period linear programming approach was used to address cost reduction considerations in the maize marketing system. Emphasis in the

study was placed on addressing costs relating to the keeping of maize stocks, purchases, sales, and trade. Lufumpa suggests that savings could be attained within the marketing system through the implementation of rational inventory and trade policies.

Endnote

- 1 Hazell, B.R.P. "A Linear Alternative to Quadratic and Semi-Variance Programming for Farm Planning Under Uncertainty". American Journal of Agricultural Economics, 53 (February 1971):53-62.

CHAPTER III
METHODOLOGY

Theory of the Linear Programming Model Under Certainty

Farmers in Zambia face many alternatives and choices under very limited resource conditions. In the production process, farmers take into account certain requirements and constraints facing them. Given this situation, farmers will try to allocate their resources so that maximum benefits are derived from the limited resources at their disposal and within the confines of their individual requirements.

One way of analyzing a farm problem of this nature is to use optimization algorithms such as linear programming.

The form of the general linear programming model for the farm is as follows:

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

Subject to:

$$\sum_{j=1}^n a_{1j}X_j \leq b_1$$

$$\sum_{j=1}^n a_{2j}X_j \leq b_2$$

.....

.....

$$\sum_{j=1}^n a_{mj}X_j \leq b_m$$

$$X_j \geq 0$$

where:

- Z is the objective function to be maximized.
- X_j is the level of an activity j which uses certain resources for its production.
- C_j is the increase of the objective function from a unit increase in X_j .

a_{ij} is the amount of resource i used by activity j .

b_i are the available amounts of scarce resources.

Similarly, the general linear programming model can be expressed in matrix form as follows:

$$\text{Max } C'X$$

Subject to:

$$AX \leq V$$

and

$$X \geq 0 \quad \forall j$$

where:

C' represents the net revenues of farm activities.

X is the level of the farm activities.

A is a matrix of scarce resource levels needed for

carrying out the farm activities.

V is a vector of available amounts of the scare resources.

The general solution to the problem can be derived by using the Lagrange approach. First the Lagrange function is specified as follows:

$$L(X_1, X_2, \dots, X_n, \lambda_1, \lambda_2, \dots, \lambda_m) = \sum C_j X_j + \sum_{i=1}^m \lambda_i (b_i - \sum_{j=1}^n a_{ij} X_j)$$

where the lambdas are called the Lagrangean multipliers.

For an optimal solution to this problem to exist, the following first-order necessary conditions must be fulfilled.

$$(a) \quad \frac{\partial L}{\partial X_j} = C_j - a_{ij} \lambda_i \leq 0$$

$$i = 1, 2, \dots, m$$

$$j = 1, 2, \dots, n$$

$$(b) \quad X_j \frac{\partial L}{\partial X_j} = (C_j - a_{ij}\lambda_i) X_j = 0$$

$$i = 1, 2, \dots, n$$

$$j = 1, 2, \dots, m$$

$$(c) \quad \frac{\partial L}{\partial X_j} = b_i - \sum_{i=1}^n a_{ij} X_j \geq 0$$

$$j = 1, 2, \dots, m$$

$$(d) \quad \frac{\partial L}{\partial \lambda_i} = (b_i - \sum_{j=1}^m a_{ij} X_j) \lambda_i = 0$$

$$j = 1, 2, \dots, m$$

Under optimal conditions the lambdas are shadow prices, i.e., they reflect the change in the objective function value due to a change in the unit of activity or resource in the solution. If the constraints in the farm programming problem are binding, then the lambdas derived from equations (c) and

(d) are positive. If the constraints are not binding, then the lambdas equal zero; i.e., when

$$(b_i - \sum_{j=1}^n a_{ij}X_j) = 0$$

then lambda is greater than zero. But, if

$$(b_i - \sum_{j=1}^n a_{ij}X_j) > 0$$

then lambda is equal to zero.

These conditions are necessary, but they are not necessarily sufficient, for an optimal solution. The first-order necessary conditions provide an explicit analytical framework for economic analysis, but they cannot be used directly to obtain an optimal solution. For example, if we assume an interior solution where all farm activities are carried out (i.e., $X_j > 0$), then, from equations (a) and (b),

we have

$$\frac{\partial L}{\partial X_j} = 0$$

Similarly, when

$$\frac{\partial L}{\partial X_j} > 0$$

then

$$X_j = 0.$$

Assumptions of linear programming

A set of assumptions usually underlines the linear programming algorithms. These assumptions are specified as follows:

1. Proportionality

- (a) The returns that activity j contributes to Z (objective function) are given by $C_j X_j$

- (b) The levels of resources used by activity j are given by $a_{ij}X_j$
- (c) This assumption implies constant returns to scale over the entire range of production of activity j . For example, if five units cost \$200 then 10 units cost \$400, etc.

2. Additivity

- (a) The total returns to the (n) activities are given by the sum of the returns to each activity.
- (b) The total resource use of the (n) activities is equal to the sum of the levels used by each activity.
- (c) This assumption eliminates interactions between activities, such as increased production of corn and soybeans when grown in rotation.

3. Divisibility

Activities may be divided into fractional units. For example, a farmer is allowed to produce 160.5 acres of corn or 325.2 kilograms of corn.

4. Finiteness

The number of activities and constraints is finite.

5. Single Valued Expectations (certainty)

All parameters in the problem are known constants.

The Empirical Linear Programming Models Under Certainty

Profit maximization is assumed in this optimization problem. Specifically, the following activities and constraints are included in this empirical model for Zambian farmers. The activities and constraints outlined below relate to all three categories of farmers. Some of the activities and constraints are common for all three categories of farmers, while others pertain to specific categories of farmers.

Data for the models

The data used in the one year models under certainty were obtained from crop budgets prepared by the Department of Agriculture in the Ministry of Agriculture. The cost of production budgets and the producer prices used are for 1988. Data on borrowing limits were obtained from Lima Bank, the major lending institution to farmers. The producer prices used are real prices.

In general the prices of Zambian commodities are much lower than the World prices as indicated in Table 3.1. Wheat is the only crop whose price is higher than the World price for the of the five years under observation. The higher prices of wheat could be the government's deliberate effort to encourage wheat production locally.

Table 3.1: World and Zambian prices
(in Zambian Kwacha per metric tons)

Year	Maize	Wheat	Sunflower	Maize	Wheat	Sunflower
	World Prices			Zambian Prices		
1984	304	337	792	272	472	430
1985	644	787	1630	315	506	558
1986	1143	1461	2718	611	960	839
1987	616	912	1640	867	1233	1400
1988	1090	1340	2760	889	2111	1800

Source: Centre for Agriculture and Rural Development and agricultural statistics Bulletins

Activities

1. Growing Activities The growing activities include land preparation, weeding or application of herbicides, and application of fertilizers. The following are the growing activities used in the programming models.

Maize Growing - MZG
 Sorghum Growing - SORGG
 Millet Growing - MILG
 Rice Growing - RICEG
 Cassava Growing - CASG
 Cotton Growing - COTG
 Sunflower Growing - SFG
 Soybeans Growing - SBG
 Groundnut Growing _ GNG
 Rainfed Wheat Growing - RFWTG
 Burley Tobacco Growing - BTOBG
 Virginia Tobacco Growing - VTOBG
 Irrigated Wheat Growing - IWTG

2. Harvesting Activities The harvesting activities include actual harvesting and post-harvest activities.

Maize Harvesting - MZH
 Sorghum Harvesting - SORGH
 Millet Harvesting - MILH

Rice Harvesting - RICEH
Cassava Harvesting - CASH
Cotton Harvesting - COTH
Sunflower Harvesting - SFH
Soybeans Harvesting - SBH
Groundnut Harvesting - GNH
Rainfed Wheat Harvesting - RFWTH
Burley Tobacco Harvesting - BTOBH
Virginia Tobacco Harvesting - VTOBH
Irrigated Wheat Harvesting - IWTH

3. Selling Activities The selling activities relate to the selling of produce at farm gate prices to the official marketing agencies and to private traders.

Maize Selling - MZS
Sorghum Selling - SORGS
Millet Selling - MILS
Rice Selling - RICES
Cassava Selling - CASS
Cotton Selling - COTS
Sunflower Selling - SFS
Soybean Selling - SBS
Groundnut selling - GNS
Rainfed Wheat Selling - RFWTS

Burley Tobacco Selling - BTOBS

Virginia Tobacco Selling - VTOBS

Irrigated Wheat Selling - IWTS

4. Consumption Activities These activities relate to on-farm household consumption of the locally produced crops.

Maize Consumption - MZCON

Sorghum Consumption - SORGCON

Millet Consumption - MILCON

Cassava Consumption - CASCON

5. Borrowing Activity This is used in the models as an alternative source of capital for the farmer. In Zambia, farmers of all categories rely heavily on borrowed capital for their farm operations.

Borrowing - BORR

6. Hire Labor Activities The large-scale commercial farmers rely entirely on hired farm labor in their operations. The other categories of farmers rely on family labor. Hired farm labor is mainly used to supplement the family labor supply.

Hire Labor - HLABOR

Constraints

- L** - This is the fixed amount of land available to the farmer for cultivation. The units of measure used are in hectares.
- GL** - This is the amount of labor available for the growing activities. The units of measure are in man-days, where one man-day is equivalent to six hours of farm work.
- HL** - Harvesting labor is the amount of labor available for the harvesting activities. The units of measure are in man-days.
- A** - Is the family labor constraint.
- GL** - Is the hired labor constraint during the growing period.
- HL** - Is the hired labor constraint during the harvesting period.
- B** - This is the borrowing limit. It is the maximum amount of money a farmer can borrow. This limit varies with the category of farmer. The large-scale farmers have a much higher limit and the traditional have the lowest. The units of measure are in Zambian Kwacha.
- K** - This is the farmer's initial capital outlay.
- C₁** - This maize consumption constraint is the amount of maize consumed by a rural farming household per year. The units are in kilograms.

- C_2 - The sorghum consumption constraint is the amount of sorghum retained by a rural farming household for on-farm consumption. The units are in kilograms.
- C_3 - The millet consumption constraint is the amount of millet retained for home consumption by a rural farming household. The units are in kilograms.
- C_4 - The cassava consumption constraint is the amount of cassava retained for consumption by a rural farming household for on-farm consumption. The units are in kilograms.

The large-scale commercial farmer's empirical model

The crops included in the large-scale commercial farmer's model are maize, sorghum, rice, cotton, sunflower, soybeans, groundnuts, rainfed wheat, virginia tobacco, and irrigated wheat. Irrigated wheat and soybeans are grown in rotation. The empirical model for the large-scale farmer is specified as follows:

$$\begin{aligned} \text{Max} \quad & - C_1 \text{MZG} - C_2 \text{SORGG} - C_3 \text{RICEG} - C_4 \text{COTG} - C_5 \text{SFG} - C_6 \text{SBG} - \\ & C_7 \text{GNG} - C_8 \text{RFWTG} - C_9 \text{VTOBG} - C_{10} \text{IWTG} - C_{11} \text{MZH} - C_{12} \text{SORGH} - \\ & C_{13} \text{RICEH} - C_{14} \text{COTH} - C_{15} \text{SFH} - C_{16} \text{SBH} - C_{17} \text{GNH} - C_{18} \text{RFWTH} - \\ & C_{19} \text{VTOBH} - C_{20} \text{IWTH} + C_{21} \text{MZS} + C_{22} \text{SORGS} + C_{23} \text{RICES} + C_{24} \text{COTS} \end{aligned}$$

$$\begin{aligned}
& + C_{25}SFS + C_{26}SBS + C_{27}GNS + C_{28}RFWTS + C_{29}VTOBS + C_{30}IWTS \\
& - C_{31}HLABOR - C_{32}BORR
\end{aligned}$$

Subject to:

1. $MZG + SORGG + RICEG + COTG + SFG + SBG + GNG + RFWTG + VTOBG + IWTG \leq \underline{L}$
2. $a_{ij}MZG + a_{ij}SORGG + a_{ij}RICEG + a_{ij}COTG + a_{ij}SFG + a_{ij}SBG + a_{ij}GNG + a_{ij}RFWTG + a_{ij}VTOBG + a_{ij}IWTG - HLABOR(GL) \leq 0$
3. $b_{ij}MZH + b_{ij}SORGH + b_{ij}RICEH + b_{ij}COTH + b_{ij}SFH + b_{ij}SBH + b_{ij}GNH + b_{ij}RFWTH + b_{ij}VTOBH + b_{ij}IWITH - HLABOR(HL) \leq 0$
- 4a. $HLABOR \leq GL$
- 4b. $HLABOR \leq HL$
5. $- SBG + IWTG \leq 0$
6. $- MZG + c_{ij} MZH \leq 0$
7. $- SORGG + d_{ij}SORGH \leq 0$
8. $- RICEG + e_{ij}RICEH \leq 0$
9. $- COTG + f_{ij}COTH \leq 0$
10. $- SFG + g_{ij}SFH \leq 0$

11. $- SBG + h_{ij}SBH \leq 0$
12. $- GNH + i_{ij}GNH \leq 0$
13. $- RFWTG + j_{ij}RFWTH \leq 0$
14. $- VTOBG + k_{ij}VTOBH \leq 0$
15. $- IWTG + l_{ij}IWTH \leq 0$
16. $- c_{ij}MZH + MZS \leq 0$
17. $- d_{ij}SORGH + SORGS \leq 0$
18. $- e_{ij}RICEH + RICES \leq 0$
19. $- f_{ij}COTH + COTS \leq 0$
20. $- g_{ij}SFH + SFS \leq 0$
21. $- h_{ij}SBH + SBS \leq 0$
22. $- i_{ij}GNH + GNS \leq 0$
23. $- j_{ij}RFWTH + RFWTS \leq 0$
24. $- k_{ij}VTOBH + VTOBS \leq 0$
25. $- l_{ij}IWTH + IWTS \leq 0$
26. $BORR \leq B$
27. $MZG + SORGG + RICEG + COTG + SFG + SBG + GNG + RFWTG$
 $+ VTOBG + IWTG + MZH + SORGH + RICEH + COTH + SFH +$
 $SBH + GNH + RFWTH + VTOBH + IWTH + HLABOR - BORR \leq K$
28. $- MZS - SORGS - RICES - COTS - SFS - SBS - GNS -$
 $RFWTS - VTOBS + (1+C_{32})BORR + CAPEND \leq 0$

Explanation of the activities and constraints included in the large-scale commercial farmer's model.

Constraint 1. The sum of all the land area under each crop included in an optimal solution of the model should be less than or equal to the total amount of land available to the large-scale commercial farmer. The farmer is not allowed to cultivate more than the fixed amount of land available to him/her.

Constraint 2. All the labor used in the growing activities of all the crops included in the optimal solution of the model should not exceed the total amount of labor that can be hired during the growing season by the large-scale commercial farmer.

Constraint 3. All the labor used in the harvesting activities of all the crops included in the optimal solution of the model should not exceed the total amount of labor that can be hired during the harvesting season by large-scale commercial farmers.

Constraints 4a and 4b. Hired labor should not exceed the total amount of hired labor available during the growing or

harvesting periods.

Constraint 5. This is a rotation specification. The total amount of land under soybeans production in one crop season should be equal to or less than the total amount of land under irrigated wheat in the following season.

Constraints 6 through 15. The constraints 6 through 15 indicate that the total amount of each crop harvested cannot exceed the total amount of that crop grown.

Constraints 16 through 25. These constraints ensure that the amounts of each crop sold in the market are not more than the amount of that crop harvested.

Constraint 26. The total amount of money borrowed by the large-scale commercial farmer should not exceed the borrowing limit imposed on them by the lending institutions.

Constraint 27. The total amount of money used in the growing and harvesting activities for each crop should be less than or equal to the sum of the money borrowed, plus the farmers' own initial capital contribution.

Identity 28. This is just an accounting identity that ensures that the revenues from the farm enterprise are not less than the farmer's initial capital outlay. This specification also requires that all the borrowed capital be repaid in full with interest by the end of the crop season.

The small-scale commercial farmer's empirical model

The crops included in the small-scale commercial farmer's model are maize, sorghum, millet, rice, cotton, sunflower, soybeans, groundnuts, rainfed wheat, virginia tobacco, and burley tobacco.

$$\begin{aligned} \text{Max} \quad & - C_1\text{MZG} - C_2\text{SORGG} - C_3\text{MILG} - C_4\text{RICEG} - C_5\text{COTG} - C_6\text{SFG} - \\ & C_7\text{SBG} - C_8\text{GNG} - C_9\text{RFWTG} - C_{10}\text{VTOBG} - C_{11}\text{BTOBG} - C_{12}\text{MZH} - \\ & C_{13}\text{SORGH} - C_{14}\text{MILH} - C_{15}\text{RICEH} - C_{16}\text{COTH} - C_{17}\text{SFH} - C_{18}\text{SBH} - \\ & C_{19}\text{GNH} - C_{20}\text{RFWTH} - C_{21}\text{VTOBH} - C_{22}\text{BTOBH} + C_{23}\text{MZS} + C_{24}\text{SORGS} \\ & + C_{25}\text{MILS} + C_{26}\text{RICES} + C_{27}\text{COTS} + C_{28}\text{SFS} + C_{29}\text{SBS} + C_{30}\text{GNS} + \\ & C_{31}\text{RFWTS} + C_{32}\text{VTOBS} + C_{33}\text{BTOBS} - C_{34}\text{FLABOR} - C_{35}\text{HLABOR} - \\ & C_{36}\text{BORR} \end{aligned}$$

Subject to:

$$\begin{aligned} 1. \quad & \text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} \\ & + \text{RFWTG} + \text{VTOBG} + \text{BTOBG} \leq \underline{L} \end{aligned}$$

2. $a_{ij}MZG + a_{ij}SORGG + a_{ij}MILG + a_{ij}RICEG + a_{ij}COTG + a_{ij}SFG$
 $+ a_{ij}SBG + a_{ij}GNG + a_{ij}RFWTG + a_{ij}VTOBG + a_{ij}BTOBG -$
 $FLABOR - HLABOR(GL) \leq 0$
3. $b_{ij}MZH + b_{ij}SORGH + b_{ij}MILH + b_{ij}RICEH + b_{ij}COTH + b_{ij}SFH$
 $+ b_{ij}SBH + b_{ij}GNH + b_{ij}RFWTH + b_{ij}VTOBH + b_{ij}BTOBH -$
 $FLABOR - HLABOR(HL) \leq 0$
4. $FLABOR \leq A$
- 5a. $HLABOR \leq GL$
- 5b. $HLABOR \leq HL$
6. $- MZG + c_{ij} MZH \leq 0$
7. $- SORGG + d_{ij}SORGH \leq 0$
8. $- MILG + e_{ij}MILH \leq 0$
9. $- RICEG + f_{ij}RICEH \leq 0$
10. $- COTG + g_{ij}COTH \leq 0$
11. $- SFG + h_{ij}SFH \leq 0$
12. $- SBG + i_{ij}SBH \leq 0$
13. $- GNG + j_{ij}GNH \leq 0$
14. $- RFWTG + k_{ij}RFWTH \leq 0$
15. $- VTOBG + l_{ij}VTOBH \leq 0$
16. $- BTOBG + m_{ij}BTOBH \leq 0$
17. $- c_{ij}MZH + MZS + MZCON \leq 0$

18. $- d_{ij} \text{SORGH} + \text{SORGS} + \text{SORGCON} \leq 0$
19. $- e_{ij} \text{MILH} + \text{MILS} + \text{MILCON} \leq 0$
20. $- f_{ij} \text{RICEH} + \text{RICES} \leq 0$
21. $- g_{ij} \text{COTH} + \text{COTS} \leq 0$
22. $- h_{ij} \text{SFH} + \text{SFS} \leq 0$
23. $- i_{ij} \text{SBH} + \text{SBS} \leq 0$
24. $- j_{ij} \text{GNH} + \text{GNS} \leq 0$
25. $- k_{ij} \text{RFWTH} + \text{RFWTS} \leq 0$
26. $- l_{ij} \text{VTOBH} + \text{VTOBS} \leq 0$
27. $- m_{ij} \text{BTOBH} + \text{BTOBS} \leq 0$
28. $\text{MZCON} \geq C_1$
29. $\text{SORGCON} \geq C_2$
30. $\text{MILCON} \geq C_3$
31. $\text{BORR} \leq B$
32. $\text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG}$
 $+ \text{RFWTG} + \text{VTOBG} + \text{BTOBG} + \text{MZH} + \text{SORGH} + \text{MILH} + \text{RICEH}$
 $+ \text{COTH} + \text{SFH} + \text{SBH} + \text{GNH} + \text{RFWTH} + \text{VTOBH} + \text{BTOBH} +$
 $\text{FLAVOR} + \text{HLAVOR} - \text{BORR} \leq K$
33. $- \text{MZS} - \text{SORGS} - \text{MILS} - \text{RICES} - \text{COTS} - \text{SFS} - \text{SBS} -$
 $\text{GNS} - \text{RFWTS} - \text{VTOBS} - \text{BTOBS} + (1+C_{36})\text{BORR} + \text{CAPEND}$
 ≤ 0

Explanations for the activities and constraints included in the small-scale commercial farmer's model.

Constraint 1. The total sum of the land area under each crop included in the optimal solution of the model should be less than or equal to the total amount of land available to the small-scale commercial farmer.

Constraint 2. All the labor used in the growing activities of all the crops included in the optimal solution of the model should not exceed the total amount of labor the family can provide, plus the labor that can be hired during the growing season.

Constraint 3. All the labor used in the harvesting activities of all crops included in the optimal solution of the model should not exceed the total amount of labor the family can provide plus the labor that can be hired during the harvesting season.

Constraint 4. The total amount of family labor used in the production process should not exceed the total amount of family labor the household is able to provide.

Constraints 5a and 5b. Hired labor should not exceed the total amount of hired labor available during the growing or harvesting periods.

Constraints 6 through 16. These constraints indicate that the total amount of each crop harvested should not exceed the total amount of that crop grown.

Constraints 17 through 19. The total amount of the crop sold plus the amount consumed cannot exceed the amount available for harvest.

Constraints 20 through 27. The constraints indicate that the amount of each crop sold should be less than or equal to the amount harvested.

Constraints 28 through 30. This represents the minimum on-farm consumption requirements for the farming household. For each of these food crops grown, a specified minimum is retained on the farm for consumption.

Constraint 31. The total amount of money borrowed by the small-scale commercial farmer should not exceed the borrowing limit imposed on the farmer by the lending institutions.

Constraint 32. This constraint shows that the total amount of money used in the growing and harvesting activities for each crop should be less than or equal to the sum of the money borrowed and the farmer's own capital contribution.

Identity 33. This identity ensures that the revenues from the farm enterprise are not less than the farmer's initial capital outlay. This specification also requires that all the borrowed capital be repaid in full with interest by the end of the crop season.

The traditional farmer's empirical model

The crops included in the traditional farmer's model are maize, sorghum, millet, rice, cassava, cotton, sunflower, soybeans, groundnuts, rainfed wheat, and burley tobacco.

Max - C_1 MZG - C_2 SORGG - C_3 MILG - C_4 RICEG - C_5 CASG - C_6 COTG -
 C_7 SFG - C_8 SBG + C_9 GNG - C_{10} RFWTG - C_{11} BTOBG - C_{12} MZH -
 C_{13} SORGH - C_{14} MILH - C_{15} RICEH - C_{16} CASH - C_{17} COTH - C_{18} SFH -
 C_{19} SBH - C_{20} GNH - C_{21} RFWTH - C_{22} BTOBH + C_{23} MZS + C_{24} SORGS +
 C_{25} MILS + C_{26} RICES + C_{27} MILS + C_{28} COTS + C_{29} SFS + C_{30} SBS +
 C_{31} GNS + C_{32} RFWTS + C_{33} BTOBS - C_{34} FLABOR - C_{35} HLABOR -
 C_{36} BORR

Subject to:

1. $MZG + SORGG + MILG + RICEG + CASG + COTG + SFG + SBG + GNG + RFWTG + BTOBG \leq \underline{L}$
2. $a_{ij}MZG + a_{ij}SORGG + a_{ij}MILG + a_{ij}RICEG + a_{ij}CASG + a_{ij}COTG + a_{ij}SFG + a_{ij}SBG + a_{ij}GNG + a_{ij}RFWTG + a_{ij}BTOBG - FLABOR - HLABOR(GL) \leq 0$
3. $b_{ij}MZH + b_{ij}SORGH + b_{ij}MILH + b_{ij}RICEH + b_{ij}CASH + b_{ij}COTH + b_{ij}SFH + b_{ij}SBH + b_{ij}GNH + b_{ij}RFWTH + b_{ij}BTOBH - FLABOR - HLABOR(HL) \leq 0$
4. $FLABOR \leq A$
- 5a. $HLABOR \leq GL$
- 5b. $HLABOR \leq HL$
6. $-MZG + c_{ij}MZH \leq 0$
7. $-SORGG + d_{ij}SORGH \leq 0$
8. $-MILG + e_{ij}MILH \leq 0$
9. $-RICEG + f_{ij}RICEH \leq 0$
10. $-CASG + g_{ij}CASH \leq 0$
11. $-COTG + h_{ij}COTH \leq 0$
12. $-SFG + i_{ij}SFH \leq 0$

13. $- \text{SBG} + j_{ij} \text{SBH} \leq 0$
14. $- \text{GNH} + k_{ij} \text{GNH} \leq 0$
15. $- \text{RFWTG} + l_{ij} \text{RFWTH} \leq 0$
16. $- \text{BTOBG} + n_{ij} \text{BTOBH} \leq 0$
17. $- c_{ij} \text{MZH} + \text{MZS} + \text{MZCON} \leq 0$
18. $- d_{ij} \text{SORGH} + \text{SORGS} + \text{SORGCON} \leq 0$
19. $- e_{ij} \text{MILH} + \text{MILS} + \text{MILCON} \leq 0$
20. $- g_{ij} \text{CASH} + \text{CASS} + \text{CASCON} \leq 0$
21. $- f_{ij} \text{RICEH} + \text{RICES} \leq 0$
22. $- h_{ij} \text{COTH} + \text{COTS} \leq 0$
23. $- i_{ij} \text{SFH} + \text{SFS} \leq 0$
24. $- j_{ij} \text{SBH} + \text{SBS} \leq 0$
25. $- k_{ij} \text{GNH} + \text{GNS} \leq 0$
26. $- l_{ij} \text{RFWTH} + \text{RFWTS} \leq 0$
27. $- n_{ij} \text{BTOBH} + \text{BTOBS} \leq 0$
28. $\text{MZCON} \geq C_1$
29. $\text{SORGCON} \geq C_2$
30. $\text{MILCON} \geq C_3$
31. $\text{CASCON} \geq C_4$
32. $\text{BORR} \leq B$

$$\begin{aligned}
 33. \quad & \text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{CASG} + \text{COTG} + \text{SFG} + \text{SBG} \\
 & + \text{GNG} + \text{RFWTG} + \text{BTOBG} + \text{MZH} + \text{SORGH} + \text{MILH} + \text{RICEH} + \\
 & \text{CASH} + \text{COTH} + \text{SFH} + \text{SBH} + \text{GNH} + \text{RFWTH} + \text{BTOBH} + \\
 & \text{FLABOR} + \text{HLABOR} - \text{BORR} \leq K
 \end{aligned}$$

$$\begin{aligned}
 34. \quad & - \text{MZS} - \text{SORGS} - \text{MILS} - \text{RICES} - \text{CASS} - \text{COTS} - \text{SFS} - \text{SBS} \\
 & - \text{GNS} - \text{RFWTS} - \text{BTOBS} + (1 + C_{36})\text{BORR} + \text{CAPEND} \leq 0
 \end{aligned}$$

Explanation for the activities and constraints included in the traditional farmer's model.

Constraint 1. The sum of all the land area under each crop included in the optimal solution of the problem should be less than or equal to the total amount of land available to the traditional farmer.

Constraint 2. All the labor used in the growing activities of all the crops included in the optimal solution of the model should not exceed the total amount of labor the family can provide plus the labor that can be hired during the growing season.

Constraint 3. All labor used in harvesting activities of all the crops included in the optimal solution of the model should not exceed the total amount of labor the family can provide plus the labor that can be hired during the harvesting season.

Constraint 4. The total amount of family labor used in the production process should not exceed the total amount of family labor supply in the household.

Constraints 5a and 5b. Hired labor should not exceed the total amount of hired labor available during the growing or harvesting periods.

Constraints 6 through 16. The total amount of each crop harvested cannot exceed the total amount of that crop grown.

Constraints 17 through 20. The total amount consumed and sold should not exceed the amount harvested of that crop.

Constraints 21 through 27. The total amount of each crop sold should be equal to or less than the total amount of crop harvested.

Constraints 28 through 31. For an optimal solution to this problem to exist, the minimum consumption requirements for the farming household should be met for each of the food crops.

Constraint 32. The total amount of money borrowed by the traditional farmer should not exceed the borrowing limit imposed on the farmer by the lending institutions.

Constraint 33. The total amount of money used in the growing and harvesting activities should be less than or equal to the total amount of money borrowed, plus the farmer's own initial capital contribution.

Constraint 34. This constraint ensures that the revenues from the farm enterprise are not less than the farmer's initial capital outlay. This specification also requires that all the borrowed capital be repaid in full with interest by the end of the crop season.

Theory of the Risk Programming Model

The techniques of Minimization of Total Absolute Deviations (MOTAD) are used in the risk programming model. The MOTAD specification, developed by Hazell in 1971, minimizes the mean

absolute deviations. It is an extension of the ordinary linear programming model. The MOTAD problem is solved by parametric linear programming algorithms. In MOTAD, risk is measured by a parameter (say, lambda) which gives an indication of the amount of deviations in income a farmer is willing to accept. The higher the lambda value the less risk averse the farmer is and the lower the lambda value the more risk averse the farmer is.

The set up for the MOTAD model is as follows:

$$\text{Max } E(\pi) = \sum_{j=1}^n \bar{C}_j X_j - F$$

Subject to:

$$(1) \quad \sum_{j=1}^n a_{ij} X_j \leq b_i$$

$$i = 1, 2, \dots, m$$

$$(2) \quad \sum_{j=1}^n (C_{rj} - \bar{C}_j) X_j - y_r + y_r \geq 0$$

$$r = 1, 2, \dots, s$$

$$(3) \quad \sum_{r=1}^s (y_{r-} + y_{r+}) = sM = \lambda$$

and

$$X_j \geq 0, \quad y_r \geq 0$$

where

E is the expected income,

\bar{C}_j is the mean net revenue for s years,

X_j is an n -by-1 vector of activity levels for the production activities,

F are the fixed costs,

a_{ij} is the amount of the i th resource required for the production of the j th product,

b_i is an m -by- 1 vector of resource or constraint levels,

\bar{C}_{rj} is the revenue from the j th activity in the r th year,

y_{r+} is an s -by- 1 vector of positive deviations from y ,

y_{r-} is an s -by- 1 vector of negative deviations from y ,

s is the sample size (or number of years for the data),

M is the mean absolute deviation, and

λ is the risk aversion coefficient

The Empirical Risk Programming Models

The risk programming models used in this study are an extension of the certainty models. The same crops included in the certainty models are used in the risk programming models as well. However, the selling prices in the objective function are average prices calculated from a ten year time series data set (1979-1988). Table 3.2 presents the real producer prices for the ten year time period (1979-1988).

The costs of the farming enterprises are assumed to be nonstochastic. New rows reflecting the risks facing the

farmers are added to the constraint structure. Risk is introduced in the models through variations in farm income arising from deviations in producer prices. The remainder of the constraints are the same as in the certainty models.

Table 3.3 presents the price deviations used in the risk programming models. Table 3.4 presents the price correlation matrix for agricultural crops in Zambia. The price of maize is positively correlated to all other crops except cotton, sunflower, Virginia and burley tobacco. Sorghum on the other hand is negatively correlated to all the other agricultural crops except millet and cassava. Cassava and burley tobacco, though negatively correlated, have the highest correlation of all the crops.

Table 3.5 presents the average and variance of the real producer prices for agricultural crops in Zambia. The figures indicate that there has been no significant variation in the real prices facing the farmers over the ten year period (1979-1988).

Table 3.6 shows the per capita consumption of the four main food crops retained by small-scale commercial and traditional farmers, for on-farm consumption.

Table 3.2: Real producer prices in Zambian Kwacha per kilogram

Year	1979	80	81	82	83	84	85	86	87	88
Maize	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
Sorghum	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Rice	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Cotton	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.4
Sunflower	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.2
Soyabeans	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Groundnuts	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.0
Rfd. Wheat	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.3
V. Tobacco	1.7	1.6	1.5	1.9	1.8	1.6	1.5	1.4	1.1	1.7
B. Tobacco	1.2	1.3	1.1	1.3	1.1	1.0	1.0	0.9	0.9	1.1
Irr. Wheat	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.3
Cassava	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1
Millet	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2

Source: Agricultural Statistics Bulletins.

Table 3.3: Price deviations used in the risk models

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
MZ	0.02	0.00	0.00	0.00	0.00	-0.01	0.01	-0.03	-0.02	0.03
SORG	0.03	0.04	0.01	0.02	-0.01	-0.01	-0.02	-0.02	-0.05	0.00
RICE	0.00	0.00	0.02	-0.05	-0.10	-0.05	0.03	0.04	0.04	0.06
COT	-0.16	-0.11	-0.05	-0.02	0.01	0.04	0.08	0.13	0.06	0.00
SF	-0.04	-0.06	-0.04	-0.06	-0.01	0.04	0.05	0.05	0.01	0.06
SB	0.00	-0.02	-0.02	-0.02	0.00	0.00	0.03	0.00	0.01	0.02
GN	-0.04	-0.03	-0.10	-0.06	-0.04	-0.08	-0.05	-0.02	0.04	0.40
RFWT	0.00	0.03	-0.01	-0.04	-0.02	-0.02	0.04	-0.01	0.04	0.00
VTOB	-0.11	0.00	0.08	-0.35	-0.27	-0.01	0.11	0.20	0.49	-0.10
BTOB	-0.15	-0.16	-0.05	-0.16	-0.03	0.08	0.11	0.15	0.21	0.01
IWT	0.00	0.03	-0.01	-0.04	-0.02	-0.02	0.04	-0.01	0.04	0.00
CAS	0.06	0.06	0.07	0.07	-0.02	-0.02	-0.04	-0.07	-0.08	-0.03
MIL	0.06	0.07	0.08	0.08	-0.07	-0.04	-0.03	-0.03	-0.05	-0.07

Source: Compiled by author

Table 3.4: Price Correlation Matrix

	MZ	SORG	RICE	COT	SF	SB	GN	VTOB	BTOB	WT	CAS	MIL
MZ	1	0.58	0.12	-0.60	-0.12	0.23	0.48	-0.50	-0.55	0.02	0.43	0.13
SORG		1	-0.15	-0.83	-0.69	-0.59	-0.09	-0.65	-0.95	-0.29	0.92	0.78
RICE			1	0.17	0.42	0.42	0.50	0.64	0.38	0.54	-0.30	-0.04
COT				1	0.77	0.45	0.70	0.43	0.86	0.07	-0.85	-0.67
SF					1	0.82	0.48	0.39	0.81	0.21	-0.88	-0.83
SB						1	0.49	0.37	0.65	0.50	-0.71	-0.74
GN							1	-0.01	0.14	0.10	-0.33	-0.47
VTOB								1	0.76	0.70	-0.58	-0.25
BTOB									1	0.38	-0.93	-0.73
WT										1	-0.32	-0.15
CAS											1	0.88
MIL												1

Source: Compiled by author

Table 3.5: Average producer prices and variances

	Average	Variance
Maize	0.134	0.0003
Sorghum	0.103	0.0007
Rice	0.225	0.0026
Cotton	0.352	0.0077
Sunflower	0.269	0.0021
Soyabeans	0.178	0.0003
Groundnuts	0.404	0.0215
Rainfed Wheat	0.249	0.0006
V. Tobacco	1.566	0.0573
B. Tobacco	1.089	0.018
Irr. Wheat	0.249	0.0006
Cassava	0.084	0.0034
Millet	0.137	0.0043

Source: Compiled by author

Table 3.6: Rural population per capita consumption
in kilograms per year

Crop	Per capita consumption
Maize	119
Sorghum	26
Millet	26
Cassava	67

Source: Compiled by author from the Food Strategy
Study, 1981.

The large-scale commercial farmer's empirical risk model

$$\begin{aligned}
 \text{Max} \quad & - C_1\text{MZG} - C_2\text{SORGG} - C_3\text{RICEG} - C_4\text{COTG} - C_5\text{SFG} - C_6\text{SBG} - \\
 & C_7\text{GNG} - C_8\text{RFWTG} - C_9\text{VTOBG} - C_{10}\text{IWTG} - C_{11}\text{MZH} - C_{12}\text{SORGH} - \\
 & C_{13}\text{RICEH} - C_{14}\text{COTH} - C_{15}\text{SFH} - C_{16}\text{SBH} - C_{17}\text{GNH} - C_{18}\text{RFWTH} - \\
 & C_{19}\text{VTOBH} - C_{20}\text{IWTH} + P_1\text{MZS} + P_2\text{SORGS} + P_3\text{RICES} + P_4\text{COTS} + \\
 & P_5\text{SFS} + P_6\text{SBS} + P_7\text{GNS} + P_8\text{RFWTS} + P_9\text{VTOBS} + P_{10}\text{IWTS} - \\
 & C_{21}\text{HLABOR} - R_1\text{BORR}
 \end{aligned}$$

Subject to:

1. $\text{MZG} + \text{SORGG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} + \text{RFWTG} + \text{VTOBG} + \text{IWTG} \leq \underline{L}$
2. $a_{ij}\text{MZG} + a_{ij}\text{SORGG} + a_{ij}\text{RICEG} + a_{ij}\text{COTG} + a_{ij}\text{SFG} + a_{ij}\text{SBG} + a_{ij}\text{GNG} + a_{ij}\text{RFWTG} + a_{ij}\text{VTOBG} + a_{ij}\text{IWTG} - \text{HLABOR}(\text{GL}) \leq 0$
3. $b_{ij}\text{MZH} + b_{ij}\text{SORGH} + b_{ij}\text{RICEH} + b_{ij}\text{COTH} + b_{ij}\text{SFH} + b_{ij}\text{SBH} + b_{ij}\text{GNH} + b_{ij}\text{RFWTH} + b_{ij}\text{VTOBH} + b_{ij}\text{IWTH} - \text{HLABOR}(\text{HL}) \leq 0$
4. $\text{HLABOR} \leq C$
- 5a. $\text{HLABOR} \leq \text{GL}$
- 5b. $\text{HLABOR} \leq \text{HL}$

6. - $SBG + IWTG \leq 0$
7. - $MZG + c_{ij} MZH \leq 0$
8. - $SORGG + d_{ij} SORGH \leq 0$
9. - $RICEG + e_{ij} RICEH \leq 0$
10. - $COTG + f_{ij} COTH \leq 0$
11. - $SFG + g_{ij} SFH \leq 0$
12. - $SBG + h_{ij} SBH \leq 0$
13. - $GNH + i_{ij} GNH \leq 0$
14. - $RFWTG + j_{ij} RFWTH \leq 0$
15. - $VTOBG + k_{ij} VTOBH \leq 0$
16. - $IWTG + l_{ij} IWTH \leq 0$
17. - $c_{ij} MZH + MZS \leq 0$
18. - $d_{ij} SORGH + SORGS \leq 0$
19. - $e_{ij} RICEH + RICES \leq 0$
20. - $f_{ij} COTH + COTS \leq 0$
21. - $g_{ij} SFH + SFS \leq 0$
22. - $h_{ij} SBH + SBS \leq 0$
23. - $i_{ij} GNH + GNS \leq 0$
24. - $j_{ij} RFWTH + RFWTS \leq 0$
25. - $k_{ij} VTOBH + VTOBS \leq 0$
26. - $l_{ij} IWTH + IWTS \leq 0$
27. $BORR \leq B$

$$28. \quad \text{MZG} + \text{SORGG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} + \text{RFWTG} + \\ \text{VTOBG} + \text{IWTG} + \text{MZH} + \text{SORGH} + \text{RICEH} + \text{COTH} + \text{SFH} + \text{SBH} \\ + \text{GNH} + \text{RFWTH} + \text{VTOBH} + \text{IWTH} + \text{HLABOR} - \text{BORR} \leq K$$

$$29. \quad - \text{MZS} - \text{SORGS} - \text{RICES} - \text{COTS} - \text{SFS} - \text{SBS} - \text{GNS} - \text{RFWTS} \\ - \text{VTOBS} + (1+R_i)\text{BORR} + \text{CAPEND} \leq 0$$

$$30. \quad D_{11}\text{MZS} + D_{12}\text{SORGS} + D_{13}\text{RICES} + D_{14}\text{COTS} + D_{15}\text{SFS} + D_{16}\text{SBS} + \\ D_{17}\text{GNS} + D_{18}\text{RFWTS} + D_{19}\text{VTOBS} + D_{110}\text{IWTS} + D_1 \geq 0$$

$$31. \quad D_{21}\text{MZS} + D_{22}\text{SORGS} + D_{23}\text{RICES} + D_{24}\text{COTS} + D_{25}\text{SFS} + D_{26}\text{SBS} + \\ D_{27}\text{GNS} + D_{28}\text{RFWTS} + D_{29}\text{VTOBS} + D_{210}\text{IWTS} + D_2 \geq 0$$

$$32. \quad D_{31}\text{MZS} + D_{32}\text{SORGS} + D_{33}\text{RICES} + D_{34}\text{COTS} + D_{35}\text{SFS} + D_{36}\text{SBS} + \\ D_{37}\text{GNS} + D_{38}\text{RFWTS} + D_{39}\text{VTOBS} + D_{310}\text{IWTS} + D_3 \geq 0$$

$$33. \quad D_{41}\text{MZS} + D_{42}\text{SORGS} + D_{43}\text{RICES} + D_{44}\text{COTS} + D_{45}\text{SFS} + D_{46}\text{SBS} + \\ D_{47}\text{GNS} + D_{48}\text{RFWTS} + D_{49}\text{VTOBS} + D_{410}\text{IWTS} + D_4 \geq 0$$

$$34. \quad D_{51}\text{MZS} + D_{52}\text{SORGS} + D_{53}\text{RICES} + D_{54}\text{COTS} + D_{55}\text{SFS} + D_{56}\text{SBS} + \\ D_{57}\text{GNS} + D_{58}\text{RFWTS} + D_{59}\text{VTOBS} + D_{510}\text{IWTS} + D_5 \geq 0$$

$$35. \quad D_{61}MZS + D_{62}SORGS + D_{63}RICES + D_{64}COTS + D_{65}SFS + D_{66}SBS + \\ D_{67}GNS + D_{68}RFWTS + D_{69}VTOBS + D_{610}IWTS + D_6 \geq 0$$

$$36. \quad D_{71}MZS + D_{72}SORGS + D_{75}RICES + D_{74}COTS + D_{75}SFS + D_{76}SBS + \\ D_{77}GNS + D_{78}RFWTS + D_{79}VTOBS + D_{710}IWTS + D_7 \geq 0$$

$$37. \quad D_{81}MZS + D_{82}SORGS + D_{83}RICES + D_{84}COTS + D_{85}SFS + D_{86}SBS + \\ D_{87}GNS + D_{88}RFWTS + D_{89}VTOBS + D_{810}IWTS + D_8 \geq 0$$

$$38. \quad D_{91}MZS + D_{92}SORGS + D_{93}RICES + D_{94}COTS + D_{95}SFS + D_{96}SBS + \\ D_{97}GNS + D_{98}RFWTS + D_{99}VTOBS + D_{910}IWTS + D_9 \geq 0$$

$$39. \quad D_{101}MZS + D_{102}SORGS + D_{103}RICES + D_{104}COTS + D_{105}SFS + \\ D_{106}SBS + D_{107}GNS + D_{108}RFWTS + D_{109}VTOBS + D_{1010}IWTS + D_{10} \\ \geq 0$$

$$40. \quad D_1 + D_2 + D_3 + D_4 + D_5 + D_6 + D_7 + D_8 + D_9 + D_{10} \leq \lambda$$

The small-scale commercial farmer's empirical risk model

$$\begin{aligned}
\text{Max} \quad & - C_1 \text{MZG} - C_2 \text{SORGG} - C_3 \text{MILG} - C_4 \text{RICEG} - C_5 \text{COTG} - C_6 \text{SFG} - \\
& C_7 \text{SBG} - C_8 \text{GNG} - C_9 \text{RFTWG} - C_{10} \text{VTOBG} - C_{11} \text{BTOBG} - C_{12} \text{MZH} - \\
& C_{13} \text{SORGH} - C_{14} \text{MILH} - C_{15} \text{RICEH} - C_{16} \text{COTH} - C_{17} \text{SFH} - C_{18} \text{SBH} - \\
& C_{19} \text{GNH} - C_{20} \text{RFTWH} - C_{21} \text{VTOBH} - C_{22} \text{BTOBH} + P_1 \text{MZS} + P_2 \text{SORGS} \\
& + P_3 \text{MILS} + P_4 \text{RICES} + P_5 \text{COTS} + P_6 \text{SFS} + P_7 \text{SBS} + P_8 \text{GNS} + \\
& P_9 \text{RFTWS} + P_{10} \text{VTOBS} + P_{11} \text{BTOBS} - C_{23} \text{FLAVOR} + C_{24} \text{HLABOR} \\
& - R_1 \text{BORR}
\end{aligned}$$

Subject to:

1. $\text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} + \text{RFTWG} + \text{VTOBG} + \text{BTOBG} \leq \underline{L}$
2. $a_{ij} \text{MZG} + a_{ij} \text{SORGG} + a_{ij} \text{MILG} + a_{ij} \text{RICEG} + a_{ij} \text{COTG} + a_{ij} \text{SFG} + a_{ij} \text{SBG} + a_{ij} \text{GNG} + a_{ij} \text{RFTWG} + a_{ij} \text{VTOBG} + a_{ij} \text{BTOBG} - \text{FLAVOR} - \text{HLABOR}(\text{GL}) \leq 0$
3. $b_{ij} \text{MZH} + b_{ij} \text{SORGH} + b_{ij} \text{MILH} + b_{ij} \text{RICEH} + b_{ij} \text{COTH} + b_{ij} \text{SFH} + b_{ij} \text{SBH} + b_{ij} \text{GNH} + b_{ij} \text{RFTWH} + b_{ij} \text{VTOBH} + b_{ij} \text{BTOBH} - \text{FLAVOR} - \text{HLABOR}(\text{HL}) \leq 0$
4. $\text{FLAVOR} \leq C$

- 5a. $HLABOR \leq GL$
- 5b. $HLABOR \leq HL$
6. $- MZG + c_{ij} MZH \leq 0$
7. $- SORGG + d_{ij} SORGH \leq 0$
8. $- MILG + e_{ij} MILH \leq 0$
9. $- RICEG + f_{ij} RICEH \leq 0$
10. $- COTG + g_{ij} COTH \leq 0$
11. $- SFG + h_{ij} SFH \leq 0$
12. $- SBG + i_{ij} SBH \leq 0$
13. $- GNH + j_{ij} GNH \leq 0$
14. $- RFWTG + k_{ij} RFWTH \leq 0$
15. $- VTOBG + l_{ij} VTOBH \leq 0$
16. $- BTOBG + m_{ij} BTOBH \leq 0$
17. $- c_{ij} MZH + MZS + MZCON \leq 0$
18. $- d_{ij} SORGH + SORGS + SORGCON \leq 0$
19. $- e_{ij} MILH + MILS + MILCON \leq 0$
20. $- f_{ij} RICEH + RICES \leq 0$
21. $- g_{ij} COTH + COTS \leq 0$
22. $- h_{ij} SFH + SFS \leq 0$
23. $- i_{ij} SBH + SBS \leq 0$
24. $- j_{ij} GNH + GNS \leq 0$
25. $- k_{ij} RFWTH + RFWTS \leq 0$
26. $- l_{ij} VTOBH + VTOBS \leq 0$

$$27. \quad - m_{ij} \text{BTOBH} + \text{BTOBS} \leq 0$$

$$28. \quad \text{MZCON} \geq C_1$$

$$29. \quad \text{SORGCON} \geq C_2$$

$$30. \quad \text{MILCON} \geq C_3$$

$$31. \quad \text{BORR} \leq B$$

$$32. \quad \text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} + \\ \text{RFWTG} + \text{VTOBG} + \text{BTOBG} + \text{MZH} + \text{SORGH} + \text{MILH} + \text{RICEH} + \\ \text{COTH} + \text{SFH} + \text{SBH} + \text{GNH} + \text{RFWTH} + \text{VTOBH} + \text{BTOBH} + \\ \text{FLABOR} + \text{HLABOR} - \text{BORR} \leq K$$

$$33. \quad - \text{MZS} - \text{SORGS} - \text{MILS} - \text{RICES} - \text{COTS} - \text{SFS} - \text{SBS} - \\ \text{GNS} - \text{RFWTS} - \text{VTOBS} - \text{BTOBS} + (1+R_i)\text{BORR} + \text{CAPEND} \leq 0$$

$$34. \quad D_{11}\text{MZS} + D_{12}\text{SORGS} + D_{13}\text{MILS} + D_{14}\text{RICES} + D_{15}\text{COTS} + D_{16}\text{SFS} + \\ D_{17}\text{SBS} + D_{18}\text{GNS} + D_{19}\text{RFWTS} + D_{110}\text{VTOBS} + D_{111}\text{BTOBS} + D_1 \geq 0$$

$$35. \quad D_{21}\text{MZS} + D_{22}\text{SORGS} + D_{23}\text{MILS} + D_{24}\text{RICES} + D_{25}\text{COTS} + D_{26}\text{SFS} + \\ D_{27}\text{SBS} + D_{28}\text{GNS} + D_{29}\text{RFWTS} + D_{210}\text{VTOBS} + D_{211}\text{BTOBS} + D_2 \geq 0$$

$$36. \quad D_{31}\text{MZS} + D_{32}\text{SORGS} + D_{33}\text{MILS} + D_{34}\text{RICES} + D_{35}\text{COTS} + D_{36}\text{SFS} + \\ D_{37}\text{SBS} + D_{38}\text{GNS} + D_{39}\text{RFWTS} + D_{310}\text{VTOBS} + D_{311}\text{BTOBS} + D_3 \geq 0$$

$$37. \quad D_{41}MZS + D_{42}SORGS + D_{43}MILS + D_{44}RICES + D_{45}COTS + D_{46}SFS + \\ D_{47}SBS + D_{48}GNS + D_{49}RFWTS + D_{410}VTOBS + D_{411}BTOBS + D_4 \geq 0$$

$$38. \quad D_{51}MZS + D_{52}SORGS + D_{53}MILS + D_{54}RICES + D_{55}COTS + D_{56}SFS + \\ D_{57}SBS + D_{58}GNS + D_{59}RFWTS + D_{510}VTOBS + D_{511}BTOBS + D_5 \geq 0$$

$$39. \quad D_{61}MZS + D_{62}SORGS + D_{63}MILS + D_{64}RICES + D_{65}COTS + D_{66}SFS + \\ D_{67}SBS + D_{68}GNS + D_{69}RFWTS + D_{610}VTOBS + D_{611}BTOBS + D_6 \geq 0$$

$$40. \quad D_{71}MZS + D_{72}SORGS + D_{73}MILS + D_{74}RICES + D_{75}COTS + D_{76}SFS + \\ D_{77}SBS + D_{78}GNS + D_{79}RFWTS + D_{710}VTOBS + D_{711}BTOBS + D_7 \geq 0$$

$$41. \quad D_{81}MZS + D_{82}SORGS + D_{83}MILS + D_{84}RICES + D_{85}COTS + D_{86}SFS + \\ D_{87}SBS + D_{88}GNS + D_{89}RFWTS + D_{810}VTOBS + D_{811}IWTS + D_8 \geq 0$$

$$42. \quad D_{91}MZS + D_{92}SORGS + D_{93}MILS + D_{94}RICES + D_{95}COTS + D_{96}SFS + \\ D_{97}SBS + D_{98}GNS + D_{99}RFWTS + D_{910}VTOBS + D_{911}BTOBS + D_9 \geq 0$$

$$43. \quad D_{101}MZS + D_{102}SORGS + D_{103}MILS + D_{104}RICES + D_{105}COTS + \\ D_{106}SFS + D_{107}SBS + D_{108}GNS + D_{109}RFWTS + D_{1010}VTOBS + \\ D_{1011}BTOBS + D_{10} \geq 0$$

$$44. \quad D_1 + D_2 + D_3 + D_4 + D_5 + D_6 + D_7 + D_8 + D_9 + D_{10} \leq \lambda$$

The traditional farmer's empirical risk model

$$\begin{aligned} \text{Max} \quad & - C_1 \text{MZG} - C_2 \text{SORGG} - C_3 \text{MILG} - C_4 \text{RICEG} - C_5 \text{CASG} - C_6 \text{COTG} - \\ & C_7 \text{SFG} - C_8 \text{SBG} + C_9 \text{GNG} - C_{10} \text{RFTWG} - C_{11} \text{BTOBG} - C_{12} \text{MZH} - \\ & C_{13} \text{SORGH} - C_{14} \text{MILH} - C_{15} \text{RICEH} - C_{16} \text{CASH} - C_{17} \text{COTH} - C_{18} \text{SFH} \\ & - C_{19} \text{SBH} - C_{20} \text{GNH} - C_{21} \text{RFTWH} - C_{22} \text{BTOBH} + P_1 \text{MZS} + P_2 \text{SORGS} + \\ & P_3 \text{MILS} + P_4 \text{RICES} + P_5 \text{CASS} + P_6 \text{COTS} + P_7 \text{SFS} + P_8 \text{SBS} + \\ & P_9 \text{GNS} + P_{10} \text{RFTWS} + P_{11} \text{BTOBS} - C_{23} \text{FLAVOR} + C_{24} \text{HLAVOR} - \\ & R_i \text{BORR} \end{aligned}$$

Subject to:

1. $\text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{CASG} + \text{COTG} + \text{SFG} + \text{SBG} + \text{GNG} + \text{RFTWG} + \text{BTOBG} \leq \underline{L}$
2. $a_{ij} \text{MZG} + a_{ij} \text{SORGG} + a_{ij} \text{MILG} + a_{ij} \text{RICEG} + a_{ij} \text{CASG} + a_{ij} \text{COTG} + a_{ij} \text{SFG} + a_{ij} \text{SBG} + a_{ij} \text{GNG} + a_{ij} \text{RFTWG} + a_{ij} \text{BTOBG} - \text{FLAVOR} - \text{HLAVOR}(\text{GL}) \leq 0$

3. $b_{ij}MZH + b_{ij}SORGH + b_{ij}MILH + b_{ij}RICEH + b_{ij}CASH + b_{ij}COTH$
 $+ b_{ij}SFH + b_{ij}SBH + b_{ij}GNH + b_{ij}RFWTH + b_{ij}BTOBH - FLABOR$
 $- HLABOR(HL) \leq 0$
4. $FLABOR \leq A$
- 5a. $HLABOR \leq GL$
- 5b. $HLABOR \leq HL$
6. $- MZG + c_{ij} MZH \leq 0$
7. $- SORGG + d_{ij}SORGH \leq 0$
8. $- MILG + e_{ij}MILH \leq 0$
9. $- RICEG + f_{ij}RICEH \leq 0$
10. $- CASG + g_{ij}CASH \leq 0$
11. $- COTG + h_{ij}COTH \leq 0$
12. $- SFG + i_{ij}SFH \leq 0$
13. $- SBG + j_{ij}SBH \leq 0$
14. $- GNH + k_{ij}GNH \leq 0$
15. $- RFWTG + l_{ij}RFWTH \leq 0$
16. $- BTOBG + n_{ij}BTOBH \leq 0$
17. $- c_{ij}MZH + MZS + MZCON \leq 0$
18. $- d_{ij}SORGH + SORGS + SORGCN \leq 0$
19. $- e_{ij}MILH + MILS + MILCON \leq 0$
20. $- f_{ij}RICEH + RICES \leq 0$
21. $- g_{ij}CASH + CASS + CASCON \leq 0$

$$22. \quad - h_{ij} \text{COTH} + \text{COTS} \leq 0$$

$$23. \quad - i_{ij} \text{SFH} + \text{SFS} \leq 0$$

$$24. \quad - j_{ij} \text{SBH} + \text{SBS} \leq 0$$

$$25. \quad - k_{ij} \text{GNH} + \text{GNS} \leq 0$$

$$26. \quad - l_{ij} \text{RFWTH} + \text{RFWTS} \leq 0$$

$$27. \quad - n_{ij} \text{BTOBH} + \text{BTOBS} \leq 0$$

$$28. \quad \text{MZCON} \geq C_1$$

$$29. \quad \text{SORGCON} \geq C_2$$

$$30. \quad \text{MILCON} \geq C_3$$

$$31. \quad \text{CASCON} \geq C_4$$

$$32. \quad \text{BORR} \leq B$$

$$33. \quad \text{MZG} + \text{SORGG} + \text{MILG} + \text{RICEG} + \text{CASG} + \text{COTG} + \text{SFG} + \text{SBG} + \\ \text{GNG} + \text{RFWTG} + \text{BTOBG} + \text{MZH} + \text{SORGH} + \text{MILH} + \text{RICEH} + \\ \text{CASH} + \text{COTH} + \text{SFH} + \text{SBH} + \text{GNH} + \text{RFWTH} + \text{BTOBH} + \text{FLABOR} \\ + \text{HLABOR} - \text{BORR} \leq K$$

$$34. \quad - \text{MZS} - \text{SORGS} - \text{MILS} - \text{RICES} - \text{CASS} - \text{COTS} - \text{SFS} - \text{SBS} \\ - \text{GNS} - \text{RFWTS} - \text{BTOBS} + (1+r_i) \text{BORR} + \text{CAPEND} \leq 0$$

$$35. \quad D_{11} \text{MZS} + D_{12} \text{SORGS} + D_{13} \text{MILS} + D_{14} \text{RICES} + D_{15} \text{CASS} + D_{16} \text{COTS} \\ + D_{17} \text{SFS} + D_{18} \text{SBS} + D_{19} \text{GNS} + D_{110} \text{RFWTS} + D_{111} \text{BTOBS} + D_1 \geq 0$$

$$36. \quad D_{21}MZS + D_{22}SORGS + D_{23}MILS + D_{24}RICES + D_{25}CASS + D_{26}COTS \\ + D_{27}SFS + D_{28}SBS + D_{29}GNS + D_{210}RFWTS + D_{211}BTOBS + D_2 \geq 0$$

$$37. \quad D_{31}MZS + D_{32}SORGS + D_{33}MILS + D_{34}RICES + D_{35}CASS + D_{36}COTS \\ + D_{37}SFS + D_{38}SBS + D_{39}GNS + D_{310}RFWTS + D_{311}BTOBS + D_3 \geq 0$$

$$38. \quad D_{41}MZS + D_{42}SORGS + D_{43}MILS + D_{44}RICES + D_{45}CASS + D_{46}COTS \\ + D_{47}SFS + D_{48}SBS + D_{49}GNS + D_{410}RFWTS + D_{411}BTOBS + D_4 \geq 0$$

$$39. \quad D_{51}MZS + D_{52}SORGS + D_{53}MILS + D_{54}RICES + D_{55}CASS + D_{56}COTS \\ + D_{57}SFS + D_{58}SBS + D_{59}GNS + D_{510}RFWTS + D_{511}BTOBS + D_5 \geq 0$$

$$40. \quad D_{61}MZS + D_{62}SORGS + D_{63}MILS + D_{64}RICES + D_{65}CASS + D_{66}COTS \\ + D_{67}SFS + D_{68}SBS + D_{69}GNS + D_{610}RFWTS + D_{611}BTOBS + D_6 \geq 0$$

$$41. \quad D_{71}MZS + D_{72}SORGS + D_{73}MILS + D_{74}RICES + D_{75}CASS + D_{76}COTS \\ + D_{77}SFS + D_{78}SBS + D_{79}GNS + D_{710}RFWTS + D_{711}BTOBS + D_7 \geq 0$$

$$42. \quad D_{81}MZS + D_{82}SORGS + D_{83}MILS + D_{84}RICES + D_{85}CASS + D_{86}COTS + \\ D_{87}SFS + D_{88}SBS + D_{89}GNS + D_{810}RFWTS + D_{811}IWTS + D_8 \geq 0$$

$$43. \quad D_{91}MZS + D_{92}SORGS + D_{93}MILS + D_{94}RICES + D_{95}CASS + D_{96}COTS + \\ D_{97}SFS + D_{98}SBS + D_{99}GNS + D_{910}RFWTS + D_{911}BTOBS + D_9 \geq 0$$

$$44. \quad D_{101} \text{MZS} + D_{102} \text{SORGS} + D_{103} \text{MILS} + D_{104} \text{RICES} + D_{105} \text{CASS} + \\ D_{106} \text{COTS} + D_{107} \text{SFS} + D_{108} \text{SBS} + D_{109} \text{GNS} + D_{1010} \text{RFWTS} + \\ D_{1011} \text{BTOBS} + D_{10} \geq 0$$

$$45. \quad D_1 + D_2 + D_3 + D_4 + D_5 + D_6 + D_7 + D_8 + D_9 + D_{10} \leq \lambda$$

CHAPTER IV
RESULTS AND ANALYSIS

The Linear Programming Results Under Certainty

Three sets of results were obtained from the linear programming certainty models, one for each category of farmer. These results are tabulated in Table 4.1 below.

Results of the traditional farm model

Under certainty the traditional farmers allocate almost all their land to burley tobacco growing. 9.38 hectares of the land is allocated to burley tobacco growing, with the remaining 0.62 hectares being used to grow just enough of the four food crops, namely maize, sorghum, millet, and cassava. The food crops in the traditional farm model are grown only to satisfy the minimum consumption requirements for the farming household. In this certainty solution for traditional farmers, no maize, sorghum, millet, or cassava sales are made. Burley tobacco is grown solely for its cash value. Therefore, all the burley tobacco grown is sold.

With this type of resource allocation, the farmers get a profit margin of 3,527 Zambian kwacha. The borrowing activity

Table 4.1: Results of the models under certainty

	TF ⁽¹⁾	SSCF ⁽²⁾	LSCF ⁽³⁾
OBJ VALUE (Z KWACHA)	3,257	52,727	1,031,138
MZG (ha)	0.27	0.15	-
SORGG (ha)	0.07	0.04	-
MILG (ha)	0.16	0.10	-
RICEG (ha)	-	-	-
CASG (ha)	0.11	-	-
COTG (ha)	-	-	-
SFG (ha)	-	-	-
SBG (ha)	-	-	41.98
GNG (ha)	-	-	-
RFWTG (ha)	-	-	-
BTOBG (ha)	9.38	-	-
VTOBG (ha)	-	39.71	284.04
IWTG (ha)	-	-	41.98
MZH (ha)	0.27	0.15	-
SORGH (ha)	0.07	0.04	-
MILH (ha)	0.16	0.10	-
RICEH (ha)	-	-	-
CASH (ha)	0.11	-	-
COTH (ha)	-	-	-
SFH (ha)	-	-	-
SBH (ha)	-	-	41.98
GNH (ha)	-	-	-
RFWTH (ha)	-	-	-
BTOBH (ha)	9.38	-	-
VTOBH (ha)	-	39.71	284.04
IWTH (ha)	-	-	41.90

⁽¹⁾ TF refers to traditional farmers

⁽²⁾ SSCF refers to small-scale commercial farmers.

⁽³⁾ LSCF refers to large-scale commercial farmers.

Table 4.1 continued

MZS (kgs)	-	-	-
SORGS (kgs)	-	-	-
MILS (kgs)	-	-	-
RICES (kgs)	-	-	-
CASS (kgs)	-	-	-
COTS (kgs)	-	-	-
SFS (kgs)	-	-	-
SBS (kgs)	-	-	83,125
GNS (kgs)	-	-	-
RFWTS (kgs)	-	-	-
BTOBS (kgs)	5,639	-	-
VTOBS (kgs)	-	39,712	568,070
IWTS (kgs)	-	-	207,813
MZCON (kgs)	600	600	-
SORGCON (kgs)	132	132	-
MILCON (kgs)	132	132	-
CASCON (kgs)	337	-	-
FLABOR (man-days)	450	450	450
HLABOR (man-days)	628	13,461	100,000
BORROW (Z KWACHA)	2,796	13,457	153,740
CAPEND (Z KWACHA)	3,257	52,727	1,031,138

comes in at 2,796 Zambian kwacha. This is the money the traditional farmer needs to cultivate 10 hectares of land with burley tobacco, maize, sorghum, millet, and cassava. All the family labor is used in the farm operations and extra labor is hired for both growing and harvesting activities.

Forcing the crops to be grown which are not currently grown in the optimal solution (i.e., rice, cotton, sunflower, soybeans, and rainfed wheat) would reduce the profit margin. Rice has the highest penalty cost. Forcing rice production in the optimal solution will reduce the profit margin by 290 Zambian kwacha. The crop with the next highest penalty cost is soybeans, followed by sunflower, cotton, and rainfed wheat, respectively. Groundnuts production, on the other hand, can be forced into the optimal solution without having the effect of reducing the profit margin.

The introduction of soybeans in the optimal solution would reduce the profit margin by 249 Zambian kwacha. Forcing sunflower, cotton, and rainfed wheat will reduce the profit margin by 223, 143, and 139 Zambian kwacha, respectively.

This optimal solution derived for traditional farmers is very sensitive to slight increases in the crop prices. For example, a change in the selling price of cassava by just 0.006 will change the basis for the optimal solution.

The shadow prices for the resource constraints indicate that the major constraining factors for the traditional farmers are land and family labor. The type of land being referred to in this solution is cleared land. Land in general is not a major constraint in Zambia. However, shortages of cleared fertile land are not unusual. Cleared land is the

major limiting factor, with a shadow price of 348 Zambian kwacha per hectare. This implies that if an additional hectare of land is added to the farm operations the profit margin would increase by 348 Zambian kwacha.

Family labor and hired labor for harvesting, with shadow prices of 0.03 and 0.30 Zambian kwacha, respectively, are the two other resources with positive shadow prices. However, the low shadow prices indicate that these resources are not very constraining in traditional farm production in Zambia. Hired labor is not usually a major constraint for this category of farmer, since they rely mostly on family labor.

When the crop combinations in the optimal solution are compared to traditional farmers' current practices as recorded in the Comprehensive Agricultural Survey of 1990, there is some difference in the type of farm resource allocation. According to the survey farmers put most of their farmland under maize production, followed by groundnuts, millet, sorghum, and sunflowers in that order. Other crops, like cotton, rice, wheat and tobacco are also grown.

In the current observed traditional farm practices, maize is not only grown for consumption needs but also as a cash crop. However, in this optimal solution only five crops (burley tobacco, maize, sorghum, millet and cassava) were grown and only one of these crops, burley tobacco, was grown

as a cash crop.

Results of the small-scale commercial farm model.

The optimal solution of the certainty model for the small-scale commercial farmer included only four of the eleven possible crops which can be grown by this category of farmers. The levels of these crops are shown in Table 4.1 above. Virginia tobacco enters the optimal solution, with the highest hectarage of 39.71, followed by maize, sorghum, and millet, with 0.15, 0.04, and 0.10 hectares, respectively. Virginia tobacco is grown primarily for sale. For the other three crops in the optimal solution, only enough of each crop is grown to satisfy the minimum consumption needs.

The profit margin for this optimal solution of the small-scale commercial farm model is 52,727 Zambian kwacha. The borrowing activity for financing farm operations enters the solution at 13,457 Zambian kwacha. All the family labor is utilized, and some hired labor is utilized for both growing and harvesting activities.

The penalty costs for forcing the crops which are not currently in the optimal solution are quite high. Forcing soybeans into the solution results in a penalty cost of 1,214 Zambian kwacha. Rice has the next highest penalty cost. Forcing rice production into the optimal solution will reduce

the profit margin by 1,170 Zambian kwacha. Sunflower, cotton, rainfed wheat, and burley tobacco have penalty costs of 1,061, 1,034, 1,033, and 827 Zambian kwacha, respectively.

The small-scale commercial farmer's optimal solution is also very sensitive to slight increases in the selling prices. The maize price is the most sensitive of all the crops. A change of 0.25 in the selling price of maize will change the solution basis of the optimal solution.

Land has the highest shadow price, at 1,328 Zambian kwacha, indicating that it is a major limiting factor in the small-scale commercial farm production. The other limiting factors are family labor and hired labor for harvesting activities, which have shadow prices of 0.3 and 0.03 Zambian kwacha, respectively. Again, these shadow prices indicate that labor is not a major constraint in small-scale commercial farm operations. Hired labor is usually a bit constraining during some peak periods for farm activities, such as harvesting.

The crops usually grown by the small-scale commercial farmers are maize, sunflower, cotton, some tobacco, millet, and sorghum. Sunflower, cotton, and tobacco are basically grown for sale while the other crops are grown for their food consumption values. Only surpluses are put up for sale. All the food crops enter the optimal solution but only enough are

grown to satisfy the minimum consumption requirements for the farming household.

Of the three cash crops usually grown by small-scale commercial farmers, only Virginia tobacco enters the optimal solution, utilizing most of the land. This type of resource allocation results in a crop combination that maximizes the profit margins.

Results of the large-scale commercial farm model.

Under the certainty model the large-scale commercial farmers allocate most of their land to Virginia tobacco growing. Virginia tobacco growing is allocated 284 hectares in the optimal solution. The other crops entering the optimal solution are soybeans and irrigated wheat, at 41.98 hectares each. Soybeans and irrigated wheat are grown in rotation. All the three crops in the optimal solution are grown primarily for sale.

With this crop allocation the farmer gets a profit margin of 1,031,138 Zambian kwacha. The amount of money borrowed for this farming operation is 153,740 Zambian kwacha. Large-scale commercial farmers hire all their labor requirements.

Rice growing gives the highest reduction in the profit margin when it is forced in the optimal solution. The penalty cost for forcing rice into the solution is 2,419 Zambian

kwacha. Forcing any one of the other crops in the optimal solution will reduce the profit margin by more than 2,000 Zambian kwacha.

The profit margins for this optimal solution are very sensitive to price fluctuations. For example, increasing the price of irrigated wheat by 0.06 Zambian kwacha will alter the solution basis of the optimal solution.

A downward shift in the prices of maize, sorghum, soybeans, and Virginia tobacco will result in changes in the solution basis. On the other hand, an upward adjustment of the prices of rice, cotton, sunflower, groundnuts, and rainfed wheat have to be increased by more than one Zambian kwacha for the optimal solution basis to be altered.

Land is the most limiting constraint with a shadow price of 2,677 Zambian kwacha. The availability of another hectare of land for production would increase the profit margin by 12,677 Zambian kwacha. The shadow prices of hired labor are 0.46 and 0.75 for growing and harvesting, respectively. This indicates that adding one more man-day will only change the profit margin by a very small amount.

The crop combination in the optimal solution is similar to the current observed practices of the large-scale commercial farmers in Zambia. Maize and rainfed wheat are the other crops usually grown by large-scale commercial farmers

which are not included in the optimal solution.

Sensitivity Analysis

From the discussion above of the optimal solutions to the models under certainty, it is indicated that all the three categories of farmers allocated most of their land to tobacco growing. Tobacco, which is grown for both domestic use and export, has a very attractive producer price relative to the other field crops grown in Zambia.

Despite the high cost of production for tobacco, the selling price is still high enough to enable the growers to earn some profit. Since tobacco does well in the export market, its selling price is usually determined from the export price which is quoted in American dollars. When converted to the Zambian kwacha, the relative price of tobacco is much higher than the domestic parity prices for the other crops.

Some sensitivity analysis is used in this study to test the stability of farm plans. Sensitivity analysis on the prices of tobacco and maize were carried out for all three categories of farmers.

Maize and tobacco were singled out for sensitivity analysis because of their special position in Zambian

agriculture and in the certainty model results outlined above. In the certainty results, tobacco is the crop that was grown most by all categories of farmers. Thus sensitivity analysis in relation to its producer price is done in an attempt to determine the effect price changes have on farm resource allocation.

Maize, on the other hand, was chosen because it is Zambia's staple food and is grown by all categories of farmers in Zambia. In spite of the importance of maize in Zambia, the certainty optimal solutions allow maize to enter the solution only at subsistence levels.

This is the case for the optimal solutions to the traditional farm and the small-scale commercial farm models. No maize growing activity enters the optimal solution in the large-scale commercial farm model. So sensitivity analysis on the price of maize is used to determine the changes in relative prices that would allow maize production to enter the optimal solutions at surplus levels.

Price sensitivity for the traditional farm model

Any increase in the price of tobacco while holding the prices of the other crops constant changes only the objective function value. The pattern of resource allocation remains the same and, therefore, the basis of the optimal solution

remains unchanged.

However, a decrease of 5.09 percent in the price of tobacco while holding the prices of the other crops constant changes the resource allocation and brings about a change in the optimal solution basis. With a 5.09 percent tobacco price decrease, the land allocation of the optimal basis solution changes. 8.2 hectares, out of the ten hectares available, are allocated to cassava growing. Burley tobacco growing is reduced to only 1.3 hectares. Maize, sorghum, and millet continue to enter the optimal solution at subsistence levels.

A further decrease of 32.13 percent in the price of burley tobacco, while holding the prices of the other crops constant, changes both land allocation and enterprise combination. Burley tobacco is no longer produced at this price level. Allocation of land to cassava production increases to 9.5 hectares, and maize, sorghum, and millet continue to enter the optimal solution basis at subsistence levels.

Maize production enters the optimal solution basis only after a large increase in the producer price of maize. A 44.57 percent increase in the price of maize, while holding the prices of the other crops constant, changes the resource allocation patterns of the traditional farm. 9.4 hectares of maize are now grown, and only 0.23 hectares of burley tobacco

are grown. Sorghum, millet, and cassava enter the optimal solution basis only at levels that satisfy the minimum consumption requirements for the traditional farming household.

When the maize price is further increased by 60.33%, burley tobacco moves out of the optimal solution basis. 9.65 hectares of maize are now grown, and sorghum, millet, and cassava continue to enter the optimal basis solution at subsistence levels.

Price sensitivity analysis for the small-scale commercial farm model

The initial basis solution allocated 39.71 hectares of land into Virginia tobacco production. As the price of Virginia tobacco is decreased, burley tobacco enters the optimal solution. While the hectarage of Virginia tobacco decreases with the price decrease, the hectarage under burley tobacco increases. Maize, cassava, sorghum, and millet continue to enter the optimal solution basis at subsistence levels.

When the price of burley tobacco is also reduced, burley tobacco goes out of the optimal solution and Virginia tobacco enters the solution. This switching pattern of land allocation between burley and Virginia tobacco continues until

a certain level of price reductions is attained.

When the price of Virginia tobacco is reduced by 60.48 percent and that of burley tobacco is reduced by 21.30 percent, a new crop enters the solution basis. At this point Virginia tobacco is no longer grown, and rainfed wheat comes into the optimal solution at a hectarage of 38.30. Burley tobacco growing remains in the optimal solution basis at 1.42 hectares. Maize, sorghum, and millet are still grown at subsistence levels.

The optimal solution is not very sensitive to maize price increases. Maize hectarage only increases substantially after the maize price has been increased by 275%, while holding the prices of other crops constant.

The case of the small-scale commercial farmer is different from the traditional farmer's situation. In the traditional farmer's situation, a new crop comes into the optimal solution when tobacco prices are decreased. This only happens at very large levels of reduction in the case of the small-scale commercial farm model.

Price sensitivity analysis for the large-scale commercial farm model

The optimal solution of the large-scale commercial farmer is very sensitive to tobacco price decreases. However, the

solution basis is not sensitive to tobacco price increases.

A slight decrease of 4.8 percent in the Virginia tobacco price drastically reduces Virginia tobacco production from 284.04 hectares to 5.04 hectares. However, the hectarages under soybeans and irrigated wheat increase by 332 percent each.

A further decrease of 7.78 percent in the Virginia tobacco price, while the prices of the other crops are held constant, increases the hectarages of soybeans and irrigated wheat. Virginia tobacco is no longer grown at this level of price reduction.

For maize to enter the large-scale commercial farmer's optimal solution, its producer price must be increased by more than 400 percent. At this level of price increase, maize enters the optimal solution basis. Soybeans and irrigated wheat go out of the optimal solution, but Virginia tobacco continues to enter the optimal solution.

A further increase in the price of maize increases the hectarage of maize, and Virginia tobacco leaves the optimal solution basis.

The Risk Programming Results

Three sets of results were obtained from the linear risk programming models (MOTAD), one set for each category of farmer. Ten basic solutions were obtained at varying levels of risk aversion.

The amount of deviations in income a farmer is willing to accept are reflected by the lambda values. Low levels of risk aversion are indicated by high lambda values, and high levels of risk aversion are indicated by low values of lambda. On the other hand, moderate levels of risk aversion are reflected by middle values of lambda over its entire range. The lambda levels ranged from zero to the largest number possible. This is the range over which the risk models were optimized. The results of the MOTAD models are tabulated in Tables 4.2, 4.3, and 4.4 below.

Results of the traditional farm MOTAD model

For the traditional farm MOTAD model, lambda values that provided optimal solutions ranged from zero to 3,125. The lambda values chosen for the 10 basic solutions are 0, 35, 54, 63, 135, 164, 340, 407, 629, and 3125. The results are shown in Table 4.2 below.

Table 4.2: Results of the MOTAD model for the traditional farmers

	I	II	III	IV	V	VI	VII	VIII	IX	X
LAMBDA	0	25	54	63	135	164	340	407	629	3125
OBJ Value (Z kwacha)	2213	2323	2362	2379	2505	2552	2686	2737	2854	3313
MZG (ha)	0.27	0.27	0.45	0.56	1.51	1.44	0.37	0.46	0.67	0.27
SORGG (ha)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MILG (ha)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
RICEG (ha)	-	-	-	-	-	-	-	-	-	-
CASG (ha)	1.98	2.17	2.18	2.18	2.10	2.10	2.84	2.89	3.01	0.11
COTG (ha)	1.45	0.12	-	-	0.33	-	-	-	-	-
SFG (ha)	-	-	-	-	-	-	-	-	-	-
SBG (ha)	-	-	-	-	-	-	-	-	-	-
GNG (ha)	3.88	4.27	4.00	3.82	2.17	2.24	1.41	0.98	-	-
RFWTG (ha)	-	-	-	-	-	-	-	-	-	-
BTOBG (ha)	2.19	2.94	3.13	3.20	3.65	3.99	5.14	5.43	6.08	9.38
VTOBG (ha)	-	-	-	-	-	-	-	-	-	-
IWTG (ha)	-	-	-	-	-	-	-	-	-	-
MZH (ha)	0.27	0.27	0.45	0.56	1.51	1.44	0.37	0.46	0.67	0.27

Table 4.2 Continued

SORGH (ha)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MILH (ha)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
RICEH (ha)	-	-	-	-	-	-	-	-	-	-
CASH (ha)	1.98	2.17	2.18	2.18	2.10	2.10	2.84	2.89	3.01	0.11
CDTH (ha)	1.45	0.12	-	-	0.33	-	-	-	-	-
SFH (ha)	-	-	-	-	-	-	-	-	-	-
SBH (ha)	-	-	-	-	-	-	-	-	-	-
GNH (ha)	3.88	4.27	4.00	3.82	2.17	2.24	1.41	0.98	-	-
RFWTH (ha)	-	-	-	-	-	-	-	-	-	-
BTOBH (ha)	2.19	2.94	3.13	3.20	3.65	3.99	5.14	5.43	6.08	9.38
VTOBH (HA)	-	-	-	-	-	-	-	-	-	-
IWTH (ha)	-	-	-	-	-	-	-	-	-	-
MZS (kgs)	-	-	413	664	2801	2643	240	442	906	-
SORGS (kgs)	-	-	-	-	-	-	-	-	-	-
MILS (kgs)	-	-	-	-	-	-	-	-	-	-
RICES (kgs)	-	-	-	-	-	-	-	-	-	-
CASS (kgs)	5591	6177	6211	6200	5966	6955	8173	9333	8705	-
COTS (kgs)	1015	80	-	-	231	-	-	-	-	-

Table 4.2 Continued

SFS (kgs)	-	-	-	-	-	-	-	-	-	-
SBS (kgs)	-	-	-	-	-	-	-	-	-	-
GNS (kgs)	2482	2732	2562	2445	1389	1432	903	630	-	-
RFWTS (kgs)	-	-	-	-	-	-	-	-	-	-
BTOBS (kgs)	1316	1765	1877	1922	2190	2393	3085	3256	3648	5631
VTOBS (kgs)	-	-	-	-	-	-	-	-	-	-
IWTS (kgs)	-	-	-	-	-	-	-	-	-	-
MZCON (kgs)	600	600	600	600	600	600	600	600	600	600
SORGCON (kgs)	132	132	132	132	132	132	132	132	132	132
MILCON (kgs)	132	132	132	132	132	132	132	132	132	132
CASCON (kgs)	337	337	337	337	337	337	337	337	337	337
FLABOR (man-days)	450	450	450	450	450	450	450	450	450	450
HLABOR (man-days)	1710	2217	2319	2355	2535	2762	3469	3627	3990	3990
BORROW (Z KWACHA)	-	1313	1349	1360	1402	1491	1742	1795	1917	2796
CAPEND (Z KWACHA)	-	2322	2362	2379	2505	2552	2686	2737	3854	3313

Initially, at high risk aversion, seven of the eleven crops modeled for the traditional farm MOTAD model enter the optimal solution. The seven crops that enter the optimal solution basis are groundnuts, at 3.88 hectares, burley tobacco, cassava, cotton, maize, millet, and sorghum, in that order. Of the four food crops in the solution basis, only cassava is grown at surplus levels for sale. Maize, sorghum, and millet are grown only to satisfy the minimum consumption limits.

As the level of risk aversion decreases, the amounts of sorghum and millet remain at subsistence levels. However, the amount of burley tobacco grown increases as the farmer's risk aversion decreases. At the lowest levels of risk aversion, only tobacco is grown for sale. The food crops continue to enter the optimal solution at subsistence levels to satisfy the minimum consumption requirements for the traditional farming household. The amount of land area allocated for maize production is low at high levels of risk aversion. However, as the risk aversion decreases the hectareage allocated to maize production begins to increase and the maize selling activity enters the optimal solution basis.

At moderate risk aversion levels the hectareage under maize production declines. At the lowest levels of risk aversion, only enough maize is grown to satisfy the minimum

consumption requirements.

Initially, at high risk aversion levels, most of the land is allocated to groundnuts production. However, as the risk aversion level begins to decline, the land area allocated to groundnuts begins to decline until finally no groundnuts are grown at low risk aversion levels.

Cotton only enters the solutions three times, twice at high risk aversion levels and once at moderate risk aversion.

Results of the small-scale commercial farm MOTAD model

The lambda levels for the small-scale commercial farm MOTAD model for the ten basic solutions are 0, 342, 515, 545, 1395, 4616, 6381, 7225, 7573, and 34312. The results are tabulated in Table 4.3.

Initially, six crops entered the basic solution at high risk aversion levels. Most of the land is allocated to millet, and the remainder of the land is allocated to groundnuts, burley tobacco, cotton, maize, and sorghum production, in that order.

For maize, groundnuts, and burley tobacco production, the hectarage declines with the decrease in risk aversion. However, at moderate risk aversion levels, land allocation is again increased for maize and groundnuts, while burley tobacco production ceases.

Table 4.3: Results of the MOTAD Model for the small-scale commercial farmer

	I	II	III	IV	V	VI	VII	VIII	IX	X
LAMBDA	0	342	515	545	1395	4616	6381	7225	7573	34312
OBJ Value (Z KWACHA)	11853	13386	13764	13830	15531	21584	24363	25638	26010	48756
MZG (ha)	3.99	2.29	2.24	2.23	3.26	7.30	15.09	18.79	19.88	0.15
SORGG (ha)	2.50	16.84	18.14	18.36	17.49	11.62	4.45	0.83	0.04	0.04
RICEG (ha)	13.75	2.34	1.21	1.01	0.10	0.10	0.10	0.10	0.10	0.10
CASG (ha)	-	-	-	-	-	-	-	-	-	-
COTG (ha)	-	-	-	-	-	-	-	-	-	-
SFG (ha)	4.77	-	-	-	-	-	-	-	-	-
SBG (ha)	-	-	-	-	-	-	-	-	-	-
GNG (ha)	9.13	3.90	3.78	3.76	4.93	11.54	9.46	8.72	8.18	-
RFWTG (ha)	-	-	-	-	-	-	-	-	-	-
BTOBG (ha)	5.86	13.03	12.69	12.64	9.62	-	-	-	-	-
VTOBG (ha)	-	1.60	1.94	2.00	4.60	9.45	10.90	11.56	11.80	39.71
IWTG (ha)	-	-	-	-	-	-	-	-	-	-
MZH (ha)	3.99	2.29	2.24	2.23	3.26	7.30	15.09	18.79	19.88	0.15

Table 4.3 Continued

SORGH (ha)	2.50	16.84	18.14	18.36	17.49	11.62	4.45	0.83	0.04	0.04
MILH (ha)	13.75	2.34	1.21	1.01	0.10	0.10	0.10	0.10	0.10	0.10
RICEH (ha)	-	-	-	-	-	-	-	-	-	-
CASH (ha)	-	-	-	-	-	-	-	-	-	-
COTH (ha)	4.77	-	-	-	-	-	-	-	-	-
SFG (ha)	-	-	-	-	-	-	-	-	-	-
SBH (ha)	-	-	-	-	-	-	-	-	-	-
GNH (ha)	9.13	3.90	3.78	3.76	4.93	11.54	9.54	8.72	8.18	-
RFWTH (ha)	-	-	-	-	-	-	-	-	-	-
BTOBH (ha)	5.86	13.03	12.69	12.64	9.62	-	-	-	-	-
VTOBH (ha)	-	2.34	1.94	2.00	4.60	9.45	10.90	11.56	11.80	39.71
IWTH (ha)	-	-	-	-	-	-	-	-	-	-
MZS (kgs)	15570	8665	8466	8432	12489	28978	60518	75504	79900	-
SORGS (kgs)	7731	52906	56999	54408	54961	36457	13875	2484	-	-
MILS (kgs)	18437	3033	1501	1236	-	-	-	-	-	-
RICES (kgs)	-	-	-	-	-	-	-	-	-	-
CASS (kgs)	-	-	-	-	-	-	-	-	-	-
COTS (kgs)	4767	-	-	-	-	-	-	-	-	-

Table 4.3 Continued

SFS (kgs)	-	-	-	-	-	-	-	-	-	-
SBS (kgs)	-	-	-	-	-	-	-	-	-	-
GNS (kgs)	10954	4676	4534	4509	5921	13846	11352	10451	9818	-
RFWTS (kgs)	-	-	-	-	-	-	-	-	-	-
BTOBS (kgs)	4589	10423	10155	10109	7697	-	-	-	-	-
VT OBS (kgs)	-	1605	1942	2001	4501	9445	10905	11563	11802	39712
IWTS (kgs)	-	-	-	-	-	-	-	-	-	-
MZCON (kgs)	600	600	600	600	600	600	600	600	600	600
SORCON (kgs)	132	132	132	132	132	132	132	132	132	132
MILCON (kgs)	132	132	132	132	132	132	132	132	132	132
CASCON (kgs)	-	-	-	-	-	-	-	-	-	-
FLABOR (man-days)	450	450	450	450	450	450	450	450	450	450
HLABOR (man-days)	5289	9503	9426	9413	8593	5082	5200	5261	5272	13461
BORROW (Z KWACHA)	5074	7556	7573	7576	7523	6585	6938	7112	7154	13457
CAPEND (Z KWACHA)	11853	13386	13764	13830	15531	21684	24363	25638	26010	48756

From the high risk aversion levels, the hectarage put under millet continues to decline with the level of risk aversion. Eventually, only enough millet is grown for consumption.

With a decrease in risk aversion, Virginia tobacco enters the basic solution and its land allocation continues to increase with the decrease in risk aversion. At the lowest levels of risk aversion, Virginia tobacco is the major crop being produced.

Results of the large-scale commercial farm MOTAD model

The lambda values for the ten basic solutions for the large-scale commercial farmers are 0, 1547, 12108, 14692, 24761, 61220, 98783, 158237, 197783, and 504625. The results are tabulated in Table 4.4.

At high risk aversion ($\lambda = 0$) nothing is grown, but as the risk aversion level decreases five crops, sorghum, cotton, soybeans, groundnuts, and Virginia tobacco, enter the optimal solution. 12.64 hectares of sorghum are grown. Soybeans, groundnuts, cotton, and Virginia tobacco also enter the optimal solution, in that order.

However, as the risk aversion level decreases some new crops enter the optimal solution while other crops leave the basis. For instance, maize enters the optimal solution while

Table 4.4: Results of the MOTAD model for the large-scale commercial farmer

	I	II	III	IV	V	VI	VII	VIII	IX	X
LAMBDA	0	1547	12108	14692	24761	61220	98783	158237	197783	504625
OBJ VALUE (Z KWACHA)	0	17380	136026	165053	228963	306740	367677	452264	502770	803508
MZG (ha)	-	-	-	0.01	49.78	71.15	191.17	58.37	86.19	-
SORGG (ha)	-	12.64	98.90	120.00	172.52	119.42	8.39	47.94	-	-
MILG (ha)	-	-	-	-	-	-	-	-	-	-
RICEG (ha)	-	-	-	-	-	-	-	-	-	-
CASG (ha)	-	-	-	-	-	-	-	-	-	-
COTG (ha)	-	3.94	30.85	37.44	46.69	-	-	-	-	-
SFG (ha)	-	-	-	-	-	-	-	-	-	-
SBG (ha)	-	11.46	89.72	108.84	-	-	-	-	-	41.98
GNG (ha)	-	9.57	74.90	90.88	68.48	114.79	89.40	137.44	138.85	-
RFWTG (ha)	-	-	-	-	-	-	-	-	-	-
BTOBG (ha)	-	-	-	-	-	-	-	-	-	-
VTOBG (ha)	-	1.14	8.92	10.83	30.52	62.64	79.05	124.25	142.96	284.04
IWTG (ha)	-	-	-	-	-	-	-	-	-	-
MZH (ha)	-	-	-	0.01	49.78	71.16	191.17	58.37	86.19	-

Table 4.4: Continued

SORGH (ha)	-	12.64	98.90	120.00	172.52	119.42	8.39	47.94	-	-
MILH (ha)	-	-	-	-	-	-	-	-	-	-
RICEH (ha)	-	-	-	-	-	-	-	-	-	-
CASH (ha)	-	-	-	-	-	-	-	-	-	-
COTH (ha)	-	3.94	30.85	37.44	46.69	-	-	-	-	-
SFH (ha)	-	-	-	-	-	-	-	-	-	-
SBH (ha)	-	11.46	89.72	108.84	-	-	-	-	-	-
GNH (ha)	-	9.57	74.90	90.88	68.48	114.89	89.40	137.44	138.85	-
RFWTH (ha)	-	-	-	-	-	-	-	-	-	-
BTOBH (ha)	-	-	-	-	-	-	-	-	-	-
VTOBH (ha)	-	1.14	8.92	10.83	30.52	62.64	79.05	124.25	142.96	284.04
IWTH (ha)	-	-	-	-	-	-	-	-	-	-
MZS (kgs)	-	-	-	44	268826	384252	1032296	315187	465401	-
SORGS (kgs)	-	51178	400559	486017	698725	483639	33981	194163	-	-
MILS (kgs)	-	-	-	-	-	-	-	-	-	-
RICES (kgs)	-	-	-	-	-	-	-	-	-	-
CASS (kgs)	-	-	-	-	-	-	-	-	-	-
COTS (kgs)	-	7883	61701	74871	93389	-	-	-	-	-

Table 4.4 Continued

SFS (kgs)	-	-	-	-	-	-	-	-	-	-
SBS (kgs)	-	22697	177643	215512	-	-	-	-	-	-
GNS (kgs)	-	15311	119834	145404	109561	183657	143034	219897	222166	-
RFWTS (kgs)	-	-	-	-	-	-	-	-	-	-
BTOBS (kgs)	-	-	-	-	-	-	-	-	-	-
VTOBS (kgs)	-	2281	17850	21660	61045	125279	158095	248510	285922	568070
IWTS (kgs)	-	-	-	-	-	-	-	-	-	207813
MZCON (KGS)	-	-	-	-	-	-	-	-	-	-
SORGCON (kgs)	-	-	-	-	-	-	-	-	-	-
MILCON (kgs)	-	-	-	-	-	-	-	-	-	-
CASCON (kgs)	-	-	-	-	-	-	-	-	-	-
FLABOR (man-days)	-	-	-	-	-	-	-	-	-	-
HLABOR (man-days)	-	2001	15663	19005	25453	38839	41525	60925	67034	100000
BORROW (Z KWACHA)	-	4852	37972	46074	52070	68390	80260	94100	103340	153740
CAPEND (Z KWACHA)	-	17380	136026	16053	228963	306740	367677	452264	502779	803408

soybeans and cotton are no longer grown. The hectarage for Virginia tobacco increases with the decrease in the level of risk aversion.

At the lowest levels of risk aversion, only three crops are grown. Virginia tobacco enters the solution, with a land area of 284.04 hectares. Irrigated wheat also enters the solution in rotation with soybeans, at 41.98 hectares of each crop.

The optimal portfolios of the models under certainty may not be very acceptable to the farming communities. These optimal portfolios consist of mainly tobacco and just enough of the food consumption crops. These optimal portfolios may not be acceptable in the sense that they limit farmers to growing very few crops. Tobacco is grown mainly for export. Therefore, farmers would have to maintain very high standards in order to compete favorably in the international markets. Furthermore, investments in the tobacco business face higher risks than before because of the worldwide efforts to curb tobacco consumption.

In addition to the foregoing, the certainty model portfolios do not seem consistent with the government's stated priorities of achieving self-sufficiency in food production. However, only a few food crops are included in the certainty optimal portfolios.

Currently, Zambia's diversification strategy calls for self-sufficiency in food production through import substitution. The incorporation of exports is regarded as secondary, after domestic needs have been fulfilled.

The MOTAD efficiency frontiers are presented in the figures on the next three pages. The frontiers show the relationship between expected farm income and the risk levels. The frontier for small-scale commercial farmers indicate that at higher levels of risk aversion, there is very little variation in expected farm income. However, as the risk aversion level decreases, variability in farm income increases. The pattern for the traditional and large-scale commercial farmers is similar to the pattern of the small-scale commercial farmers.

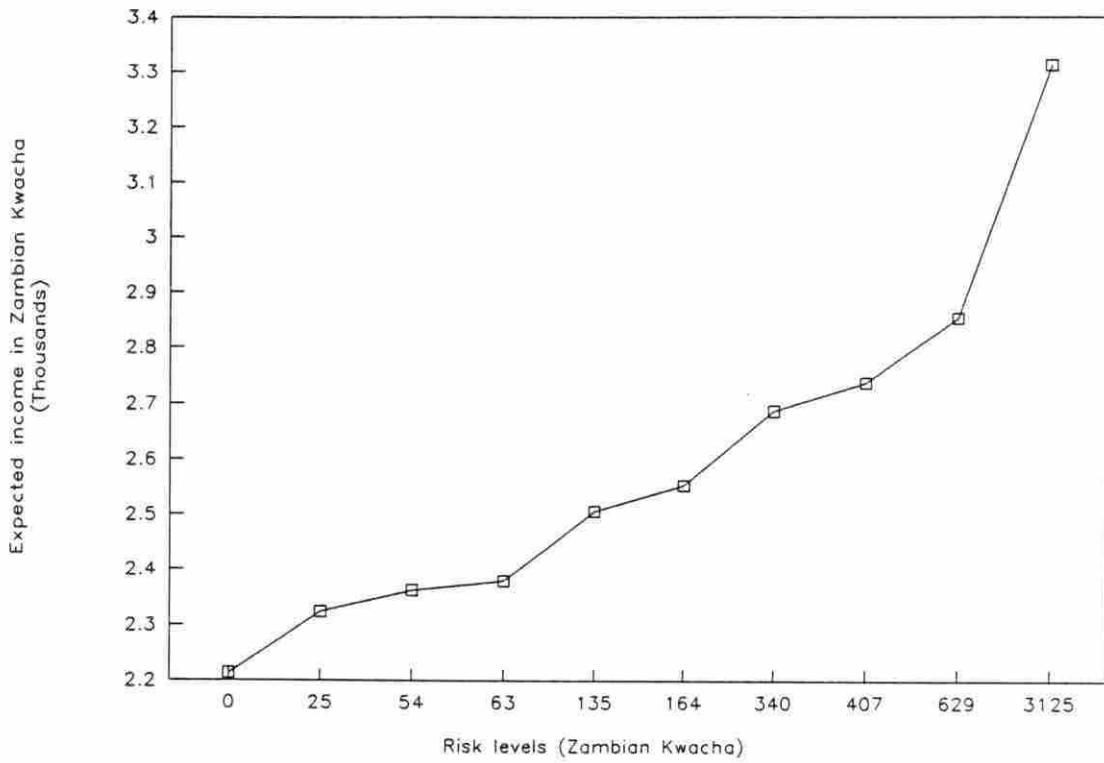


Figure 4.1: MOTAD Frontier at Selected Levels of Risk for the Traditional Farmer (TF)

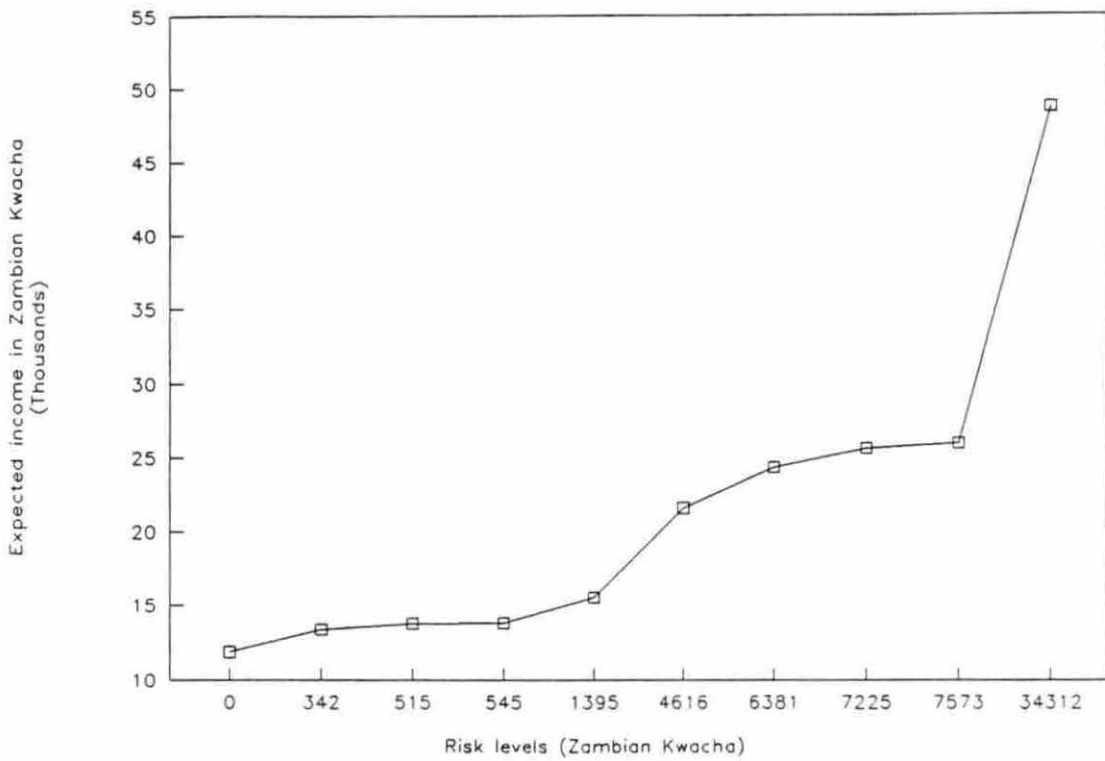


Figure 4.2: MOTAD Frontier at Selected Levels of Risk for the Small-scale Commercial Farmer (SSCF)

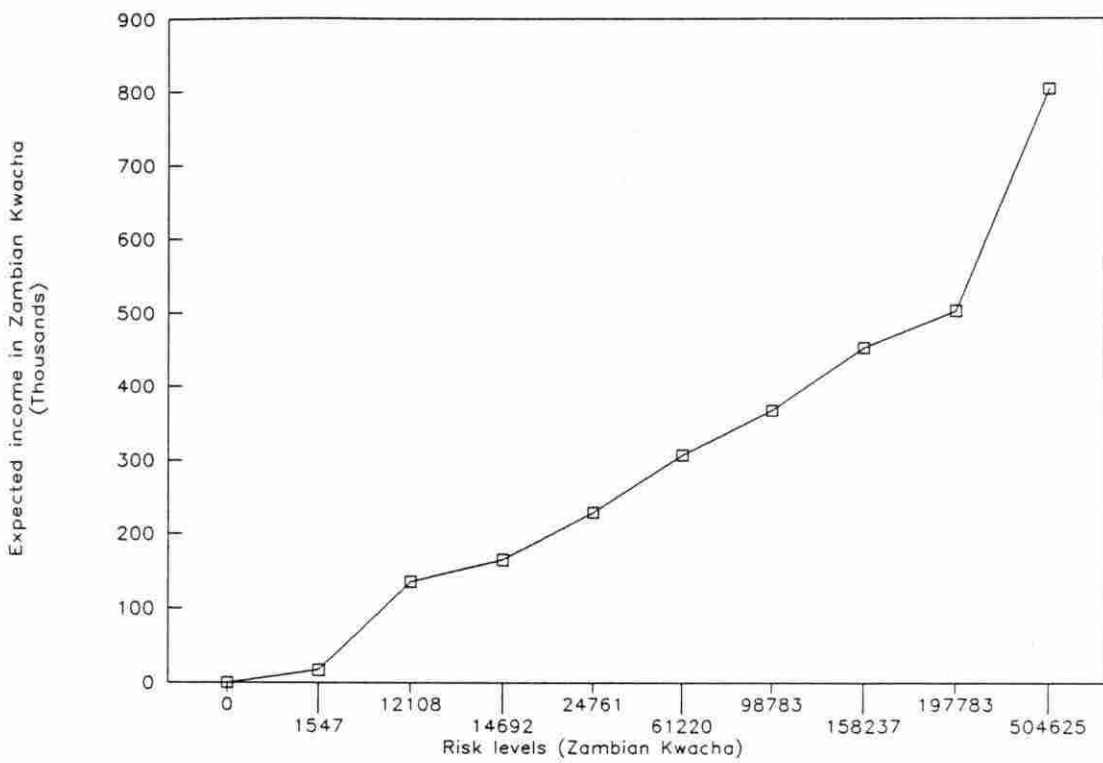


Figure 4.3: MOTAD Frontier at Selected Levels of Risk for the Large-scale Commercial Farmer (LSCF)

CHAPTER V
SUMMARY AND CONCLUSIONS

Zambia continues to face a lot of economic problems, most of which stem from the lop-sided structure of the economy. For a long time now, Zambia has relied almost entirely on the mining industry as the major foreign exchange earner. However, the events of the early 1970s left the Zambian economy very vulnerable to external shocks. The mining industry could no longer be relied on to provide sufficient foreign exchange for the country. Eventually, foreign exchange reserves were depleted and foreign debt became a main source of capital inflow for the economy.

In an effort to restructure the economy, the government has made serious attempts to shift emphasis from mining to agriculture. Lack of adequate understanding of Zambian agriculture has resulted in a series of rushed and often not effective policy formulation. It is, however, well recognized that agriculture in Zambia has great potential for contributing to the restructuring process of the economy and towards overall national development.

With the newly-placed emphasis on agriculture, there is an urgent need to understand the farmers who are the intended

targets of agricultural policy in Zambia.

This study was conceived as an attempt to understand better the decision making process of Zambian farmers. The major objective of the study was to analyze resource allocation by Zambian farmers under certainty and risk considerations. Three categories of farmers, traditional farmers, small-scale commercial farmers, and large-scale farmers, were included in the study.

From the results of the certainty model, the most profitable crop combination for the traditional farmers was burley tobacco in addition to the food crops of maize, sorghum, millet, and cassava. The small-scale commercial farmers, on the other hand, realized more profits by growing more of Virginia tobacco in addition to the food crops. Large-scale commercial farmers realized their largest profit margins by producing a crop combination of Virginia tobacco, soybeans, and irrigated wheat.

Unlike in the certainty modeling situation, the inclusion of risk in programming models provided solutions that are closer in similarity to current observed farm practices.

Maize (which is Zambia's staple and is grown by all three categories of farmers) was only produced for consumption by the traditional farmers and the small-scale commercial farmers. The study also shows that farmers in Zambia can make

more money by producing some of the crops they do not usually grow.

All the three certainty models allocated most of the land to tobacco. This is mostly due to the relatively attractive price for tobacco. The price of tobacco is usually much higher than the prices of the other agricultural commodities. The tobacco price is based on the export parity price because tobacco is mainly grown for export. The export price for tobacco is quoted in U.S. dollars and when converted to Zambian Kwacha, the price is much higher, in absolute and real terms, than the prices of the other agricultural crops.

The optimal allocation patterns of the certainty models are not consistent with observed current farm practices in Zambia. The certainty solutions allocate most of the land to tobacco growing. However, under the current observed farm practices, most of the land is used for maize production.

On the other hand, the optimal risk programming solutions have a much wider range of agricultural crops. The results of the models incorporating risk are more consistent with observed current farm practices on Zambian farms. Therefore, the optimal risk programming results would be more acceptable to the farmers. This indicates that risk is a very important component to be considered in Zambian agriculture today.

There is a great need for Zambia to review the pricing policies for agricultural commodities. The use of cost of production pricing should not be the main basis for pricing agricultural commodities. Other factors such as cross price elasticities should be considered. Also the responsiveness to market supply and demand conditions should be incorporated in pricing policies.

There is also need to re-evaluate the use uniform pricing policies. Currently, the differences in efficiency levels in the different regions and also between categories of farmers, are not considered. Use of regional pricing would encourage farmers to grow crops which are comparatively more profitable for their areas.

Farmers should be encouraged to grow crops that are more adaptable to their areas. The cost of production pricing method for farm produce should not be based on national cost of production averages for each category of farmers. This fails to take into account the comparative efficiency in resource use for different ecological zones and for different farmers.

The Zambian Government should try to make the marketing of agricultural commodities more efficient by streamlining the operations of the agricultural marketing institutions.

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APPENDIX I

CHRONOLOGY-ZAMBIAN AGRICULTURAL DEVELOPMENT

CHRONOLOGY-ZAMBIAN AGRICULTURAL DEVELOPMENT⁽¹⁾

- 1856 David Livingstone was appointed as British Consul in Zambezi area.
- 1867 Diamonds were discovered in South Africa.
- 1880 The discovery of gold deposits in Kimberly, South Africa.
- 1885 The General Act of the Berlin Conference was signed on the political and economic future of Africa.
- 1888 The General Act of the Berlin Conference was signed on the political and economic future of Africa.
- 1888 Cecil Rhodes had brought the whole diamond industry in South Africa under his control.
- 1890 Rhodes with his pioneer column arrived in what is now Harare and his British South Africa Company began to administer North and South Zambezi.
- 1891 Rhodes was given permission to extend his Company's power across the Zambezi.

1 Wood, A.P. et al. The Dynamics of Agricultural Policy and Reform in Zambia. Iowa State University Press, Ames, Iowa, 1990.

- 1891 Rhodes voluntarily occupied territories now called Malawi.
- 1891-97 The Rhodes' Company fight against the Matabele and Mashona tribes.
- 1894 An agreement was made on the Congo border.
- 1897 A peace agreement was signed between the Rhodes' Column and the Matabele and Mashona tribes.
- 1900 A treaty was signed between the chief of the Barotse, Lewanika and the Royal Charter Company at Victoria Falls.
- 1900 The whole territories of present Zambia had been included in the Charter granted to the British South Africa Company.
- 1904 The Broken Hill lead and zinc mines started operation.
- 1905 The British South Africa Company administration started to collect hut and poll tax.
- 1905 The first Asians arrived in Northern Rhodesia.
- 1906 The railway reached Broken Hill (Kabwe).
- 1909 A 506 mile railway line was completed and linked the South with the Congo border.
- 1911 Livingstone was chosen as the capital of Northern Rhodesia.
- 1911 North-Western Rhodesia and North-Eastern Rhodesia, each of which was separately administered by the

British South Africa Company, were combined under the name of Northern Rhodesia.

- 1913 A meeting was held in Fort Jameson (Chipata) on the alienation of the reserves.
- 1922 A referendum offered the white population the choice of amalgamation with the Union of South Africa or local autonomy.
- 1924 The Charter of the South Africa Company expired the Northern Rhodesia became a protectorate administered by a governor on behalf of the British Government.
- 1926 Copper mines in the Copperbelt region came into operation.
- 1924 The first of the "Blue Books" appeared when Britain assumed responsibility for the administration of Northern Rhodesia.
- 1926 Copper mines in the Copperbelt region came into operation.
- 1927 The road to Fort Rosbery in the present Luapula Province from the Copperbelt was opened.
- 1928-29 "Native reserves" were established along the line of rail, as well as in small areas in the east and north, where there was a problem of Europeans and Africans desiring use of the same land.
- 1929 The Great East Road was opened for traffic.

- 1932 A bridge was built on the Luangwa River.
- 1935 Lusaka became the capital of Northern Rhodesia.
- 1936 The Tobacco Board was established.
- 1937 The Cattle Marketing and Control Ordinance was enacted.
- 1937 The Rhodes-Livingstone Institute was founded.
- 1937 The Scheme for Development of the Production of Groundnuts and Beans was accepted.
- 1938 Burley tobacco was first grown by Africans in the Petauke area of the Eastern Province.
- 1938 The official government report announced that "Under Company rule attention was mainly given to Southern Rhodesia, the less attractive northern area being left as a backward agricultural region of principal interest as labor recruiting ground."
- 1938 The Native Development Board was set up.
- 1940 The Agricultural Teacher Training Center was established at Senga Hill.
- 1942 The first report of the Ecological Survey of North-Eastern Rhodesia was completed.
- 1942 The process of resettlement in Fort Jameson and the Petauke Districts started.
- 1943 Resettlement in the Copperbelt area started.

- 1944 Lusaka Wheat Station was established, mainly for experimental work on irrigated wheat.
- 1945 G. F. Clay's Memorandum on Post War Development Planning in Northern Rhodesia was presented.
- 1945 The first Ten Year Development Plan for Northern Rhodesia was prepared.
- 1947 The Ten Year Development Plan was approved by Legislative Council.
- 1947 The Tobacco Experimental Station at Choma was opened.
- 1947 The land in Northern Rhodesia was divided into three categories:
- Native Reserve Land
 - Native Trust Land
 - Crown Land
- 1947 The African Farming Improvement Scheme was introduced in Southern Province.
- 1948 The Peasant Farming Scheme started to operate in Easter Province.
- 1948 A new pricing system was introduced which rested on the double payment.
- 1949 The Board of African Agriculture was set up.
- 1950 The Natural Resources Board was established.
- 1950 17,994 ploughs were recorded in the Southern Province out of a total of 22,746 for the whole country.

- 1951 The Second Annual Congress of the Northern Rhodesia Farmers' Union was held.
- 1951 A uniform pricing policy proposed in the Clay's Memorandum was implemented to a limited extent.
- 1952 The Eastern Province Agricultural Produce Board was established.
- 1952 The Improved Farmer Scheme was extended to the Central Province.
- 1953 British Central Africa comprised the two protectorates of Northern Rhodesia and Nyasaland, and the self-governing colony of Southern Rhodesia was formed into the Central Africa Federation.
- 1953 The North-western Province achieved a provincial status with its headquarters in Solwezi.
- 1953 A 15,000 ton grain silo was opened in Lusaka.
- 1954 The Maize Control Board extended its operation to include the handling of groundnuts.
- 1954 The Eastern Province Agricultural Board extended its control to cover the purchase and sale of groundnuts.
- 1955 The decision to create the Kariba Lake was made.
- 1955-59 The master plan for the development of Northern Rhodesia was made.
- 1955-60 The Barotseland Protectorate Scheme of Development was implemented.

- 1956 The Rhodesian Selection Trust Copper Company lent the government 4 million Kwacha, interest free, to encourage rural development in areas from which it drew much of its labor.
- 1957 The Northern Rhodesia Grain Marketing Board was joined with that of Southern Rhodesia in the Federal Board.
- 1957 The Federation achieved one of the highest growth rates in Gross National Product to be found in Africa, i.e., 11.7% for the year.
- 1957 The Federal Government presented a five-year development plan to the Federal Assembly.
- 1958 The Department of Agriculture became separately responsible for African agriculture.
- 1958 Luapula Province was created.
- 1960 The Lake Kariba dam was officially opened.
- 1960 Ndola Sugar Refinery was opened.
- 1962 Britain was forced to take action which led to the formulating of a new constitution which came into operation in October and gave Africans their first majority in the Legislative Council.
- 1962 The new land on the Native Reserves and Native Trust Lands Adjudication and Titles Ordinance was promulgated to enable farmers to register titles through their local native authority.

ZAMBIA

- 1964 The Republic of Zambia was created.
- 1964 A UN/ECA/FAO mission headed by Dudley Seers presented its report on social and economic development to the Northern Rhodesian Government.
- 1964 The Federal Grain Marketing Board was replaced by the Grain Marketing Board, which was mainly involved in the purchase of controlled residual products at the line of rail.
- 1964 The Agricultural Rural Marketing Board (ARMB) was established and was given the responsibility for providing marketing services in the "non viable areas."
- 1964 The first Central Planning Unit was set up.
- 1964 The Mazabuka District of Southern Province, Western Province (except for Kaoma District), Central, Luapula, North-western and Eastern provinces were declared as ARMB activity areas.
- 1964 The Agricultural Marketing Committee was established.
- 1964 A record crop of 24.2 million pounds of Virginia tobacco was harvested.
- 1965 Maize and groundnuts were controlled products in Eastern, Copperbelt, Southern, and Central provinces.

- 1965 The Cheap Milk Scheme was introduced.
- 1965 The Department of Marketing and Economics was set up within the Ministry of Agriculture to deal with marketing and trade policy, and industry import and export controls.
- 1965 The Grain Marketing Board took on the construction and operation of a cotton ginnery in Lusaka.
- 1965 The cooperatives were announced as a basic way of agriculture development.
- 1965 A separate Department of Cooperatives was formed within the Ministry of Agriculture.
- 1965-66 The Transitional Development Plan was implemented.
- 1965 The pipeline from Beira to Rhodesia was closed.
- 1965 Choma, Kalomo, and Gwembe Districts in Southern Province were declared as ARMB areas.
- 1966 The Credit Organization of Zambia (COZ) was formed.
- 1966 Seed cotton became a controlled product.
- 1966 Kaoma District of Western Province was included in ARMB activities.
- 1966 The Virginia Tobacco Tenant Farming Scheme started.
- 1966-70 The first National Development Plan was implemented.
- 1967 The Grain Marketing Board began to transport tobacco from the rural areas to the Tobacco Board.

- 1967 The functions of the ARMB were passed to the Grain Marketing Board in the Southern, Central, and Western provinces.
- 1967 The functions of the Grain Marketing Board were expanded to purchases of various types of beans, cow peas, sunflower seeds, sorghum and soybeans in the line of rail provinces.
- 1967 There were 466 registered farming cooperatives covering a total land area of 45,000 acres.
- 1968 The Mulungushi economic reforms passed 51 percent ownership of 23 major companies to the Zambian Government.
- 1968 A new pipeline was opened from Dar-es-Salaam to the Copperbelt.
- 1968 The first Zambian sugar from Nakambala Sugar Estate was obtained.
- 1968 The Tobacco Board of Zambia (TBZ) was established.
- 1968 183 tractors were distributed under the Tractor Mechanization Scheme.
- 1968 The Zambia Cattle Development Company was formed.
- 1969 The Grain Marketing Board was appointed as an agent of the government in the marketing of fruit and vegetables and became an importer and distributor of seed, fertilizer, fruits, and vegetables.

- 1969 The One Acre Scheme started in Eastern Province.
- 1969 A Land Acquisition Act was announced.
- 1969 The National Agricultural Marketing Board (NAMBOARD) was established. Essentially it amalgamated the GMB and ARMB functions. NAMBOARD received a monopoly on the purchase, sale, import, export, and storage of maize as well as a monopoly on the distribution of sale at fertilizers.
- 1969 The Second National Convention on Rural Development, Income, Wages, and Prices in Zambia was held in Kitwe with 1,500 delegates attending.
- 1969-70 A difficult crop year was experienced.
- 1969-70 An agricultural census was conducted that included traditional farmers.
- 1970 The first National Cooperative Conference was held.
- 1970 The new Cooperative Society Act was passed by Parliament.
- 1970 The Coffee Plantations Scheme was introduced in Northern Province.
- 1970 The Tea Plantations Scheme was introduced in Luapula Province.
- 1970 The Kafue Textiles plant was officially opened.
- 1970 The Agricultural finance Company (AFC) took over the operations previously carried out by the Credit

- Organization of Zambia which was liquidated as a result of serious financial difficulties.
- 1970 President Kaunda shifted emphasis in farming from engine to animal power.
- 1970 The Land Mapping Project in Zambia was initiated by the Zambian Government.
- 1970 The total harvest was only one-third of that in 1967.
- 1970 The Cooperatives Law was modernized.
- 1970 A new higher maize producer price was announced.
- 1971 The Registration and Development of Villages Act was passed by Parliament.
- 1971 A uniform pricing system was introduced.
- 1971 The producer price of maize was raised again.
- 1971 Zambia achieved self-sufficiency in maize.
- 1971 The Ford Foundation was commissioned by the Zambian Government to do a thorough study of NAMBOARD and to make recommendations with respect to its financing, management practices and organizational arrangements.
- 1972 The modernized cooperatives law came into force.
- 1972 The United National Independence Party (UNIP) started to function as the single legal political party.
- 1972 The Swedish International Development Agency (SIDA) supported the Intensive Development Zone (IDZ) program in Eastern Province.

- 1972-76 The Second National Development Plan was implemented.
- 1972-73 The Intensive Development Zone program was initiated, based on the Second National Development Plan.
- 1973 SIDA funded the IDZ program in Northern Province.
- 1973 The Zambian border with Southern Rhodesia was closed.
- 1973 Exports of agricultural commodities represented only one percent of the value of total exports.
- 1974 Oil prices rise.
- 1974 Copper prices fall dramatically.
- 1974-75 All regional price differentials of crops were eliminated.
- 1975-76 A survey of maize and tobacco farms along the line of rail was made.
- 1975 The Rural Reconstruction Center (RRC) Program was established.
- 1975 The Cooperative Credit Scheme was initiated within the cooperative movement with the objective of increasing the standard of living of subsistence farms through promotion of their agricultural production.
- 1977 The Ford Foundation financed the pilot survey of the traditional farmers in Central and Northern provinces.
- 1978 GTZ funded the IRDP in North-western Province.
- 1978 The government policy towards rural development shifted from the ID to the IRDP.

- 1978-79 The IDZ program was reformulated as the Integrated Rural Development Program based on the Third National Development Plan.
- 1978 Village Industry Services was established.
- 1979 The Mpongwe Wheat Scheme was introduced.
- 1979 SIDA funded the IRDP in Luapula Province.
- 1979 Producer prices for maize were increased by 32 percent, beginning a period of improved producer incentives.
- 1979 The Light Tractor Division was joined to the Land Development Services.
- 1979-83 The Third National Development was implemented.
- 1980 FINNIDA funded the Agricultural Extension Program in Luapula Province.
- 1980 The Lima Extension and Farmer Training Program was initiated.
- 1980 The Local Administration Act of 1980 was passed by Parliament.
- 1980 The Ministry of Agriculture and Water Development Planning Unit was expanded.
- 1980 The Population and Housing Census was conducted.
- 1980-90 "Operation Food Production" was implemented.
- 1981 The Overseas Development Administration (ODA) supported the IRDP to include Mpika and Chinsali

Districts in Northern Province and Serenje District in Central Province.

- 1981 The first Provincial Planning Unit was established in Mongu.
- 1981 The Cooperative Sector Support Program was initiated.
- 1981 The subsidy on maize consumption was reduced by over 50 percent.
- 1981 The role of the marketing parastatal, NAMBOARD, was reduced by decentralizing management control to the cooperatives and allowing them more freedom in marketing.
- 1981 Changes in tax laws and tariff structure provided increased incentives for agricultural production. Income tax was reduced from over 50 percent to 15 percent for farmers. Equipment was given accelerated write-offs and tariffs and duties on most equipment were eliminated.
- 1981 The role of the tobacco parastatal was reduced by selling off land and assets to the private sector.
- 1982 The IBRD/IFAD sponsored the Eastern Province Agricultural Development Program.
- 1982 The price of copper reached its lowest real value during the past 50 years.
- 1982 Producer prices were increased in real terms between 3

- percent and 15 percent. Purchase prices were announced for cassava and sorghum.
- 1982 Retail prices were decontrolled for all major products except wheat, maize, and candles. This increased the flow of goods into rural areas.
- 1983 The Gwembe IRDP program was supported by several donors.
- 1983 The kwacha was devalued by 20 percent and allowed to float against a basket of currencies of major trading partners. This was partially in recognition of the need to reduce import demand and encourage new exports.
- 1983 Fertilizer subsidies were reduced and the price of fertilizer was allowed to rise by 60 percent.
- 1983 Producer prices were increased in real terms by 7 to 20 percent.
- 1983 The subsidy to NAMBOARD was reduced.
- 1983-84 The Lima Loan Scheme was initiated.
- 1984 Producer prices were increased and for the first time border prices instead of costs of production were introduced in the pricing decision for all crops except maize.
- 1984 Wheat price controls were eliminated.

- 1984 Floor prices were established for all controlled commodities except maize. Farmers were free to negotiate for a higher price.
- 1984 Consumer subsidies on maize were reduced and prices allowed to increase 22 percent.
- 1984 In October exporters of nontraditional exports were allowed to retain 50 percent of the foreign exchange earnings generated from export sales.
- 1985 Restitution payments to cooperatives were eliminated, forcing cooperatives to become more cost conscious.
- 1985 Subsidies on tractor hire units were decreased and rates allowed to increase by 40 percent.
- 1985 Subsidies to NAMBOARD were increased and NAMBOARD was reinstated as the primary buyer and seller of maize with cooperatives acting as agents of NAMBOARD.
- 1985 Consumption subsidies on maize meal were reduced approximately 40 to 50 percent.
- 1985 A foreign exchange auction system was started.
- 1985 Producer prices for maize were increased 95 percent over the previous season.
- 1985 Producer prices on processed agricultural items such as dairy products and sugar were decontrolled.
- 1985-86 The "go back to the land" policy was strongly supported by the Zambian Government.

- 1986 Fertilizer subsidies were decreased further and prices allowed to increase almost 200 percent in one year.
- 1986 NAMBoard's monopoly on maize and fertilizer marketing was eliminated as cooperatives and private traders were allowed to market maize.
- 1986 The domestic fertilizer producer was allowed to charge import parity on compound fertilizer.
- 1986 Consumer subsidies were eliminated on breakfast meal and prices on lower quality mealie-meal were set at K28.31 per 50 kilogram bag. The price increases were partially rescinded in the face of riots.
- 1987 Due to continued lack of foreign exchange agreement with the London Club to negotiate and consolidate short-term commercial arrears, payments on the short-term commercial arrears have been delayed.

APPENDIX II

BACKGROUND INFORMATION ON ZAMBIA

Location and Climate⁽¹⁾

Zambia has a land area of about 750,000 square kilometers. The country is flat and between 900 and 1400 meters in altitude. It shares borders with Zaire and Tanzania in the north; Malawi and Mozambique in the east; Zimbabwe and Botswana in the south; Namibia in the southwest and Angola in the west.

Lying between 8 and 18 degrees latitude south and 22 and 34 degrees longitude east, the country has a sub-tropical climate and vegetation. There are three distinct seasons: the warm-wet season stretching from November through April, during which 95 percent of the annual precipitation falls, a cool dry winter season from May to August, with the mean temperature varying between 15 and 27 degrees centigrade, and a hot dry season during September and October, 27 to 32 degrees centigrade. The annual rainfall varies between 1270 millimeters (50 inches) in the North to about 760 millimeters (30 inches) in the center and to less than 760 millimeters (30 inches) in the South of the country.

Zambia's vegetation may be very broadly classified as woodland savanna which are a mixture of various trees, tall

1 Ministry of Agriculture and Cooperatives, 1988

Agricultural Statistics Bulletin. Lusaka, Zambia, 1988.

grass, herbs, and other woodland savanna, which are mainly of the deciduous type usually to be found on the main plateau. However, these also occur in other areas such as the maize farming areas of the Southern and Lusaka provinces. Forests occur mainly in the North-Western parts of the country. These areas are a major source of timber in Zambia. Thick forests are also found in the Northern parts of the country. Grasslands occur mainly in the seasonal flood plains of the Western Province, the Kafue flats and Bangweulu Swamps.

Administratively, the country is divided into nine provinces and fifty-seven districts.

Population

At independence in 1964, Zambia's population was 3.5 million. Over the five-year period from 1964 to 1969 the population grew to 4.06 million. In the 1980 census, the population of Zambia was recorded at 5.67 million, showing an increase of 39.66 percent over the 1969 census figure of 4.06 million.

At the last census of population in 1990, the population of Zambia was estimated at 7,818,447, of which 50.8 percent were females and 49.2 were males. The average annual population growth rate was estimated at 3.2 percent per year.

Table A1 below shows the population increases from 1963 to 1990 and the population growth rates at each census.

Table A1: Population and population growth at each census.

Year	Population (in millions)	Population Increase During the intercensal period (%)
1963	3.49	-
1969	4.06	2.72
1980	5.68	3.63
1990	7.82	3.77

Compiled by author from Agricultural Statistics Bulletins.

Table A2: Rural, urban population 1963-1990 (in thousands) and percentage urban

Year	Total Population	Rural	Urban	Percent Urban
1963	3,490	2,774	716	20.5
1969	4,057	2,865	1,192	29.4
1980	5,679	3,239	2,440	43.0
1990	7,818	4,533	3,286	42.0

Compiled by author from different statistical reports.

Zambia has one of the highest urban populations in Africa, with 42 percent of the population currently living in the urban areas. In 1963, only 20.5 percent of the population lived in the urban areas, with the rest living in the rural areas, but this percentage has increased over the years, as shown in Table A2 above. At the last census in 1990, the percent urban population decreased by one percent, mainly due to a decrease in rural to urban migration. This may have been brought about by the declining economic opportunities in the urban areas, which in some cases has resulted in a reversal of the migration pattern.

APPENDIX III

TOTAL MARKETED PRODUCTION OF VARIOUS AGRICULTURAL CROPS

Table A3: Total marketed production of various agricultural crops (in metric tons)^(a)

Crop	1965	1966	1967	1968	1969
Maize	257804	387023	381049	257083	263766
Wheat	0	0	0	0	0
Rice	0	0	0	0	47
Sorghum	1	3	0	1	1108
Millet	50	48	60	44	10
Sunflower	0	0	0	0	4
soyabeans	0	0	0	0	0
Groundnuts	7309	11590	14183	4954	8258
Seed Cotton	2098	5299	1778	4032	6901
V. Tobacco	6600	6268	4947	6279	5023
B. Tobacco	855	275	285	240	255

^a The zeros indicate that no data are available

Source: Agricultural Statistics Bulletins

Table A3: Continued

Crop	1970	1971	1972	1973	1974
Maize	132207	383894	588524	399152	588090
Wheat	0	0	0	0	0
Rice	93	170	260	345	358
Sorghum	530	102	221	35	325
Millet	33	5	3	0	0
Sunflower	0	11	124	398	4003
soyabeans	0	0	0	0	37
Groundnuts	3601	6779	6508	3217	3626
Seed Cotton	5446	12675	8349	5225	2173
V. Tobacco	4796	5908	5532	6222	6301
B. Tobacco	388	384	471	430	501

Table A3: Continued

Crop	1975	1976	1977	1978	1979
Maize	559481	749972	696451	41656	335959
Wheat	934	3948	5324	5251	6528
Rice	1009	2093	1860	2925	1852
Sorghum	92	106	799	818	149
Millet	0	3	1	0	0
Sunflower	8243	15965	13321	7551	11919
soyabeans	367	604	1274	1187	1295
Groundnuts	6499	9467	7462	2234	2737
Seed Cotton	2602	3884	8929	8430	14916
V. Tobacco	6466	6262	5588	3704	4591
B. Tobacco	502	212	312	264	381

Table A3: Continued

Crop	1980	1981	1982	1983	1984
Maize	382266	693342	513502	531164	564087
Wheat	9585	11700	12843	10216	11314
Rice	2213	2800	2896	5068	54327
Sorghum	93	0	13832	12421	14675
Millet	238	0	0	97	16
Sunflower	17238	19050	21304	30465	40425
soyabeans	3531	0	3876	6898	9555
Groundnuts	2028	1360	773	1042	1158
Seed Cotton	22913	16721	12786	2018	43907
V. Tobacco	4127	2318	2079	2287	2489
B. Tobacco	554	669	704	537	497

Table A3: Continued

Crop	1985	1986	1987	1988	1989
Maize	636267	954667	656644	1349098	63958
Wheat	251370	19000	26353	25501	0
Rice	4948	5641	4586	4153	5478
Sorghum	1122	894	337	2771	1004
Millet	54	287	197	541	0
Sunflower	25496	26651	6968	17179	18647
soyabeans	10602	12953	2340	19720	25244
Groundnuts	2419	6280	1772	573	433
Seed Cotton	30254	33357	20156	58530	30666
V. Tobacco	2132	3352	2900	3738	3366
B.Tobacco	566	545	651	612	1266