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Quantification of the trade-offs in Zambia
between environment, employment,
income and food-security

by

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39003

Working Papers are preliminary material circulated to stimulate discussion
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Preface

This Working Paper is one of a series of environmental studies undertaken as part of the World Employment Programme of the ILO. It reports on the use of modelling to assist policy makers responsible for land allocation in trading off commercial, social and environmental interests. On the basis of a set of objectives and priorities and on the basis of the necessary field data, the study presents policy makers with a quantified optimal solution (in terms of the model) where objectives suggest contradictory actions. Moreover, the study enables policy makers the simulation of solutions when priorities are varied.

The study concerns the Middle Zambezi Valley of the Kariba Lakeshore, a region of Zambia that is representative of other regions of the African continent. The objectives pursued are Environmental Quality (EQ), Employment (EM), Income Maximisation (IM) and Food Security (FS). The trade-off between these objectives arises from controversial proposals to clear large areas of environmentally valuable forests in order to develop irrigation-based agriculture and thus to increase incomes and employment.

The main finding of the study is the presence of a significant level of complementarity between employment in tourism and the maintenance of environmental quality, albeit that this complementarity is subject to adequate environmental protection measures designed to manage adverse environmental effects of tourism on the environment. The same complementarity is not found between employment in agriculture and the maintenance of environmental quality. Nor are the objectives of food security and income maximisation advanced in equal measure when comparing agriculture and tourism. Under the circumstances, the study suggests a strategy by which at least 50 per cent of the land now considered for clearing should not be developed for irrigation cropping. The justification for this strategy lies in the opportunities for tourism based on Zambia's wildlife and natural environmental endowments. As with agriculture, a tourist sector will contribute to diversification away from Zambia's heavy dependence on mining, especially of copper. Furthermore, the tourist sector offers the advantage of, as it were, being able to both *have* and *use* the environment and - by virtue of this harmony between development and conservation - to maintain the agricultural option as well as other options not presently foreseen. By contrast, in the proposed agricultural development the range of options might be reduced irretrievably together with part of Zambia's natural heritage.

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1 Aims and scope

The aim of this research is to formulate an environmental policy for the Middle Zambezi Valley of the Kariba Lakeshore in Zambia. The general location of this area is shown in Figure 1.1, and the policy issues that are raised in this area are representative of the many that are rapidly becoming common in Africa. The need for an environmental policy stems from conflicts and public concerns that have arisen due to several development project proposals in the area. These proposals specifically include the clearing of approximately 162, 000 hectares of a medium density forest area for agricultural development with irrigation. Proponents of these projects claim that irrigated agriculture could raise the levels of income and consumption, and ensure stable supplies of food during periods of drought. It is indeed true that the occurrence of droughts and famines is frequent in the area. Further, this area is also one of the poorest in Zambia in terms of per capita incomes (approximately K150 per year), and nutritional intakes are claimed to be well below recommended levels (National Commission for Development Planning 1986, 1988, Zambia Nutrition Commission 1986). However, the expressions of concern regarding these projects are due to the environmental costs which are likely to be high. The clearing of the forests would lead to the loss and displacement of flora and fauna, some of which are fast becoming scarce in Africa. Further, there is also general concern that deforestation contributes to climatic changes that would prompt desertification.

Apart from famines and droughts, the moves for agricultural development programmes stem from Zambia's present economic difficulties. Zambia's dependence on a single commodity, namely copper, and declining commodity prices have led to falls in export earnings which in turn have triggered a host of other difficulties. These include, contraction in gross domestic product, large deficits in the balance of payments, shortage of foreign exchange, and the expansion of the debt burden. As indicated in Table 1.1, the Zambian economy has displayed real losses in GDP since the early 80s. Further, the economy cannot depend on a single commodity alone. Hence agricultural development has been seen as a viable avenue for diversification. The calls for agricultural development also stem from the fact that despite nearly 60 percent of the population being engaged in agriculture, food imports have grown rapidly over the years.

The main focus of this study is an evaluation of the proposed schemes for irrigation in the context of four social objectives, namely income maximisation (IM), employment (EM), environmental quality (EQ), and food security (FS). All four objectives are pertinent as well as important. The extremely low incomes, unemployment, and the frequent incidents of drought underlay the need for the IM, EM and FS objectives.

Figure 1.1: The location of the Study Area

Table 1.1
Zambia's Economic Performance - Trends in Selected Indicators

<u>Indicator</u>	<u>1980</u>	<u>1982</u>	<u>1984</u>	<u>1986</u>	<u>1988</u>
Per capita GDP(1980 kwachas)	547	526	470	465	409
Current account balance(1980 Kwachas 10 ⁶)	-848	-449	-226	-549	-
Terms of Trade Index	60	28	26	23	-
Total Foreign Debt (US\$ 10 ⁶)	-	-	3080	4785	5557
Inflation	-	6.2%	19.5%	82.3%	32.5%
Labour Force (10 ⁶ persons)	2.7	2.9	3.1	3.6	3.9

The concerns regarding a range of environmental costs and the evidence of adverse environmental outcomes of the attempts at accelerated agricultural development elsewhere in Africa (for example, Sudan, Burkina Faso) prompt the need for the EQ objective. The study seeks answers to a set of questions which include:

1. What is the contribution of irrigated agriculture to growth in incomes and employment?
2. What is the nature of the trade-offs between IM from agriculture and EQ?
3. What are the impacts on IM and EQ of imposing requirements of full employment?
4. What are the impacts of imposing the requirements of stable food supplies?
5. What is the value of environmental resources and services, and are these worth being sacrificed for additional income and employment?
6. Can incomes and employment be improved without sacrificing environmental resources?

The paper is structured as follows. The study area is described in the next section. Subsequently, the linear programming model employed in this paper is described in section 3. This description also deals with the valuation of irrigated agriculture and a demonstration of trade-offs between the stated objectives. The programming model allows for the fact that agricultural production in the study area is frequently subjected to the uncertainty of droughts. Section 4 presents the empirical work. In section 5 the monetary valuation of EQ is addressed together with a reassessment of the viability of irrigated agriculture. The final section contains concluding remarks as well as reasons for the need to undertake further research in the study area.

2 The study area: the middle Zambezi valley of the Kariba Lakeshore

The study area lies approximately 200 kilometres to the South of Zambia's capital city Lusaka. It is bounded by Lake Kariba and Zimbabwe to the South and the escarpment to the North, and consists of the administrative districts of Siavonga, Gwembe, and Sinazongwe (Figure 2.1).

2.1 The Kariba Dam

The dam was constructed in 1959 for hydro-electricity generation for Zambia and Zimbabwe. However, in recent years there have been proposals for utilising surplus water from the lake for irrigation purposes. Some of these proposals involve the provision of access to vast tracts of land to multinational corporations who have the ready investment capacity to very quickly clear large areas of forests and initiate agricultural production.

The Zambezi River Authority, the organisation charged with overseeing the operation of the Lake Kariba dam, has indicated that the lake water level should be at least 475 metres deep for hydro-electricity generation; and that the lake water levels have been well above this critical level over the past 25 years. Further, according to Clayton (1985) the electricity generated by the dam far exceeds the power demand requirements for these two countries. For example, the combined demand for electricity from Zambia and Zimbabwe is approximately 14,092 GHW while the capacity of the Kariba dam is approximately 19,425 GHW. Hence, it is plausible to assume that irrigation and hydro-electricity would not be conflicting enterprises, at least in the short to medium term, as long as lake water levels are maintained at said depth of 475 metres. Although irrigation and electricity generation may not be in conflict, irrigation is in conflict with the maintenance of environmental quality, as we illustrate below.

Figure 2.1: The Study Area

2.2 Soils and ecology

The soils of Lake Kariba, as described by Scudder (1962), are of pre-karoo and alluvial formation. Whereas the pre-karoo soils are at the foot of the escarpment, the karoo and alluvial soils are found between Lake Kariba and the escarpment and around the shores of Lake Kariba respectively. From the soil scientists' point of view, for example Maclean (1969), the alluvial soils are highly suitable for cropping activities, whilst the clay soils could be cultivated only with irrigation. However, these soils have a high sodium content, and hence irrigated agriculture could lead to problems of salinity as experienced at several locations elsewhere.

Scudder (1962) divided the topography of Lake Kariba into three zones namely:

- (a) flat land from the shores of Lake Kariba to about 15 kilometres inland;
- (b) hilly and rugged land starting from around 16 kilometres from the lake up to about 35 kilometres in land;
- (c) and flat land from about 36 kilometres from the lake up to about 80 kilometres in land.

The proposals for agricultural development have been confined to the third zone mentioned above. This zone is of a medium density forest with approximately 1500 trees per hectare. The vegetation is dominated by open deciduous canopy 6 to 8 metres high. The dominant species of canopy are *Acacia*, *Agansonia* and *Combretum*. The fauna are predominantly a wide ranging species of birds, and herbivores such as monkeys (including baboons), deer, zebras, and giraffes. The adjoining hilly area is in fact a dense stand of forest with larger fauna and flora. The tree densities are approximately 3000 trees per hectare and their heights range from 18 metres upwards. While large herbivores such as elephants and buffaloes are found, here the fauna is predominantly made up of carnivores such as lions, leopards and rhinos. One significant implication of clearing the land area intended for agriculture, that is the medium density forest, is that many of the herbivores would be displaced into the adjoining dense forest area where they are likely to fall prey to the carnivores. Accordingly, the costs of agricultural development include not only the destruction of habitat and its species but also disturbance to the prevailing ecological balance between the medium and high density forested areas.

2.3 Climate

Since the study area lies in a valley, it is generally hot throughout the year with the hottest temperature reaching 40°C in the months of October and November. The relatively cold months are between May and August, with the coldest month being July, registering an average mean temperature of 15°C. The hot and cold temperatures fall within the general broad categories of the wet and dry seasons. While the wet season is from November to April, the dry season is from May to October.

The average rainfall during the wet season has been 721 millimetres. Further, records reveal that during a 34 year period (1952/53 to 1985/86), rainfall has been above the mean average only 50% of the time. That is, rainfall has been below average every other year. Normally, no rainfall is expected during the dry season and any rainfall that occurs in this season would be exceptional. The mean rainfall of 21 millimetres during this season makes it practically impossible for crops to be grown without irrigation.

2.4 Population and economic activity

Some 12,000 families are dispersed amidst the medium density forest area, and are concentrated in small sets of communities that display subsistence agriculture. At present approximately 14,000 hectares of land are cultivated in the form of small holdings, that is approximately one hectare per family. The main crops grown are sorghum, maize and

sunflower, whilst some cotton is also grown. The average annual per capita income is extremely low, namely K150 in 1985 prices. This low income also coincides with a high degree of unemployment and underemployment. The precise extents of labour utilisation are difficult to assess due to the subsistence nature of production. Surveys also suggest that the calorific intakes are well below recommended levels, and frequent droughts no doubt exacerbate these problems. Existence under these circumstances places considerable pressure on the environmental resources of the area. That is, families are prompted to use the forest resources for food and fuel as well as attempt to enhance their incomes by supporting the poaching of wild life resources, some of which are indeed scarce. Hence, whilst environmental considerations are no doubt important, they cannot be easily isolated from considerations pertaining to income.

Although subsistence agriculture is confined to sorghum, maize, sunflower and cotton, the climatic features of the region also permit the cultivation of other crops such as rice, soyabeans and wheat. The development proposals include these crops. The income derived from current agricultural practices is presented in Table 2.1.

Table 2.1: Income from current agricultural practices in the study area

Year	Maize	Sunflower	Cotton	Sorghum	Total	Incom /he
	K(000)					
1976	2527	735	4502	0	7764	
1977	1838	1257	8	0	3103	
1978	1892	369	2713	0	4974	59
1979	2051	1748	3505	0	7304	87
1980	1166	440	3524	0	5130	61
1981	1537	178	1511	0	3226	38
1982	410	111	1032	9	1562	19
1983	689	141	588	17	1435	17
1984	882	373	362	597	2214	26

Source: Department of Agriculture, and Central Statistics Office, Lusaka.

As expected, one observes an unstable pattern of income, and the fluctuations in income are associated with fluctuations of rainfall. Clearly, the maximisation of income, and the minimisation of output instabilities due to the irregular nature of rainfall in the study area, are important social objectives for the region. The implementation of irrigation programmes could serve to achieve these objectives. However, it would be less than prudent to confine the costs of developing irrigated agriculture to the traditional resources of land labour and capital. The natural environment and its components are also vital resources that are either impaired or lost in the development of irrigated agriculture. Hence, in this study, we evaluate the viability of irrigated agriculture by incorporating the natural environment as an essential ingredient. The models that permit this evaluation are described next.

3 Method of analysis - formulation of models

3.1 The nature of the models

The literature on agricultural development in drought prone areas is explicit on the need to incorporate the risks and uncertainties that are associated with drought (Hazell and Norton, 1986). Further, the literature also favours the use of mathematical programming models for the determination of land use decisions that involve the spatial allocation of resources. This is primarily governed by the ability of mathematical programming models to evaluate an infinite set of resource allocation patterns from a set description of the prevailing resource endowments. However, this advantage would inevitably depend on whether or not the mathematical descriptions of the endowments and their utilisations are an adequate representation of reality, especially in terms of the processes of utilisation (McMillan, 1975).

Problems involving risks and spatial patterns of resource allocation are perhaps best resolved by quadratic programming models with a quadratic objective function and linear constraints. In their application to agricultural land use decisions, these models are formulated to maximise the expected revenue from various land uses minus the cost of risk taking, subject to the usual resource endowment constraints of land, labour, and capital. The quadratic form is due to the costs of risk taking being defined in terms of variance of returns from land use. Thus risk is defined as dispersions around the mean, namely expected income, and the model is formulated to choose patterns of resource allocations that minimise these dispersions. Although quadratic programming is theoretically adequate, its applicability is limited due to the lack of ready accessibility to suitable algorithms and difficulties associated with computation.

However, a simplification and a more readily applicable transformation of quadratic programming models was presented by Hazell (1971), where the variance term was replaced by mean absolute deviations. This replacement enables the model to be linear instead of quadratic. Since these models are designed for the "minimisation of total absolute deviations" from a prescribed objective, they are usually referred to by the acronym MOTAD. Further, these models are also more readily applicable due to the availability of a variety of linear programming algorithms. Although the usefulness of linear programming could be questioned due to its assumptions, namely linearity, additivity, and convexity, empirical findings, for example Johnson (1966), suggest that the restrictiveness of these

assumptions would not be significant, especially in the context of agricultural land use decisions. Hence linear programming has found widespread application in agriculture; for example Hardaker and Troncoso (1979), Hazell and Norton (1986), and McCamley and Kliebenstein (1987).

In this study, a variant of Hazell's MOTAD model is used, namely Target-MOTAD, which was introduced by Tauer (1983). Whilst the original MOTAD models measure risk in terms of absolute deviation of income from mean income, Target-MOTAD models measure risk as absolute deviations from prespecified values of target income. The relevance of Target-MOTAD is mainly due to the fact that mean income need not necessarily satisfy basic needs, whilst target incomes do. Hence, it is possible to define the risks that are prompted by droughts in terms of the failure to meet the basic needs of human existence.

Given that there are two distinct seasons, namely the wet and the dry, Target-MOTAD models are formulated for each of these seasons. Further the model formulation is also performed in the context of two options namely "with irrigation" and "without irrigation". Given that rainfall is virtually nonexistent during the dry season, the "without irrigation" option is confined to only the wet season. In each of the models environmental quality constraints are explicitly introduced in order to facilitate the derivation of trade-offs between IM and EQ. The models for each of the options are described below.

3.2 The Models

The main components of the model for each option are:

- (a) a rainfall simulator,
- (b) a Target-MOTAD model.

The simulation of rainfall was performed with the rainfall records for the period 1952/53 to 1985/86. Following Sharma and Nyumbu (1985), the simulated value of rainfall is reduced by 10.5% to allow for run-off losses. The simulated values of rainfall were then used to determine: expectations of income, soil moisture levels and the risk of drought and crop failure.

The Target-MOTAD model for the "with irrigation" option is shown in Figure 3.1. The model solution for a given season reveals:

- (a) the mix of crops to be grown;
- (b) the amount of lake water to be used for irrigation;
- (c) the amount of credit to be given to the farmers.

$$\text{Maximise Net Income} = \text{Expected value of income from cropping} - (\text{cost of irrigation}) - (\text{cost of credit})$$

subject to the constraints of:

land,
labour,
soil moisture,
capital and credit,
limit on irrigation,
deviation from target income and risk aversion levels, and
targets on the EQ objective.

Figure 3.1: Target-MOTAD model for the "with irrigation" option

The model for the "without irrigation" option differs from the model described above in terms of the absence of the variables pertaining to irrigation and its application to only the wet season. The inclusion of credit as a decision variable was deemed relevant given that the literature on development economics has recognised the lack of access to institutional credit by the poor as an important source of persistent poverty. The issues surrounding limited access to credit are detailed elsewhere (Anderson and Thampapillai, 1990). The evidence of strong associations between poverty and the lack of access to institutional credit has often been used as the argument for a relaxation of the requirements for credit access. Hence, the incorporation of credit as a variable in this model would enable the examination of whether ready access to credit has an effect on agricultural production and thereby on income levels. That is, we assume that the crop production and irrigation activities involve credit.

The objective function of the Target-MOTAD model concerns the maximisation of expected income from seven crops, namely maize, cotton, sunflower, soyabeans, sorghum, rice and wheat. It is assumed that production of these seven crops within the limitations of the constraints has to take place in five zones of the study area. Following information that was furnished by farmers and agricultural officers in the area, the target income was nominated as K100 million for the "with irrigation" option, and as K20 million for the "without irrigation" option. Further, in quantifying the risk-taking behaviour of farmers in the region, it was assumed that they are willing to tolerate losses (deviations) of up to K20 million in the context of irrigation, and up to K4 million in the absence of irrigation. The rationalisation of these values is based on the premise that the people in the study area generally tolerate losses of up to twenty percent of expected income.

Ideally the constraints pertaining to EQ targets need to be defined in terms of the various species of fauna and flora and of the impacts that agricultural production decisions bear on the environment. As indicated above, the area that is intended for agricultural development bears a diverse range of species. However, since the population counts of

the various species are unknown, we have assumed that the EQ target can be defined as the number of hectares of land preserved. By systematically varying this target, that is by varying the amount of land that is preserved or denied for development, a trade-off function that reveals the relationship between IM and EQ can be derived. As shown subsequently, these trade-off functions can be also derived in the context of imposing the requirements of full employment, and maintaining at least the minimum requirements of food production to avert the adverse consequences of drought.

For purposes of clarity and expository convenience, the conceptual definitions and the empirical estimation of the various components of the models are presented in the appendix, and the results of the model applications are considered next. The models were applied across thirty scenarios that were generated from values of simulated rainfall. Each scenario had six sets of rainfall values, where each set consisted of two rainfall values for a given year; that is, one for the wet season and another for the dry season. Each set was hence used as a state of nature in the Target-MOTAD model for quantifying the risks; that is, estimating the deviations from target income. Since each state of nature is a year and we consider six states of nature, the solution of the model application can be interpreted as resource allocation strategies for a six-year period.

4 Application of the models and the evaluation of the options

As indicated in Section 1, the main aim of this study is to evaluate the viability of the irrigation option whilst recognising environmental resources as essential ingredients of development. However, the discussion below commences with an examination of the impacts of irrigation development without any environmental considerations. The changes due to the recognition of the environmental quality objective are first introduced in Section 4.2. These changes reflect on the objectives of full employment and food security as well as income maximisation.

4.1 The income impacts of agricultural development

The comparison of the two options in terms of specific variables is presented in Table 4.1. Clearly the implementation of irrigation is by far a superior option in terms of income. Net income with irrigation is almost five times the amount of net income that is generated without irrigation. Further, the model solution for the option without irrigation generates an income that is almost twice the amount that is presently generated in the region. With both options full employment is feasible. This indicates that even without irrigation, income can be improved by reallocating resources from the current patterns of allocation. However, these increases in income and full employment of labour are possible only when the entire land area is cleared for agricultural production.

Further, the information presented in Table 4.1 does not pertain to model solutions that are restricted by minimum food supply requirements. When such restrictions are not imposed, the irrigation option would prompt a shift in resources away from food crops to

cash crops, such as cotton, which have a higher consumptive use water. That is, in the absence of irrigation, resource allocation is confined to the cultivation of food crops which have a lower consumptive use of water.

It should also be noted that the patterns of resource allocation in the context of both options (that is, with and without irrigation) are based on the assumption of access to institutional credit. The net incomes reported in Table 4.1 are of course net of interest charges. The importance of credit was assessed by solving the models without the credit variables. In the case of the with irrigation option, the value of net income fell from K82 million in the wet season to K25 million. That is, a drop of nearly K60 million. In the case of the without irrigation option, this fall was about K24 million; that is a drop from K33 million to K9 million. Hence the viability of both options in terms of generating additional income is dependent on providing access to institutional credit.

Table 4.1: Comparisons of the effects of the two irrigation options

	<i>With Irrigation</i>		<i>Without Irrigation</i>
	Wet Season	Dry season	Wet season
Net Income	K81.92 M	K69.34 M	K33.04 M
Amount of credit	K 5.81 M	K 5.81 M	K 3.68 M
Irrigation cost	K 5.20 M	K17.80 M	-
Crops grown	Maize, Cotton	Maize, Cotton	Sorghum Wheat
Extent of land used	162,000 ha	161,401 ha	162.7
Unemployment	nil	nil	nil

As a proportion of GDP in 1985 prices, the irrigation option contributes to approximately five percent, which is a significant contribution given the relatively small size of the project. The direct per capita gains from irrigation per year to those in the study area amount to nearly K1800. Given that existing per capita incomes in the area are around K150, the income increase is indeed significant. When secondary effects are included by using a spending multiplier of 3.33, a value that was used in other studies, for example, Maleka (1989), the income benefits from irrigation amount to approximately K500 million or approximately 15 percent of GDP in 1985 prices. The contribution of the irrigation option to per capita national income is K62.5. This is no doubt a sizeable contribution.

Although both the "with" and "without" irrigation options generate increases in income, these increases are depicted by model solutions that involve the clearing of the entire 162,000 hectares of forest land. Given that the scarcity of ecosystems and wild life has become an issue of global significance, the impacts of preserving the land area (that is, prohibiting any form of development) need to be assessed against the monetary gains that can be generated by irrigation. This is considered next.

4.2 The impacts of introducing the EQ objective

As indicated, due to the paucity of data, the EQ objective was quantified in terms of the extent of land preserved. The assumption is that when a hectare of land is denied for agricultural development, then all items that are carried by this parcel of land are preserved. From an ecological stance, this assumption is indeed weak, since the compartmentalisation of land into parcels of hectares must invariably disrupt ecological systems. Nevertheless, the assumption is retained for reasons of empirical convenience; and is used for the derivation of the EQ-IM trade-off functions.

The derivation of the trade-off function is performed by systematically reducing the amount of land that is made available for agriculture, and maximising the IM objective for each state of reduced land availability. The value of the IM objective for various extents of preservation are presented in Table 4.2 for both the "with" and "without" irrigation options. The trade-offs between IM and EQ are presented in Figure 4.1(a). As expected, the trade-off function for the without irrigation option is well within that of the with irrigation option. These functions provide useful information in the sense that decision makers are made aware of the amount of income benefits that have to be sacrificed in order to preserve the environment. As indicated in Table 4.2, the pursuit of the EQ objective also involves sacrifices in terms of employment benefits. It was therefore possible to demonstrate the trade-offs between employment and environmental quality objectives as portrayed in Figure 4.1(b). It is evident that with both options of irrigation, the impact on employment is hardly noticeable until EQ exceeds 40 percent preservation. The effects of recognising employment are considered in more detail below.

The trade-off curves that have been shown here are not efficiency frontiers in terms of all resources. Labour and capital resources become redundant as the extent land preserved increases. Instead, these curves are efficiency frontiers in terms of land (and its environmental resources), since at any point on the trade-off curves these resources are exhausted between the two objectives.

The IM-EQ trade-off curve for the "without irrigation" option enables an assessment of the efficiency of the present management of land use in the study area. As indicated above, the trade-off curves shown here are economic efficiency frontiers in terms of the allocation of land between EQ and IM, and the models used also recognise the perception of risk and uncertainty by the residents of study area. The surveys carried out in the study area reveal that the annual regional income is nearly K3.35 million and that approximately 16,000 hectares of land are being cropped. This places the present management strategies on the frontier at point A in Figure 4.1(a), noting that 90% preservation corresponds to the utilisation of 16,000 hectares of land. The result indicates that the residents of the study area are most probably internalising all risks and uncertainties that surround their existence and are using their land resources efficiently.

Table 4.2: The impacts of EQ on the IM objective

<i>Extent of EQ (percentage)</i>	<i>Value of the IM objective:</i>		<i>Extent of Employment:</i>	
	<i>with irrigation (K 10⁶)</i>	<i>without irrigation (K10⁶)</i>	<i>with irrigation (percent)</i>	<i>without irrigation (percent)</i>
0	151	33	100	100
10	137	32	98	100
20	122	30	96	100
30	108	28	94	100
40	94	25	92	84
50	80	22	86	72
60	63	18	69	60
70	48	14	52	50
80	32	9	35	40
90	15	5	17	29
100	0	0	0	0

There are two further issues that deserve attention.

- (1) The employment impacts of pursuing the EQ objective warrant further consideration in view of the high degree of unemployment and under-employment of labour in the study area.
- (2) Given the frequent incidents of drought, targets for food production to ensure stable supplies of food become important.

The first of these issues stems from the concern that rural unemployment invariably leads to rural-urban migration and places undue pressures on urban resources. The targets for food production are also warranted on the grounds that the nutritional intake of the residents of Lake Kariba are well below recommended levels. The impacts of these other social goals are considered next.

Figure 4.1(a): The IM-EQ Trade-off curves for both irrigation options

Figure 4.1(b): The Employment-EQ Trade-Off Curves

4.3 The impacts of other social goals

Given that countering the process rural-urban migration is recognised as a matter of great importance, the employment goal was defined as full employment. This merely involved the redefinition of the labour constraint in the models to ensure that all available labour in the region is utilised. The food security goal was incorporated by adding two more constraints to each model to state that the production of maize and that of sorghum should each be at least equal to a minimum threshold. This threshold was determined on

the basis of the nutritional requirements of the area's residents and was defined as the allocation of at least 30,000 hectares each for maize and sorghum. The impacts of the employment (EM) and food security (FS) goals are summarised in Table 4.3.

The models were solved for each of these policy goals separately as well as together. It was not possible to generate a trade-off function between EQ and IM in the context of the "without irrigation" option when either or both of the EM and FS goals were included. This was not the case in the context of the "with irrigation" option. The implication of this result is as follows.

If irrigation is not made available, and the goals of minimum food supply and full employment are to be satisfied, then the entire land area has to be cleared; that is, the EQ objective is not compatible with the other objectives.

Table 4.3: Impacts of Employment and Food Security Goals

EQ (percentage)	Value of the IM objective when:			
	EM&FS absent (K10 ⁶)	Only EM present (K10 ⁶)	Only FS present (K10 ⁶)	EM&FS present (K10 ⁶)
0	151	142	128	116
10	137	136	123	115
20	122	122	110	109
30	108	108	97	97
40	94	93	82	0
50	80	0	66	0
60	63	0	51	0
70	48	0	0	0
80	32	0	0	0
90	15	0	0	0
100	0	0	0	0

The trade-off functions that incorporate the impacts of EM and FS goals are shown in Figure 4.2. The impacts of these other policy goals in terms of the maximum area of land that can be preserved and the value of preservation (in terms of opportunity costs) are summarised in Table 4.4. For example, should only the food supply goal be introduced, then it is possible to preserve nearly 62% of the land area, whilst the maximum extent of land that can be preserved with the full employment goal is 48% of the total land area. When both food supply and employment goals are introduced, the maximum amount of land that can be preserved reduces to 35% of the land area. The opportunity cost value of preservation reveals the amount of income benefits that have to be sacrificed to achieve the maximum feasible extent of preservation under each policy scenario, and is equal to the highest attainable value of IM in each scenario.

Figure 4.2: Comparison of the IM-EQ Trade-Off Curves for the "With Irrigation" Option - presence and absence of the EM and FS goals.

Table 4.4: The opportunity cost value of preservation and the maximum feasible extents of preservation for different policy scenarios

Policy Scenario	Maximum feasible extent of preservation	Value of max preservation as an opportunity cost (K10 ⁶)
EM & FS absent	162,000 ha or (100% EQ)	151
Only EM present	78,000 ha or (48% EQ)	142
Only FS present	101,000 ha or (62% EQ)	128
EM & FS present	57,000 ha or (35% EQ)	116

Figure 4.3: The IM-EQ Trade-Off Curve with EM and FS

Should the prevailing set of policy objectives be: the maximisation of income, the maintenance of environmental quality, stable food supply, and full employment, then the search for a policy option is confined to the inner most trade-off curve in Figure 4.2. This curve is reproduced in Figure 4.3. The type of information that can be gained from Figure 4.3 is as follows. Given the recognition of stable food supply and full employment, an income target of K100 million and an EQ target of preserving 35% land area are inconsistent. However, under similar circumstances, an income target of K100 million and an EQ target of 16% are both attainable. Likewise, an income target of K 50 million and 24% preservation for EQ are also attainable.

The net present value (NPV) of income gains from a selected set of policy scenarios are summarised in Table 4.5. The policy scenarios are all centred around having the irrigation option. The NPVs were computed by assuming a five percent discount rate and a 25 year time horizon, and the net incomes generated by the model solution to be annuities over this time horizon. Even if these NPVs may appear to be significant, especially in the context of a community that is faced with poverty, there is an explicit need to attempt the valuation of environmental quality by more direct means (that is by methods other than those involving opportunity costs of preservation). This is due to the vast extent of land that has to be cleared for agricultural development. That is, the estimation of the true social value of the environment needs to be assessed. Section 5 will attempt this assessment.

Table 4.5: NPV of the IM objective for selected policy scenarios (with irrigation)

NPV of the IM objective when the policy scenario is:				
Extent of EQ (percentage)	EM&FS present (K10 ⁶)	only EM present (K10 ⁶)	only FS present (K10 ⁶)	EM&FS absent (K10 ⁶)
0	1600	1959	1766	2084
10	1587	1877	1697	1890
20	1504	1683	1518	1683
30	1338	1490	1338	1490
40	0	1283	1131	1283
50	0	0	911	1104
60	0	0	704	869
70	0	0	0	662
80	0	0	0	442
90	0	0	0	207
100	0	0	0	0

5 The valuation of environmental quality

It should be noted that given the sparseness of ecological data and limitations of time, the methods to evaluate environmental quality are subject to a number of the deficiencies commonly cited in the relevant literature. Three approaches were used to attain a monetary assessment of environmental quality.

- (1) Estimation of the Zambian community's demand for preserving the study area.
- (2) Estimation of the demand of those outside Zambia to preserve the study area.
- (3) Estimation of replacement costs.

The value of preservation in terms of demand was approximated by adding the values that were derived from the first two approaches.

5.1 The Zambian demand for preservation

The Zambian community's demand for preservation was estimated by applying the method of contingent valuation to a selected number of individuals in Lusaka. This method involved specifying a particular monetary value and finding out whether the subject is willing to pay either more or less to have the study area preserved. If for example, the subject were willing to pay more, then the value is systematically bid up until the subject is willing to pay no more. Alternatively, had the subject been willing to pay less the value is systematically bid down until the subject is willing to pay no less. The average annual willingness to pay (WTP) that was elicited by this method was approximately K250 per person. However, all members of the sample who were subjects in the valuation process had annual incomes in excess of K12,000. Further, an examination of past income distribution data suggests that those earning in excess of K12,000 per year amount to only about ten percent of the population. Hence, the benefit of preserving the study area by this method was estimated as:

$$\begin{aligned} (\text{the average WTP})(0.1)(\text{population of Zambia}) &= \text{K}(250)(0.1)(7.2) \text{ million} \\ &= \text{K}180 \text{ million.} \end{aligned}$$

Whilst some may argue that the value of preserving the environment by this method could be an over-estimate, it should be noted that this value is conservatively based only on the WTP of 10 percent of the population for which preferences are known. That is, had the WTP of the entire population been considered, then the value of preservation is likely to be much higher. Hence the value of K180 million can be regarded as an estimate at the lower end of the spectrum of values for the preservation of the study area.

However, there are some difficulties in comparing the values of WTP that have been

ascertained by bidding games with those that are determined by prevailing prices (despite the premise that prices are, in fact a manifestation of WTP). For example, the gains of irrigation development were valued by prevailing prices. These difficulties stem from the following observation. Most of the respondents in the contingent valuation method were on average willing to pay only between 0.2 and 0.5 percent of their income towards preservation. In the mean time, their WTP for say, steady employment or stable supplies of food is likely to be higher. However, some of these discrepancies may also arise from the public good characteristics of environmental services and resources.

5.2 Foreign demand for preservation

Two methods were, applied to estimate this demand. In the first method, the demand of those outside Zambia for preserving the study area was equated to the expenditure that is incurred by tourists who visit the area. Tourism data on Zambia reveals that the number of foreign tourists has steadily increased from around 87,000 in 1980 to about 189,00 in 1990. This data source also reveals that tourism revenue (in 1985 prices) has risen from K25 million in 1980 to K137 million in 1990. Using projected figures in Fourth National Development Plan, the average annual value of tourism amounts to K123 million. Further, it is believed that at least fifty percent of the tourists who visit Zambia would visit the study area. Hence by way of the expenditure method, the WTP for preservation by those outside Zambia was equated to K61.5 million.

The second method of valuation was also related tourism. A questionnaire that sought a subject's response to changes in the cost of a visit to the study area from his/her place of origin, was distributed to a sample of tourists in Australia as well as in Lusaka. The number of visits had to be specified in the context of a six year period. The choice of a six year period was governed by the Target MOTAD model being also set in that context. The cost of a visit ranged from US\$10,000 to US\$500. So, for example, a sample question reads as follows:

"Should the cost of a visit to the Lake Kariba area of Zambia be \$ 1000 (including return airfares accommodation and meals), how many trips would you make during a six year period?"

As expected, the revealed frequency of visits was higher at \$500, whilst virtually no one was willing to make even one visit at \$10,000. The information from each individual was used to derive individual demand curves which were then horizontally aggregated. The area below the aggregate demand curve becomes a measure of the value of the benefits of preservation. The value of preservation by this method was more modest than the previous one. It amounted to \$US0.8 million, which in 1985 prices is equivalent to K1.6 million.

The second method in fact follows the principles adopted by Hotelling (1949) in deriving the demand for recreation by the method of travel costs. In the context of the study area, this method has probably yielded an under-estimate since the sample surveyed is not likely to be a true representative of those visiting the study area. Alternatively, the tourism revenue that has been drawn from actual expenditures by tourists, and the assumption of 50% of the tourists visiting the study area is not entirely unrealistic. This

is because Lake Kariba is one of the biggest lakes in the world, and its surrounding environs are endowed with diverse wild life. Hence the value of preservation in terms of demand may be approximated to the sum of the value derived by contingent valuation, namely K180 million and that based tourism revenue namely, K61.5 million. That is, the value of preservation by way of WTP is K241.5 million.

5.3 Method based on replacement

The method of replacement cost is based on the premise that the value of an item is equal to the cost of replacing it. Hence, should irrigation development be deemed essential, then the wild life and plant species, specially those that face the threat of extinction, should be rehabilitated into a similar environment elsewhere. These rehabilitation costs are equivalent to the costs of replacement. The cost estimates as provided by the Department of Wild Life and National Parks ranged from US\$ 800 million upwards. That is values starting from K1600 million in 1985 prices. Should such a method of valuation be regarded as relevant, any development that involves the disruption of the ecological system becomes nonviable.

Given that the environment with all its inhabitants is an input in production, the principles that underlay the method of replacement-cost valuation cannot be easily rejected. That is every plant and animal life that is lost has value, since agricultural development cannot proceed without effecting such a loss.

5.4 An evaluation of EQ values

The values that have been derived by the application of the various methods have been summarised in Table 5.1. A comparison of these values with the net incomes generated by agricultural development indicate that preservation is by far more valuable than outright agricultural development involving the clearing of the entire land area.

Table 5.1: Summary of the monetary values of preserving the environment

	<u>Method of Valuation</u>	<u>Monetary Value</u>	<u>Present Value</u>
1.	A. Demand within Zambia	K 180 million	K 3600 million
	B. Tourism Expenditure	K 61.5 million	K1230 million
	C. Total WTP	K 241.5 million	K 4830 million
2.	Replacement Cost	K 1600 million	K 32000 million

Recall that the highest NPV for the IM objective was K2084 million (Table 4.5). As shown in Table 5.1, the lowest present value for the preservation of the environment (at least within the confines of this study) is K4830 million. Further, the valuation of the environment by replacement costs does not permit any consideration whatsoever of development. Hence it appears that irrigation development is not a viable option when the criterium of decision making is the maximisation of net social benefits, i.e. benefits accruing from all social goals.

However, suppose that the valuation of the environment by replacement costs is rejected on the grounds that the biological species that are lost could be found elsewhere in Zambia. Then the validity of the valuation methods based on the demand for the environment becomes crucial in the choice of an appropriate policy. Further, given the extent of poverty and unemployment in Zambia, income considerations do inevitably dominate the choice of policy decisions. For these reasons the value of the environment might be relegated to the commercial component of the demand for the environment. This commercial or tangible component is in fact tourism revenue, the present value of which is K1230 million. That is, decision makers are likely to acknowledge tourism revenue from overseas visitors as a measure of value, and disregard the local Zambians' expressed WTP which does not enter into any actual transaction.

For reasons of simplicity, assume that EQ benefits are uniformly distributed across the study area, and that the value of preservation is directly proportional to the extent of preservation. If such an assumption is acceptable, then it is possible to search for a policy on the basis of the *"tangible value of policies"*. This value can be defined as:

$$(The\ present\ value\ of\ the\ IM\ objective) + (The\ present\ value\ of\ the\ Tourism\ revenue\ component\ of\ the\ value\ of\ EQ)$$

This tangible value was computed for the maximum feasible extent of preservation in the context of the four different policy scenarios that were presented in Table 4.4, namely EM and FS are absent, recognition of EM only, recognition of FS only, recognition of both EM and FS. These tangible values are presented in Table 5.2.

Table 5.2: The "tangible value of policies"

<i>Policy</i>	<i>Maximum possible extent of preservation</i>	<i>Tourism revenue (10⁶ Kwacha)</i>	<i>Value of IM (10⁶ Kwacha)</i>	<i>Tangible value (10⁶ Kwacha)</i>
EM and FS absent	100%	1230	0	1230
Only EM	48%	590	1269	1859
Only FS	62%	762	690	1452
EM and FS present	35%	430	1325	1755

Interpreting Table 5.2, the policy "only EM", for example, imposes the requirement of full employment, and the maximum extent of land that can be preserved in this context is 48%. The estimate of tourism revenue in this instance is assumed to be 48% of the tourism revenue that is earned when the entire land area is preserved; that is $K(0.48)(1230)$ million = K590 million. As indicated, "tangible value" is maximised when a policy of preserving nearly half the extent of the study area is pursued along with full employment. Hence, in terms of whether Zambia should proceed with agricultural development or, alternatively, preserve the Middle Zambezi valley in its natural state, the analysis thusfar would favour the latter option or an option that permits partial development. However, should pecuniary considerations dominate, then a partial development to satisfy the goal of employment appears to be more relevant. To a different degree, either solution permits Zambia to protect and develop its comparative advantage in tourism by virtue of its wild life and environmental endowments.

6 Conclusions

The results of this study indicate that income, employment and environmental goals could be complementary in terms of preserving and enhancing the quality of environmental resources for tourism development. Evidence from elsewhere in Africa, especially Kenya and Zimbabwe supports this type of complementarity. Hence, it may be prudent for Zambia to exploit its comparative advantage in terms of the endowments of wild life and other natural amenities to generate income by way, for instance, of wild life park development. Instead of clearing the 162,000 hectares of land for agricultural development, it may be more desirable to increase tree densities by afforestation and thereby permit the growth of wild life populations. Such action, apart from its beneficial environmental effects, may potentially generate more income in the long run subject to the development of tourism. Furthermore, environmental protection and maintenance itself constitutes a source of employment. Accordingly, an important question to be analysed is the extent to which the quality as well as the quantity of environmental resources could be enhanced while optimising income and employment benefits. This aspect, however, has not been analysed due to resource limitations. Nonetheless, the analysis presented is sufficiently robust to recommend againsts large-scale clearing of the environment for irrigation development. Instead the preferred policy is one of partial development. While satisfying the goal of full employment, under partial development nearly half the study area would be left in its preserved state.

It is possible that decision makers in the study area as well as elsewhere in Zambia would support an option of partial development instead of extensive deforestation for development. The reason lies with the emergence of an environmental awareness that has pervaded all levels of Zambian society. This awareness is reflected in the fact that Zambians portray their image overseas in terms of wild life and natural resource endowments. There are some nineteen protected areas in Zambia spanning approximately six million hectares, which is nearly nine percent of the national land area and well above the African average of 3.5 percent (World Resources Institute 1990).

The value of this study is not confined to the specific policy options addressed. The

study establishes a model that can be applied to a variety of decisions that involve conflicting purposes. In view of this generality, it seems appropriate to conclude with a note concerning the need for further study.

Further research is important since the problems addressed in the Middle Zambezi Valley are representative of the environmental problems found across most of Africa. Extensions to this study would necessarily involve a more detailed definition of the environment and thereby illustrate, as far as possible, precise changes that could occur in the "economy-environment" relationships. These changes could be demonstrated in the context of pursuing traditional growth oriented activities such as agriculture as well as environment oriented activities such as afforestation and preservation. A possible way of achieving this is to formulate a systems framework that consists of an environment simulator as well as an economy model.

The basis for such an extension has already been established in this study. Recall that the framework used in this study (Section 3) consisted of a rainfall simulator, and a stochastic land use model for agricultural development. The rainfall simulator can be replaced by the environment simulator, the components of which could include predictors of key environmental variables such as climate changes, soil loss, salinity levels of the ground water table, and the population sizes of biological species. The economy model would replace the land use model and could include income-generating activity variables as well as traditional fiscal and monetary policy instruments. By permitting interactions between the two models within the systems framework, policy instruments that stabilise the environment as well as sustain the economy can be more adequately defined. For example, the interactions could be performed in the context of a recursive two-stage analysis. The first stage might involve the determination of the status of environmental variables, and the second stage the allocation of resources including the environmental ones that were determined in the first stage to maximise income. The imposition of criteria such as renewability in the second stage would constrain the extent to which income can be maximised, and the decisions taken in the second stage would in turn influence the status of the environmental variables. A sustainable state of equilibrium between the two stages can be defined as one when the resource allocation decisions in the second stage retain the status of the environmental variables of the first stage in terms of criteria such as renewability.

Appendix

The Target-MOTAD model for the "with irrigation" option is as follows:

$$\text{Maximise } Z = \sum_{q=1}^5 \sum_{j=1}^7 [C_{qij} X_{qij} - \sum_{q=1}^5 \sum_{j=1}^7 K_{qij} w_{qij} - \sum_{q=1}^5 \sum_{j=1}^7 b_{qij}]$$

Subject to:

$$\sum_{q=1}^5 \sum_{j=1}^7 a_{qij} X_{qij} < L_{qi}$$

$$\sum_{q=1}^5 \sum_{j=1}^7 A_{qij} X_{qij} < l_{qi}$$

$$\sum_{q=1}^5 \sum_{j=1}^7 Q_{qij} X_{qij} - \sum_{q=1}^5 \sum_{j=1}^7 b_{qij} < M_{qi}$$

$$\sum_{q=1}^5 \sum_{j=1}^7 t_{qij} X_{qij} - \sum_{q=1}^5 \sum_{j=1}^7 W_{qij} < R_{qi}$$

$$\sum_{q=1}^5 \sum_{j=1}^7 W_{qij} < LW_i$$

$$\sum_{q=1}^5 \sum_{j=1}^7 C_{qij} X_{qij} + y_i > T_i$$

$$\sum_i p_i y_i = \beta$$

$$L_{qi} > L_t$$

$$X_{qij}, b_{qij}, W_{qij} > 0.,$$

where the various terms are represented as follows:

X_{qij} = the number of hectares of land devoted for crop j , grown during season i , in zone q ,

C_{qij} = the expected income measured in Zambian kwacha per hectare from crop j , grown during season i , in zone q

- W_{qij} = amount of water in hectare millimetres supplied to crop j grown during season i , zone q ;
 b_{qij} = the amount of cash credit in kwacha obtained for crop j grown during season i , zone q ;
 K_{qij} = the cost per hectare millimetre of irrigating crop j , grown during season i , zone q ;
 I_{qij} = annual interest charge on cash credit that was obtained for crop j , during season i , zone q ;
 a_{qij} = the amount of land required to produce one unit of crop j during season i in zone q ;
 L_{qi} = the amount of available land in zone q ;
 l_{qi} = the amount of labour in man-days available in zone q ;
 A_{qij} = the amount of labour in man-days required to produce one hectare of crop j during season i in zone q ;
 Q_{qij} = the amount of cash capital required for the production of one unit of crop j during season i in zone q ;
 M_{qi} = the amount of cash capital that is available at the start of season i in zone q ;
 R_{qi} = the amount of rainfall after subtracting run-off from the simulated rainfall values measured in millimetres in zone q during season i ;
 t_{qij} = the crop consumptive use for crop j during season i in zone q ;
 LW_i = the amount of water available above the critical level of 475 metres in season i ;
 y_i = deviations below target revenue during season i ;
 T_i = target revenue during season i .
 p_i = the probability of the i^{th} state of nature; and
 β = risk aversion coefficient, and
 L_t = EQ target for preservation.

Given that there are five zones, seven crops, two seasons and six states of nature, $q = 1, \dots, 5$;

$j = 1, \dots, 7$; $i = 1, 2$; and $s = 1, \dots, 6$.

The estimation of each component of the objective function and constraints is now considered in turn. Apart from field surveys, the data sources for empirical estimation were the Department of Agriculture (various years).

Expected Incomes

Following Rae (1971a,b), Anderson, Dillon and Hardaker (1977), Hazell and Scandizzo (1977), Dillon and Scandizzo (1978) and Hazell and Norton (1986), the expected incomes have been estimated by relying on the subjective knowledge of decision makers in the study area. This was due to the sparseness of data, and the following procedure was used during the field survey stage.

- (a) First, farmers and agricultural officers were asked to indicate in millimetres the amount of rainfall that they thought constituted either a good or medium or bad year for each of the seven crops being dealt with in this study. This indication is based on crops growing to normal full maturity.
- (b) Secondly, farmers were asked to subjectively indicate the income that they would get from each crop for various states of nature (that is, simulated values of rain fall). Their subjective estimates were validated by consultation with agricultural officers in the area. If the subjectively estimated value of income for crop j during season i for state of nature k is denoted as G_{ijk} ; and the probability of the state of nature k during season i , is p_{ik} ; then the expected income is $\Sigma[p_{ik}(G_{ijk})]$. The estimation of these expected incomes for a sample of a few scenarios is illustrated for Maize in Table A.1.

Table A.1 also contains absolute deviations (Y_{ik}) which are explained subsequently. The probabilities, (p_{ik}), were derived by estimating relative frequencies from twenty five year rain fall record. The value $\Sigma[p_{ik}(G_{ijk})]$, when estimated for the q^{th} zone is in fact C_{qij} .

Cost of irrigation

The per unit cost of irrigation was estimated by annualising the investment costs and treating all costs (investment and maintenance costs) as annual costs. Further, following the information provided by the Zambian authorities, it was assumed that the capital investment in the irrigation project has a life span of 50 years. Following this method the cost of irrigation was estimated to be 0.14 kwachas per hectare millimetre in each zone.

Table A.1: Expected incomes and associated deviations for maize

Year	State of Nature (Rainfall) mm	P_{ik} Probability of State of Nature	MAIZE			COTTON		
			G_{ijk} Kwacha	$P_{ik}G_{ijk}$ Kwacha	Y_{ik} Kwacha	G_{ijk} Kwacha	$P_{ik}G_{ijk}$ Kwacha	Y_{ik} Kwacha
1	675	0.23	250	58	63	250	58	68
2	495	0.12	100	12	-87	150	18	-32
3	405	0.09	50	5	-137	100	9	-82
4	1035	0.06	300	36	113	200	15	68
5	855	0.12	300	36	113	200	24	18
6	675	0.23	250	58	63	250	58	68
Total			---	187		---	182	

Note: $Y_{ik} = G_{ijk} - \sum(P_{ik})(G_{ijk})$

Cost of credit

Cost of credit refers to the interest rates charged on farmers' loans by official lending institutions. Although interest rates vary widely in the Zambian economy, herein it is equated to 5% on the premise that this rate manifests the social productivity of capital.

Constraints

The empirical estimation of each of the above constraints is briefly considered next. Taking the land constraint first, the land in the study area was divided into five zones based on Scudder's study (1962). These five zones were shown in Figure 2.1. The zonal hectares shown in Table A.2 below pertain to cultivable land, and have been estimated, (following discussions with authorities in the study area) on the assumption that 40 percent of the land in each zone would be available for crop production; that is, after excluding land parcels with soils of high sodium content. It is assumed that each of the seven crops in the model has an equal chance of competing for available land in each zone.

Table A.2: Cultivable zones and their extents in the study area

Zone	Cultivable area
1	13,260 ha
2	32,340 ha
3	49,860 ha
4	30,000 ha
5	36,600 ha
Total	162,300 ha

Labour requirement and availability were calculated in man days per hectare per season and according to crop. Total man days required for a particular crop is dependent on hired labour, the size of a family and the number of its members available for work during a given period and on the number of working days in that period. Hence, in field surveys carried out in the study area, direct questionnaires were used to elicit the information on labour requirement and labour availability. This information was used in the estimation of the coefficients of labour requirement, namely A_{qij} and labour availability, namely l_{qi} .

To define the credit constraint, information on the following items were elicited in the field surveys:

- (a) amount of cash capital required for a crop;
- (b) amount of cash capital that is available at the start of a season;
- (c) farmers' marginal propensity to save.

Values for the soil moisture constraint were calculated on the basis of consumptive use for each of the seven crops in the model. These values are presented together with the coefficients pertaining to the constraints described above in Table A.3. As indicated, the inclusion of the limit on irrigation (LW_i) as a separate constraint is to ensure that the depth of the lake does not fall below 475 metres; that is, to minimise the risk of over-utilising water from Lake Kariba.

Table A.3: Resource requirements per hectare of each crop

	Maize	Cotton	Sunflower	Soyabeans	Sorghum	Rice	Wheat
Labour (Man-days)	44	84	30	32	74	66	36
Cash Capital (Kwacha)	36	20	10	25	8	14	30
Soil Moisture (mm)	790	640	690	740	550	990	890

The constraints pertaining to the cost of risk taking are defined as:

- (i) negative deviations from a prespecified target revenue;
- (ii) the sum of negative deviations multiplied by the probabilities of the states of nature.

A state of nature has been defined as a particular set of rainfall values during a year. The first risk constraint, namely

$$\sum_{q=1}^5 \sum_{j=1}^7 C_{qij} X_{qij} + y_i > T_i,$$

specifies a decision makers' behaviour as explained by Tauer (1983). That is, whilst wanting to maximise expected income from various activities, decision makers are also concerned about their revenue falling below a critical target (T_i). Following Watts, Held and Helmers (1984) and Hazell and Norton (1986), the second aspect of a decision maker's perception of risk is that the expected value of total deviations below the target over a planning period should be confined to a specific value. To define this aspect of risk perception, Tauer (1983) equated the sum of the product of the probabilities of each state of nature and the deviation associated with the appropriate state of nature. This is specified as:

$$\sum p_i y_i = \beta$$

If (β) is assigned a value of zero, then it represents a situation where no negative deviations from the target revenue are allowed during any time period and the decision maker is purely risk averse. Conversely, when (β) is assigned a larger number, then the decision makers are assumed to be less risk averse.

The deviations below the target revenue were estimated by subtracting the expected incomes from the subjectively estimated values of income that are associated with each state of nature. A sample of these deviations (Y_{ij}) is presented in Table A.1. Further, as indicated above, the Target-MOTAD model for the "without irrigation" option differs only in terms of the absence of the irrigation variables, that is W_{qij} , and a lower estimate for target income (T_i) and the risk aversion coefficient (β).

REFERENCES

- Anderson, J.R., Dillon, J.L. and Hardaker, J.B. (1977): *Agricultural Decision Analysis*, Iowa State University Press, Ames.
- Anderson, J.R. and Thampapillai, D.J. (1990): *Soil Conservation in Developing Countries: Project and Policy Intervention*, Paper No.8, Policy Research Series, The World Bank, Washington D.C.
- Clayton, R. (1985): "Demand and supply of hydro-electric power from the Kariba Dam", in Handlos, W.L. and Howard, G.W. (eds.), *Development Prospects for the Zambezi Valley in Zambia*, University of Zambia Kafue Basin Research Committee, Lusaka.
- Department of Agriculture (1984-86): *Annual Reports*, Lusaka.
- Department of Agriculture (1983): *Agricultural Credit in Zambia*, Planning Division Report No. 2, Lusaka.
- Dillion, J.L. and Scandizzo, P.L. (1978): "Risk attitudes of subsistence farmers in Northern Brazil: A sampling approach", *American Journal of Agricultural Economics*, 6, 3, 425-435.
- Hardaker, J.B. and Troncoso, J.L. (1979): "The Formulation of MOTAD Programming Models for Farm Planning using Subjectively Elicited Activity Net Revenues", *European Review of Agricultural Economics*, 6, 1, 47-60.
- Hazell, P.B.R. and Norton, R.D. (1986): *Mathematical Programming for Economic Analysis in Agriculture*, Macmillan Publishing Company, New York.
- Hazell, P.B.R. and Scandizzo, P.L. (1974) "Competitive demand structures under risk in agricultural linear programming models", *American Journal of Agricultural Economics*, 56, 2, 235-244.
- Hazell, P.B.R. and Scandizzo, P.L. (1977): "Farmers' expectations, risk aversion and market equilibrium under risk", *American Journal of Agricultural Economics*, 59, 1, 204-209.
- Hazell, P.B.R. (1971): "A linear alternative to quadratic and semi-variance programming for farm planning under uncertainty", *American Journal of Agricultural Economics*, 53, 1, 53-56, 1971.
- Hotelling, H (1949): Letter quoted in the Economics of Public Recreation: And Economic Study of the Monetary Evaluation of Recreation in the National Parks, National Parks Service, United States Department of the Interior, Washington D.C.
- Johnson, H.G. (1966): "Factor Market Distortions and the Shape of the Transformation Curve", *Econometrica*, 34, 3, 689-98.
- Maleka, P.T. (1990): Systems Modelling Approach to Drought Management Strategies in the Lake Kariba District of Zambia, unpublished PhD thesis, University of Wollongong.
- McCamley, F. and Lliebenstein, J.B. (1987) "Describing and Identifying the Complete Set of Target MOTAD Solutions", *American Journal of Agricultural Economics*, 69,3,669-73.
- Maclean, A.H. (1969): *Moisture Characteristics of some Zambian Soils*, Soil Science Report No. 5, Mt. Makulu Research Station, Chilanga.
- McMollan, C. (1975): *Mathematical Programming*, John Wiley and Sons, New York.
- National Commission for Development Planning (1986): *Annual Third National Development Plan*, Lusaka.

- National Commission for Development Planning (1986): *Study on Food Strategy*, Lusaka.
- National Commission for Development Planning (1988): *Economic Reports*, Lusaka.
- Nutrition Commission of Zambia (1986): *A State of Zambian Nutrition*, Lusaka.
- Rae, A.N. (1971a): "An empirical application and evaluation of discrete stochastic programming in farm management", *American Journal of Agricultural Economics*, 53, 4, 625-628.
- Rae, A.N. (1971b): "Stochastic programming, utility and sequential decision problems in farm management", *American Journal of Agricultural Economics*, 53, 3, 448-459.
- Scudder, T. (1962): *The Ecology of the Gwembe Tonga*, Manchester University Press, Manchester.
- Sharma, T.C. and Nyumbu, I.L. (1985): "Some hydrology characteristics of the Upper Zambezi Basin" in Handlos, W.L. and Howard, G.W. (eds.) *Development Prospects for the Zambezi Valley in Zambia*, Kafue Basin Research Committee, The University of Zambia.
- Tauer, I.W. (1983): "Target MOTAD", *American Journal of Agricultural Economics*, 65, 3, 606-609.
- Watts, M.J., Held, L.J. and Helms, G.A. (1984): "A comparison of Target MOTAD to MOTAD", *Canadian Journal of Agricultural Economics*, 32, 175-185.
- Zambia Nutrition Commission (1986): *Annual Report*, Lusaka.
- World Resources Institute (1990): *World Resources: A guide to the Global Environment*, Oxford University Press, New York.

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