REGIONAL MODEL FOR RURAL LAND USE PLANNING: AN APPLICATION OF GOAL PROGRAMMING

I. Nhantumbo, J.B. Dent, G.S. Kowero, and D.R. Oglethorpe[1]

ABSTRACT. —Strong demand for firewood and construction material in the urban areas of Mozambique, especially Maputo city, coupled with slash and burn agriculture, has led to an increase in deforestation. As a measure to mitigate this and other problems facing the forestry sector, the government designed what is known as Strategies for Forestry Development (1991) which includes a reforestation strategy. This contemplates the involvement of the community as a way forward for afforestation since the government has limited funds to embark in large-scale reforestation programs. This paper reports the results of a study which explored the potential for using Weighted Goal Programming (WGP) in assessing the impact of integrating trees into the farming systems in the province of Maputo. Models of typical farms from five ecozones were constructed and aggregated in an effort to assess the impact of the reforestation strategy, at provincial (macro) level, while focusing on the use of resources at the household (micro) level. Despite the scarcity of data and political and climatic instability, which influenced the quantity and quality of data, the planning framework results show that all regional goals can at least be achieved. Land use is predicted to change in all ecozones with regard the land allocation to individual crops. Furthermore, allowing each typical farm to be able to plant at least one hectare with trees was found to be possible, but with some changes in the level of performance of the current farm activities. In addition to income generation, the reforestation strategy was found to reduce adult underemployment, especially in the grassland ecozone, however, in some ecozones it implied the use of more child labour. There is potential for applying mathematical programming in land use conflict resolution in a data scarce environment.

INTRODUCTION

In many developing countries, clearance of forestry resources for construction and energy supply in urban areas accompanied by slash and burn agricultural practice, has resulted in deforestation. In Mozambique, and particularly the Maputo province, (the capital city of which is home to a large proportion of the national population), such a situation led the government to design what is known as the Strategies for Forestry Development (1991) which includes a Reforestation strategy. This states that the community should participate in the replacement of the forest resources extracted in order to guarantee their sustainable use. In some zones, such a strategy has been implemented without previous appraisal of the relevant technical and socio-economic issues involved. The result was a significant underachievement of the projects' aims in terms of tree survival rate and management of plantations, either in woodlots or in intercropping systems. Therefore, it can be argued that such situations arise as a direct result of introducing a tree component into existing agricultural systems without considering the potential conflicts such as labour availability and its allocation to the different farm activities.

This research attempts to use a relatively sophisticated *ex ante* planning approach, in a data scarce environment, to explore the mechanisms by which reforestation should take place. A modelling framework is constructed where both technical and socio-economic goals are incorporated to deal with the assessment of reforestation strategy under an integrated land use context. In this way, the study analyses the impact of tree plantation in conjunction with already competing farm activities as well as conflicting household and regional goals.

[1] I. Nhantumbo and J.B. Dent, The University of Edinburgh, Institute of Ecology and Resource Management, Agriculture Building, West Mains Road, Edinburgh EH9 3JG, Scotland, UK, Tel. 0131 535 4080, Fax 0131 667 2601, e-mail: ISILDAN@SRV0.BIO.ED.AC.UK. G.S. Kowero, Centre for International Forestry Research, Jakarta, Indonesia. D.R. Oglethorpe, SAC, Agriculture Building, West Mains Road, Edinburgh EH9 3JG, Scotland, UK, Tel. 0131 535 4080, Fax 0131 667 2601.

The reforestation strategy is therefore a two-level decision problem involving the farm and the regional levels. Although the subject of this paper is focused on the latter, it incorporates constraints reflecting the activity of the former. The paper presents preliminary results of a regional model that aims to analyse the trade-offs among regional goals and their impact at the farm level in terms of land use, dietary issues, tree plantations, conservation and income levels.

MULTIPLE CRITERIA DECISION MAKING (MCDM)

Advances in science and computer technology questions the validity of the traditional single objective planning approach (Dent and Jones 1993) due to inadequacy of such criterion to represent satisfactorily the multiple objectives decision problems related with land use planning (Spronk and Matazarro 1992). The decision-maker (DM), at micro or macro level, generally looks for a compromise result, i.e., trade-offs amongst goals. Multiple criteria decision making methods (MCDM) take into account the various objectives of the DM and start with the definition of "best" which differs for each individual in the society. This, according to Kazana (1988), is the basic distinction between MCDM and linear programming (LP). Cohon (1978) also considers that multiobjective approaches assign adequate roles for both the analyst and the DM. In other words, the analyst generates alternatives and objective trade-offs while the DM makes value judgements about the relative significance of those alternatives.

With regard to the Reforestation strategy, implementation implies adoption of agroforestry systems by rural farmers in Mozambique. A survey conducted for this study showed that, in the case of the Maputo province, farmers have preference for village woodlots over intercropping. Kazana (1988) states that agroforestry systems in small farming systems in developing countries is mainly a decision making problem at a micro-economic level, because, also according to Janssen (1995), farmers control the use and management of the natural resources.

Therefore, a bottom-up planning approach appeared the appropriate procedure for this research. In order to do this, rural Maputo was classified into five ecozones based on existing land use, described by Saket (1994). A survey was conducted in each of these ecozones in order to elicit information regarding farm household objectives and constraints concerning food security, availability of fuel wood and wood for construction and income generation activities. Also, a survey of Maputo planning authorities was conducted to elicit the regional goals associated with the implementation of the reforestation strategy.

Goal programming (GP), one of the MCDM based on the geometric definition of "best" is regarded as a model which operationalizes the Simonian approach of "satisfaction" to the fulfilment of the DM's objectives (Rehman and Romero 1993 quoting Simon 1955, 1957). GP has two variants: Lexicographic Goal Programming (LGP) which is based on pre-emptive ordering of goals and priorities by the DM, and Weighted Goal Programming (WGP), based on a simultaneous consideration of goals and minimization of the sum of relative weighted undesired deviations from the targets. WGP was applied in the regional model, which is discussed further in the section 3.

A criticism of the limited application of GP is the large amount of data required from the DM (including objectives, targets, weights and priorities) and for estimation of the technical coefficients of the decision variables. This is a particularly important limitation in developing countries were planning in subsistence farming is made difficult due to a lack of record keeping of farm performance and where lack of co-ordination between agricultural and forestry extension services is likely to reduce the reliability of information provided by the DM. However, Rehman and Romero (1993) defend the application stating that sensitivity analysis can be used to generate information and reduce the amount of data needed from the DM.

METHODOLOGY

Introduction

In Maputo province there is a recognised energy problem due to high surplus demand of fuel wood. This is partly caused by the growing market in the urban areas. However, recent socio-economic, political and drought conditions led to the situation where the main source of survival for farmers was through exploitation of the natural forest, which provided a ready source of income. This is despite the fact that, according to existing forest legislation (MA-DNFFB 1987) the rural population can only exploit, for their consumption, third and fourth class species for poles and firewood without licensing. In the event of infringement, i.e., clear felling of trees with diameters greater than 30 cm for commercial purposes, fines ranging from US$52 to 155 can be charged. However, perhaps due to the recognition of the fact that forest products were the only source of farm livelihood during the civil war and drought periods, the government was passive in enforcing this legislation. The coexistence of these two issues (demand for income in the rural areas and demand for wood products in Maputo-city) led to deforestation which resulted in some zones having fuel wood shortages even for local consumption.

Previous studies by Getahun (1991) and Bila (1992) and results of the survey for this study have shown that farmers recognise deforestation as a problem and tree plantation as a possible solution, as did the policy makers when they designed the 1991 Reforestation strategy. Therefore, this suggests that the apparent disparity in the definition of the problem facing the macro and the micro level of policy making, in other words, what Janssen (1995) calls aggregation of private and public rationale, may not be important. Consequently, it is hypothesised that solving farm level problems may simultaneously solve higher hierarchical level policy problems.

In this modeling approach typical farm models are used as the basic building blocks of the regional model and are aggregated for Maputo province. These individual farm models allow us to understand how farmers' interact with the environment and thus what their likely voluntary response to policy will be, in order to meet their own goals, given land and labour resource limitations. The aggregation of the farm models is designed to model the overall farmer response to regional plans for meeting food and wood demands, as well as conservation policies for the natural forest within a regional budget constraint.

The Framework of the Regional Model

The Farm Models

The farm models representative of each ecozone comprise five main groups of decision variables: growing crops, selling surplus produce, purchasing food to offset deficits, nonfarming activities (NFA) (harvesting natural forest, carving, brewing, brick making) and tree plantation activities (PT) as shown in the Figure 1. In addition, the main constraints on these farm activities include land, seasonal labor, production reconciliation, diet balance and NFA reconciliation.

Representative farms were selected from each ecozone classified in terms of similar cropping patterns and yields, same limitations in terms of inputs and technologies such as access to irrigation or not and alternative rural employment opportunities. Hazell and Norton (1986) state that simple rules like similar yields and similar technologies as well as similar land to labor ratios reduce aggregation bias and maintain a certain degree of conformity to Day's (1963) aggregation conditions. These include technological homogeneity, pecuniary proportionality, and institutional proportionality regarding respectively, the same production possibilities, proportional returns, and proportional constraint vectors (in this case, land).

The "Regional Pool" Activities and Constraints

The aggregated surplus from each ecozone creates a common pool of activities at the regional scale. This permits interecozone trade, particularly of food products, to satisfy deficits in production of crops essential to the diet (Figure 1). The constraints and activities of this common pool comprise the total number of assumed homogeneous

farms in each ecozone supplying the surplus of food, wood products and construction materials to the “regional pool” (Fig.1) from which Maputo-city requirement is supplied (once aggregated interecozone trade is satisfied). This illustrates a realistic exchange of food products amongst ecozones, because there are markets in the rural areas which enable farmers from deficit zones (like dryland, grassland and open forest) to purchase from surplus zones without having to travel to Maputo-city.

Activities	Ecozone 1 Crop , Buy, Sell ,NFA ,PT ...	... ...	Ecozone 5 Crop, Buy, Sell ,NFA, PT ...	'Regional pool' Food ,Wood ,Bricks	Maputo-city demand Food , Wood, Bricks	Deviational variables n1 p1 . .. n5 p5	Sign	RHS
Objective	0		0	0	0	w1 0 ... 0 w5		
Constraints								
Land							<=	ha
Labour							<=	0
Prod. Rec.	**Ecozone 1**						<=	0
Diet Bal.							>=/<	Kcal
NFA Rec.							<=/=	
Land							<=	ha
Labour							<=	0
Prod. Rec.		.....					<=	0
Diet Bal.							>=/<	Kcal
NFA Rec.							<=/=	
Land							<=	ha
Labour							<=	0
Prod. Rec.			**Ecozone5**				<=	0
Diet Bal.							>=/<	Kcal
NFA Rec.							<=/=	
Pool Crops Fish Poles Firewood Charcoal Bricks	-	.....	-	**1**	**1**		**=**	0
Ecozone Crops	**+**	**...**	**+**	**-1**			=	0
Income	- - + -/+ -/+	...	- - + -/+ -/+				>=/<	$
Reg.Goals								
Food					**+**	1 -1 .. 1 -1	=	100
Fuelwood					**+**		=	100
Poles					**+**		=	100
Conservation	+	...	+				=	100
Budget	+	...	+				=	100

wi = W*100/Ti W= weights, i= ith goal, Ti= target of the ith goal

Figure 1.—Structure of the regional model

Regional Goals

A survey of staff at the Eduardo Mondlane University in Maputo, the Ministry of Agriculture and Fisheries and provincial and district agricultural officers, was conducted to elicit the goals of the reforestation strategy as viewed by these different planning entities. A summary of the ranked goals as perceived by these policy makers (PMs) is shown in Table 1.

Table 1.—Summary of the goals and the desired achievement function

Goals	Targets	Deviational variables
Fuelwood (bags)	3,743,249	Minimize underachievement
Poles (m3)	44,146	Minimize underachievement
Food (Kcal)	11,214,310,020	Minimize underachievement
Conservation (ha)	97,735	Minimize underachievement
Budget ($)	2,765,900	Minimize overachievement

Although policy makers provided the goal typology, values for respective targets were estimated from previous studies. The values of the targets regarding consumption of fuel wood and poles were based on a study by Nhantumbo and Soto (1994). However, these target values also take into account the demand for energy from the food processing industry (Perreira 1990).

The food target is based on population information (DNE 1994) and daily energy requirements, aggregated to reflect annual demand and consumption. Unlike the farm models, no dietary constraints were included in the regional model due to the complexities associated with the heterogeneity of the population in terms of their origin and dietary habits and disparity of income levels between urban and suburban dwellers in Maputo-city.

With regard to the conservation target, it was assumed that each household would plant at least one hectare of trees. The budget constraint reflects, in turn, the cost of planting that area with any of the tree species included in the farm model (*Leucaena* spp., *Eucalyptus* spp, *Melia* spp.).

Weights and Deviational Variables

As indicated above there are various key decision-makers at the regional level. It therefore appears more appropriate to rank the several goals of the DM/PMs and derive weights which encapsulate not only their preferences, but also reflect the relative importance attached to the goals as well as the relative significance of positive or negative deviations (Cohon 1978).

The weights for each goal were determined using the procedure described by Yoon and Huang (1995) for derivation of weights from ranks. These were determined by the frequency at which each goal was placed at a certain rank by the various policy makers. Exchanges in the position of ranks allowed the evaluation of the trade-offs amongst the objectives according to associated weights (see results).

Weighted Goal Programming (WGP) simultaneously considers all goals in a composite objective function minimizing the deviations between goals and aspiration levels (Romero and Rehman 1989; Romero 1991). The objective function of a WGP model is meaningless when it aggregates incommensurable deviational variables (Romero 1991). Therefore, a normalisation method which scales the deviational variables using relative percentages was used. Besides reducing significantly the range of units which can affect results of models run in the simplex algorithm, it provides meaningful results because the objective function is a sum of percentages, which are adimensional, and the new sets of weights (w_i/b_i) represent the preference of the DM.

RESULTS OF THE REGIONAL MODEL

The Scenarios

The regional model was run four times each time changing the weights or the relative importance of goals as defined by planners or policy makers (Table 2). This was done to assess how farm activities might change and thus how the regional situation might benefit from changing priorities.

Table 2.—Weights associated to the goals in each scenario

Scenarios	Run A (survey)	Run B	Run C	Run D
Fuelwood	Highest	2nd Highest	2nd Highest	3rd Highest
Poles	Highest	2nd Highest	2nd Highest	3rd Highest
Food	2nd Highest	Highest	3rd Highest	Lowest
Conservation	3rd Highest	3rd Highest	Highest	2nd Highest
Budget	Lowest	Lowest	Lowest	Highest

These changes of preferences may be dictated by change in the economic situation resulting from political stability and better climatic conditions, change in policy makers, and hence their perception of the problems and priorities.

The Achievement Function

The representative farm models for each of the ecozones were run first as LP and Lexicographic Goal Programming (LGP) models in which the efficiency determined the maximum use of all resources available in the first case and, trade-offs between farm goals were provided in the second case. However, alternatives generated by the WGP aiming for the 'satisfaction' of the regional goals resulted in a large proportion of unused resources, such as labour and land.

Table 3 presents the achievement of the various goals, with the target multiples (the number of times the target is exceeded) given for each scenario. All multiples are positive since all goals were at least achieved.

Table 3.—Targets multiples resulting from change in priorities of Pms

	Run A	Run B	Run C	Run D
P1 (Fuel wood)	2.17	1	1	1
P2 (Poles)	111.53	69.8	69.62	38.93
P3 (Food)	1.06	1	1.10	1.33
P4 (Conservation)	1.42	1.33	1.32	1.56
P5 (Budget)	1.33	1.24	1.23	1.49

In Run A when wood for energy supply to Maputo-city is the most important for the policy makers, then three of the four ecozones producing charcoal, produce at their full capacity. This results in more than twice as much fuel wood being produced over that required by the target. The result is validated by experience in the Maputo-city market where shortages of firewood are uncommon, despite difficulties of access to the production zones experienced by timber merchants in the wet season. Increased production and transportation costs generally reflect higher fuel wood prices, rather than less supply.

Only one ecozone currently produces poles from the natural forest. However, with tree plantations the supply of volume required for building houses in the Maputo-city suburbs is substantially surpassed (P_2) in all runs. It should

be stressed, however, in a similar fashion to fuel wood and food goals, wood demand for construction in the rural areas is endogenous to the representative farm model and the target of the region refers only to the Maputo-city consumer demand. The achievement of this goal is directly associated with the conservation goal which is also overachieved (P_4).

The Grassland ecozone has the highest area of land allocated to trees at 21 ha, 17 ha, 16 ha and 27 ha, per household, respectively, in Run A, Run B, Run C and Run D, and this is the main reason for such an excess over the target level. In all the other ecozones, the representative farm only plants one hectare. This result seems to correspond to the fact that the Grassland ecozone is the poorest ecozone in terms of agricultural performance and in terms of opportunities for income generation. Therefore, it is reasonable that the reforestation strategy offers an alternative both in terms of employment and income from wood sales. This also conforms with the reasoning that farmers in the most productive ecozones have no preference for planting large areas with trees, but would rather plant enough to hinder the expansion of the saline land, for instance. Conversely, the Thicket ecozone, still has a significant natural tree cover and it would not be rational, in terms of sustainable use of the natural forest, to substitute it with plantation of *Eucalyptus* spp., for instance. Therefore, a one-hectare plantation as shown by the model output may not be a pessimistic target.

In the Dryland ecozone, the rationale for planting only one hectare of trees may be associated with the fact that farmers may be willing to expand their agricultural land in order to meet consumption requirements rather than transforming the ecozone into a forest area. The particular benefit that this ecozone can get is from the improvement of soil fertility through incorporation of leaf biomass if the selected tree specie was *Leucaena* spp. instead of *Eucalyptus* spp. Finally, in the Open Forest ecozone, the plantation of one hectare can be justified as protection of the crops from the reported damage of strong winds.

The food goal is expressed in terms of dietary energy (Kcal) and the solutions of all but one scenario (Run B) show an overachievement of this goal. In the first three scenarios such satisfaction is derived mainly from sweet potato and fish. However, Run D, appears more realistic due to a wider range of crops supplying a significant amount of maize and cassava which together with sweet potato and by-products form the major contributions to the diet of Maputo-city consumers from the ecozones.

It also is worth mentioning that diet constraints (Figure 1) have been included as endogenous constraints to each of the farm models. These may be interpreted as all ecozones satisfying the ‘domestic’ demand for food. Consequently, it may also suggest that in Maputo province everyone has access to food to meet at least the minimum energy requirement. Nevertheless, the purpose of including such constraints is to simply evaluate the level of food self-reliance of the farm. The interecozone trade serves to show the potential capacity of the ecozones generating surplus to supply the deficient ones.

Finally, it is obvious that planting more area than the conservation target stipulates will need more investment, hence the overachievement of the budget target.

Farmers Response in terms of Land Use and Income

The change in the relative importance of the goals also results in a modification of farmers response in terms of land allocation to individual crops and the total area farmed by each typical farm. Although there is only a slight change (perhaps negligible) in the total farmed area particularly in the less productive areas (Dryland, Open forest and Grassland), land allocation per crop changes significantly in all ecozones illustrated by the changes which occurred within the food goal as shown in Table 2.

As regards income generation constraints, because the multiobjective regional model seeks a compromise solution then the income generated by the five representative farms only covers the minimum bound ($10,000). Despite that, it is important to retain this constraint because even though it was difficult to derive the income distribution envisaged by the policy makers, the reforestation strategy can only succeed if its implementation does not mean

that farmers would have to forego too much in terms of food security, for instance, which can come from their own production or from purchases if cash is available.

DISCUSSION AND CONCLUSIONS

Clearly for such a planning tool to be successfully operational, validation of the farm-level component of the model becomes an issue. McCarl (1984) defines a model as an 'adequate' abstraction of reality for its anticipated use. Validation is a process of evaluation of the usefulness of such model. Therefore, to comply with this basic requirement of modelling, the farm models which form the main building blocks of the regional model, were validated via expert opinion, an acceptable and widely used method (McCarl 1984; Hazel and Norton 1986). Furthermore, due to the difficulties of data availability and its reliability for construction of models for policy analysis in Mozambique, as in many developing countries, particular emphasis was given to the logic structure of the model. This, according to Hazel and Norton (1986), is better than compounding the data problems with poor logic. Therefore, subjective judgement of the output assuming a broad comprehension of the system represented by the model (Dent and Blackie 1979) was used under the concept that the model should be judged relevant for its task (Beck et al. 1995). Consequently, having judged the basic structures to be valid, the link between the various parts of the model, the "regional pool" and the Maputo-city demand activities set the trade relations between ecozones and with Maputo-city market. Hence, it can reasonably be concluded that the regional model structure adequately represents the problem.

One important aspect that is also worth mentioning concerns the assumptions made to reduce aggregation bias. A basic assumption of the model implies that farmers within each ecozone have similar production possibilities and despite the relatively free access to land, traditional explicit and implicit rules create uniformity of land tenure conditions. This guarantees the proportionality of resource endowments, which according to Norton (1995), are probably the most relevant of Day's criteria for unbiased aggregation. Moreover, the survey data for this research and previous observations by Getahun (1991) and Bila (1992) showed that farmers are aware of environmental and fuel wood shortage problems created by deforestation and, similarly to the policy makers, see reforestation as the likely solution. Therefore, this reduces what Jansen (1995) considers a shift in the rationale (private and public) due to aggregation of farm to regional level.

In short, this model is a proposed for *ex ante* policy analysis regarding the potential impact of implementation of the participatory reforestation strategy in Maputo province and possibly in other provinces of Mozambique where the reforestation strategy has particular relevance. The model output delivers information regarding the opportunity cost resulting from shifts in the definition of the importance of goals and the resulting impact at a micro level. The final confidence in the model can only grow, as Beck et al. (1995) underlines, with its successful application. This, of course, implies operational validation or validation of the model as it is used (McCarl 1984). Nevertheless, the basis for planning and analysing the potential impact of a reforestation strategy has been built and provides a framework for similar analyses in data scarce environments.

REFERENCES

BECK, M.B., A.J. JAKEMAN, AND M.J. MCALLER. 1995. Construction and evaluation of models of environmental systems. In *Modelling change in environmental systems*, ed. A.J. Jakeman, M.B., Beck and M.J. McAleer, pp. 3–35. Chichester: John Wiley & Sons.

BILA, A.T. 1992. *Trees for sustainable fuelwood production in rural subsistence farming at Boane, Maputo*. Bsc Honours in Agroforestry Dissertation. UK: University of Wales..

COHON, J. 1978. Multiobjective programming and Planning. *Mathematics in science and engineering*. Vol. 140. Academic Press.

DAY, R.H. 1963. On aggregating linear programming models of production. *Journal of Farm Economics*. 45:767–813.

DENT, J.B., AND M.J. BLACKIE. 1979. *Systems simulation in agriculture*. London: Applied Science Publications.

DENT, J.B., AND J.W. JONES. 1993. Multiple criteria analysis in agricultural systems—editorial. *Agricultural Systems*. 41(3): 235–37

DNE. 1994. *Anuario estatistico*. Maputo: DNE-MPF.

GETAHUN, A. 1991. *Forestry extension in Mozambique*. Maputo: FAO.

HAZELL, P.B.R., AND R.D. NORTON. 1986. *Mathematical programming for economic analysis in agriculture*. New York: Macmillan Publishing Company.

JANSSEN, W.G. 1995. Aggregating economic knowledge for use at national, regional, sector and farm level. In Eco-regional approaches for sustainable land use and food production, eds. Bouma, J., A. Kuyvenhoven, B.A.M., Bouman, J.C., Luyten, and H.G. Zandstra. *Systems Approach for Sustainable Agricultural Development*, 4.

KAZANA, V. 1988. Optimization techniques for agroforestry production systems. In *Economic evaluation and management of agroforestry: a novel problem?* Proceedings of a workshop, Depart. of Forestry and Natural Resources, The University of Edinburgh, eds. Sinclair, F.L., Kazana, V. and Shrimpton, pp. 42–51.

MCCARL, B.A. 1984. Model validation: An overview with some emphasis on risk models. *Review of Marketing and Agricultural Economics* 52(3): 153–73.

MA-DNFFB. 1987. *Manual de legislaçao florestal*. Maputo: DNFFB.

NHANTUMBO, I, AND S. SOTO. 1994. *Mercado de produtos madeireiros e nao madeireiros*. Maputo: FAO..

NORTON, R.D. 1995. Response to section C. In Eco-regional Approaches for Sustainable Land Use and Food Production. *Systems Approach for Sustainable Agricultural Development*, 4: 237–47.

PEREIRA, C.R. 1990. *National survey of biomass/woodfuel activities in Mozambique*. Maputo: SADCC.

REHMAN, T., AND C. ROMERO. 1993. The application of the MCDM paradigm to the management of agricultural systems: some basic considerations. *Agricultural Systems*. 41(3): 239–55.

ROMERO, C., AND T. REHMAN. 1989. Multiple Criteria Analysis for agricultural decisions. *Developments in agricultural economics*. Vol. 5. Elsevier.

ROMERO, C.1991. *Handbook of critical issues in goal programming*. Oxford: Pergamon..

SAKET, M. 1994. *Report on the updating of the exploratory national forest inventory*. Maputo: FAO.

SPRONK, J., AND B. MATARAZZO. 1992. Interactive multifactorial planning: state of the art. *Rivista di Economia Agraria*. 47(4): 531–43

TABUCANON, M.T., P. BERCK, AND D. BIGMAN. 1993. Applications of multiple criteria decision-making methodology in food policy analysis. In *Food security and food interventions in developing countries*, ed. P. Berck, pp. 151–74. UK: CAB International.

YOON, K.P., AND C. HWANG. 1995. *Multiple attribute decision making: An introduction*. London: Sage Publications.