NORAGRIC WORKING PAPERS

No. 8 September 1995

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Use of Compromise Programming Technique in Solving Multiple Criteria Decision Making Farm Planning Models

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Summary

This study points out the weaknesses of the existing applications of compromise programming technique in solving multiple criteria decision making farm planning models. An empirical example with several variations is then presented to demonstrate the consequences of improper use of this technique with a view to help researchers to construct better models in the future.

Key words

Compromise programming, Decision maker, Farm planning, Multiple criteria decision making.

1. Introduction

The importance of the use of multiple criteria decision making (MCDM) techniques has been widely emphasised as a more sensible way of analysing the management problems in agricultural, natural resources and environmental, and integrated rural development systems (Dent and Jones, 1993). The justification for the use of these techniques lies in their ability to approximate the real world conditions more logically and precisely. By handling a number of objective functions simultaneously, they dispense with an important limitation of the traditional mathematical techniques of handling only a single objective function at a time. Their popularity among a number of researchers during the past decade or so, therefore, is quite understandable. These techniques appear to be the worthy and legitimate successors of the conventional programming methods. As a logical corollary of the developments in any science, therefore, the MCDM methods are gaining more popularity among the agricultural and resource economists during recent times. These methods have been used to analyse a great variety of problems varying from simple farm planning problems to those of environmental degradation and management in a number of countries all over the world.

Considerable literature now exists on the application of MCDM techniques to the management of natural resources, such as, fisheries, agricultural land, forestry, water, etc. (Romero and Rehman 1987[1], 1989, 1993). More recently, the <u>Agricultural Systems</u> brought out a special issue in 1993 to encourage more regular applications of the MCDM methodologies and techniques for analysing problems of farm planning and natural resource management. Such

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1 This study gives a categorised bibliography on the use of MCDM framework for the solution of problems in natural resource management covering about 150 references from journals and books published in English .

studies, however, continue to suffer from some limitations of mis-specifications of the models. There has been a tendency to incorporate a number of objective functions rather in a mechanistic way without paying much attention to the crucial issue of assigning appropriate weights. Distortions in the results may have also occurred due to linear approximation of some of the non-linear objective functions included in MCDM models.

This paper discusses some important weaknesses in the applications of MCDM farm planning models in the past where compromise programming technique (CP) was used. It first outlines the theoretical framework of CP and then briefly reviews the weaknesses in the applications of MCDM farm planning models, with special reference to the use of CP technique. An empirical example is then given to demonstrate the consequences of improper use of the technique in the context of farm planning problem from Songea District in Tanzania. A number of alternate formulations of the model have been solved to show as how the mechanistic use of this relatively new, powerful and promising technique of analysis can lead to quite imprecise results. Finally, a concluding section emphasising the need for proper use of CP for solving MCDM farm planning models is given. It is hoped that such an effort will go a long way in helping the researchers to improve formulation and solution of MCDM farm and natural resource planning models in the future.

2. Theoretical Framework of Compromise Programming

CP is by now a well-known technique for choosing a unique optimum from usually a large set of efficient solutions to MCDM models. It may be defined as

$$\max/\min Z(X) = G[Z_1(X), Z_2(X), \ldots, Z_k(X)]$$
subject to $X \in F$,

where Z(X) is a k x 1 vector of objective functions, X is an n-dimensional vector of decision variables and F is a feasible set.

The first step in CP is to establish the "ideal point" that has optimal values for different objectives (Z^*_j) as its co-ordinates. It requires the optimisation of each of the objectives separately and obtains the corresponding values of the remaining objectives. Since the ideal point is often infeasible, it is useful only in serving as a standard against which all the compromise solutions can be evaluated. Thus, CP helps to choose feasible solutions closest to the ideal point as the best compromise. It involves the setting up of a payoff matrix, the diagonal elements of which represent the ideal values for different objectives. The second step is to obtain the deviation d_j between the j^{th} objective value and its ideal value, i.e.,
$d_j = Z^*_j - Z_j(X)$.

Normalisation of the deviation obtained above often needs to be done for consistent results when the units of measurement are not the same for the objectives under consideration (Zeleny 1982). This is done as follows:
$d_j = \{Z^*_j - Z_j(X)\}/\{Z^*_j - Z_{*j}\}$,
where Z_{*j} is the anti-ideal point for the j^{th} objective.

Finally, the appropriate measure of distance is selected and the compromise set of solutions obtained. For this purpose, CP introduces the following set of distance functions:
$L_r(w, k) = [\ \Sigma(w_j d_j)^r\ ]^{1/r}$,
where the importance of discrepancy between actual and ideal value of the j^{th} objective is given by w_j weight. For detailed exposition of CP within the farm planning context, see Romero and Rehman (1985) and Romero, Amador and Barco (1987). The following two sets of linear programming models are generally solved to obtain the compromise solutions corresponding to a given farm planning problem:

I. Min $L_1 = \sum w_j \{Z^*_j - Z_j(X)\} / \{Z^*_j - Z_{*j}\}$
subject to $X \in F$, and

II. Min. $L_\infty = d_\infty$
subject to
$w_j \{Z^*_j - Z_j(X)\} / \{Z^*_j - Z_{*j}\} \leq d_\infty$, $j=1,2,.., k$;
and $X \in F$.

Whenever a researcher has an access to non-linear programming routines for solution, a third type of linear compromise farm planning model corresponding to the L_2 metric may also be solved. Such a model may be written as follows:

III. Min $L_2 = [\sum [w_j \{ Z^*_j - Z_j(X)\} / \{Z^*_j - Z_{*j}\}]^2]^{1/2}$, $j=1,2,.., k$;
and $X \in F$.

L_1, L_2 and L_∞ metrics in the above models respectively represent the "longest" distance, the "shortest" distance (in geometric sense) and "Chebysev" distance, with a magnitude of d_∞, where only the largest deviation counts. The family of L_r metrics will always produce a non-dominated point for all r in the range of 1 to ∞. The L_1, L_2 and L_∞ metric problems, therefore, define a subset of the efficient sets (Yu 1973). The L_1 and L_∞ metric problems are linear. Given standard regularity assumptions, it can be shown that unique global optimum exists for such problems (Lakshminarayan, et al 1991). Majority of the applications of compromise farm planning models were, therefore, restricted to the solution of such problems only. The L_2 metric problem is non-linear with a smooth and convex quadratic function everywhere for which the local optimum is also a global optima (*ibid*).

3. Weaknesses of MCDM Farm Planning Models using CP Technique for obtaining Solution

In this section a few important applications of MCDM farm planning models, taken from different research journals have been reviewed. An effort is made to cover as wide a spectrum of weaknesses in the applications of these models as possible. The main weakness of such models lies in their choice of several objective functions in a rather mechanistic way and assigning weights to them without a sound empirical basis[2].

3.1 Objective Functions Considered for Simultaneous Optimisation

An idea about the number and type of different objective functions generally considered for simultaneous optimisation in the MCDM farm planning problems by the researchers in the past can be had from Table 1.

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[2] Some of the issues and problems connected with the use of vector optimisation approaches, like compromise programming, are also discussed in Rehman and Romero (1993).

Table 1. Some important applications of MCDM models to farm planning problems.

S. No.	Authors and the year of study	Country	Objectives
1.	Romero and Rehman (1985)	Hypothetical example	1. Max. NPV of investment 2. Min. casual labour hiring
2.	Romero, Amador & Barco (1987)	Spain	1. Max. gross margins 2. Min. seasonal Labour 3. Max. employment
3.	Sankhayan, Prihar & Cheema (1988)	India	1. Max. Gross margins 2. Max labour employment 3. Min. capital borrowing 4. Min. labour hiring 5. Min. labour use variability
4.	Lakshminarayan, Atwood, Johnson & Sposito (1991)	USA	1. Min. productivity loss 2. Min. cost of production 3. Min. sediment damage
5.	Zekri and Romero (1992)	Spain	1. Max. gross margin 2. Max. employment 3. Min. seasonal labour 4. Min. water consumption
6.	Maino, Berdegue & Rivas (1993)	Chile	1. Max. gross margins 2. Min. of economic risk 3. Max. family labour use
7.	Piech & Rehman (1993)	UK	1. Max. gross margins 2. Max. permanent labour utilisation 3. Max. business trading surplus 4. Min. of casual labour hiring 5. Min. annual total variable costs
8.	Zekri and Romero (1993)	Spain	1. Max. net present value 2. Max. employment 3. Min. seasonal labour 4. Min. of water consumption 5. Min. of energy use for irrigation
9.	Siskos, Despotis and Ghediri* (1994)	Tunisia	1. Max. gross margin 2. Max. employment 3. Min. seasonal labour 4. Min. tractor utilisation 5. Min. forage production

* This study does not make use of compromise programming.

The number of objective functions, considered for simultaneous maximisation and minimisation, has varied from two to five. Maximisation of gross margins and minimisation of seasonal labour were usually integral elements of the set of such objectives in most cases. The other objectives included the minimisation of economic risk, casual labour hiring, capital borrowing, cost of production, etc., and maximisation of either family or permanent labour.
As far as MCDM technique is concerned, it provides an algorithm for solving a farm planning model with a given number of objective functions. The choice of the set of objective functions is, however, left to the planner who should approximate the state of mind of the decision maker (DM) as closely as possible. It should be borne in mind that the set of such objectives may not vary from one type of economy to another only but also within the same economy depending on whether the model represents a macro, meso or micro level situation. The selected objectives should, therefore, be fully justified under the economic, social, political and psychological environment faced by the decision maker. MCDM provides no substitute for common sense in this regard. The quality of results generated by such models depends heavily on judicious choice of the set of objective functions.

The sets of objective functions considered for optimisation in a number of different applications of MCDM farm planning models in the past can hardly be justified from the point of view of a rational individual farmer operating under the environment characteristic of free market economy. Inclusion of such objectives in the model is unnecessary if redundant and can be harmful if they are not. We will discuss these issues in somewhat detail.

(i.) Maximisation of family labour use/permanent labour utilisation
Inclusion of the objective of maximisation of labour, family or permanent, in most MCDM individual farm planning models appear quite contrary even to common sense[3]. Why should the use of family or permanent labour be extended beyond the maximum level of gross margins? What is the harm in using less of family or permanent labour if gross margins could be maximised by doing so? This will result in greater satisfaction both for the decision maker as well as for the family/permanent labour. The former would have more profits and the latter more leisure (less drudgery) as the family/permanent labour could earn/be paid higher wages for less hours of work. Thus from the point of view of a rational individual decision maker, maximisation of leisure should have probably been a better choice of objective function in farm planning models instead.

(ii.) Minimisation of Casual labour hiring
There appears little economic or other justification in minimising the use of (casual) hired labour as done by the authors of farm planning studies at number 1, 3 and 5 in Table 1. Instead, the labour hiring should have been allowed to take place as long as it was available, manageable and profitable. There appears no valid reason for an individual farmer to use as little hired labour as possible. If the supply of casual labour was not enough during one or more periods, the same should have been used as constraint/s. Similarly, if management of hired labour was a constraint or if the DM had a strong preference against the use of this type of labour, it should have been treated as such. There is no sound reason to bring the use of hired labour as close to "zero", its "ideal" value in the context of CP, as possible. Thus the inclusion of an objective of minimisation of casual labour hiring in different applications of compromise farm planning models has rather been mechanistic. Through the conscious or unconscious use of false mathematical rigour, such an action has unnecessarily added to the avoidable complexity in MCDM modelling.

(iii.) Minimisation of Capital Borrowing/ Cost of Production/ Total Variable costs
The objective of minimisation of borrowed capital should also ideally be handled in an identical way like that for casual hired labour. Whenever maximisation of gross margins is treated as one of the objectives, it would be preferable to treat cost of production and total variable costs as constraints rather than objectives as done in some of the studies. This will help maintaining a simpler framework for the farm planning models at no cost of precision of results.

(iv). Minimisation of water consumption/energy use for irrigation/ tractor utilisation/ forage production, etc.
Inclusion of such objectives in the farm planning MCDM framework is also open to criticism. Instead of incorporating objective functions for minimisation of water consumption/energy use/tractor utilisation, etc., it would be preferable to maximise the returns per unit use of water, energy or tractor and treat them as constraints in the farm planning models, if required.
On the basis of foregoing discussion, there appears no sound economic or other basis for the inclusion of more than three objectives from among the set of objectives considered by different studies listed in Table 1 for simultaneous optimisation in a typical MCDM farm planning model. These objectives are maximisation of income (gross margins), and minimisation of income risk and the seasonal labour variations over the year, which are indeed

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[3] Inclusion of the objective of maximisation of employment though may appear justifiable in some other cases (Zekri and Romero, 1993), yet the question as to who prepares such a farm plan for whom remains unanswered.

conflicting from any rational individual farmer's point of view. Thus, the various studies of MCDM farm planning models, including those using compromise programming technique, could have been brought closer to reality by excluding some of the other objective functions and perhaps consider incorporating them as constraints only.

3.2 Weights attached to different Objective Functions

Careful choice of objective functions may be of limited value if sufficient care is not taken in assigning appropriate weights to them. The results can be very sensitive to the weights that are assigned to different objectives in a given MCDM farm planning model. This point has been clearly brought out by Sankhayan et al (1988) who experimented with five sets of weights in order to generate L_1 and L_∞ compromise farm plans. Similar conclusions[4] can also be drawn from another study by Zekri and Romero (1993) after carefully comparing the results from the first scenario using equal weights, i.e., $w_1 = w_2 ... = w_5$, with those from second scenario having unequal weights, i.e., $w_1 = w_2 = w_5 = 1$ and $w_3 = w_4 = 2$. It is, therefore, essential to take utmost care in this regard by assigning preferential weights to different objective functions which should be empirically based on an interaction with the decision maker rather than the planner making an arbitrary choice. This point has, however, been lost sight of by most studies making use of compromise farm planning models in the past.

Majority of the studies referred to in Table 1, with the exception of those at serial numbers 3, 7 and 8, have paid little attention to resolve the problem associated with assigning proper weights to different objective functions considered for simultaneous optimisation. Without making any empirical effort to use realistic weights for different objectives, these studies appear to have arbitrarily settled for the easiest option of giving equal importance to objectives like that of maximisation of gross margins and minimisation of seasonal labour, economic risk, etc. The relative importance given to different objectives in studies at serial numbers 3, 7 and 8, though arbitrary, represent some efforts to approximate reality by simulating the sensitiveness of farm planning models to changes in preferential weights chosen.

In view of the importance of this problem, it is necessary that the researchers in the future make serious attempts at using weights that are empirically based on thorough interaction with the decision maker rather than choosing arbitrary weights or getting satisfied with simulations using different weights. Efforts at making simulations may often produce a large number of solutions which goes against the very spirit of choosing an unique optimum solution through the use of CP technique.

3.3 Approximation of some of the Non-linear Objective Functions by Linear Functions

At least to the best of our knowledge, no effort seems to have been made so far to incorporate the non-linearities in some of the objective functions in the farm compromise planning models. Quadratic programming developed by Markowitz (1952) for portfolio analysis has been well known to the farm planners for a long time as a useful method to deal with gross margin uncertainty. For the reasons of complexity and unavailability of adequate quadratic programming codes for solving such models, an alternate method using parameteric linear programming was proposed by Hazell (1971). Even more than two decades after its development, the practitioners of MCDM farm planning models have continued approximating some of the quadratic objective functions like the minimisation of economic risk and seasonality of labour by using Hazell's now classic MOTAD model[5]. With the availability of

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[4] The authors have, however, concluded in a slightly different context that the solutions obtained were rather stable.

[5] Invariably all the farm planning compromise models have used such a technique for linear approximation of non-linear functions.

powerful computer codes for solving the non-linear programming models in the recent times, there is a strong case for the use of exact rather than approximation methods.

Thus, there are possibilities to improve the performance of MCDM models, including the compromise programming models, in farm planning by incorporating directly the non-linearities inherent in some of the objective functions[6].

4. An Empirical Example of MCDM Farm Planning Model using CP Technique

The consequences of the weaknesses in the use of CP technique for solving MCDM farm planning models discussed in the preceding section can better be demonstrated with the help of an empirical example. This has been done by solving alternate model formulations for an average farm household in Songea District of Ruvuma Region, Tanzania. It was based on a random sample of 94 households selected from four villages and the data referred to the agricultural year 1991-92.

4.1 Description of the MCDM Farm Planning Model

After a thorough interaction with the sample farmers, the MCDM farm planning problem faced by an average farmer in the area of study was appropriately modelled so as to approximate the reality as closely as possible in all respects. The model so constructed is summarised in Table 2. It brings out the details about the constraints, activities and objective functions along with their measuring units. In all, there were 31 constraints, including two accounting equations, and 35 real activities and one linear and two non-linear objective functions. The necessary details about the technical coefficients for the j^{th} activity and i^{th} resource or constraint are also given. The coefficient has been replaced with "1" wherever it equals unity.

The explanation of the abbreviations used in the table are as follows:

x_j = the level of j^{th} activity - production, input purchase (labour hiring according to month, fertiliser purchase according to type and borrowing of working capital), consumption and product sale.

c^l_j, c^w_j, c^f_j, and c^s_j = expected price of j^{th} labour hiring activity (j= January, February,..., December), capital borrowing activity, j^{th} fertiliser purchase activity (j= urea and ammonium sulphate) and sale price for the j^{th} product (j=1, 2,.., 8) respectively. The abbreviation c_j has been used in general to denote expected price (cost) of j^{th} activity.

a^l_{ij}, a^w_{ij}, a^f_{ij}, a^{tl}_{ij}, a^y_{ij} and a^t_{ij} = respectively the requirements of labour during the i^{th} month (i= January, February,..., December), working capital, fertilisers, total labour and yield per unit of j^{th} production activity (j= 1,2,.., 8), and the fuel requirements for curing the tobacco production per unit of activity. c^l_j, c^w_j, c^f_j, and c^s_j have also been used as technical coefficients in some constraints. Only coefficient a_{ij} has, however, been used in the general formulation of the model to represent technical requirement of the j^{th} activity for the i^{th} resource or constraint.

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[6] This is not specific only to the compromise programming problems but applies to all the programming problems in general.

Table 2. Summary of Model Constraints, Activities and Objective Functions for an Average Farm Household in Songea District, Tanzania

Constraints/Objective functions	Real Activities (x_j) Produ-ction (8)	Lab hiring (12)	Cap. borro-wing (1)	Fert. purch-asing (2)	Product Sale (8)	Consum-ption (4)	Right hand side (b_i)
Constraints:							
Land: (acres)							
Categories (2)	1	0	0	0	0	0	≤ LA#
Labour: (man days)							
January to December (12)	a^l_{ij}	-1	0	0	0	0	≤ FL
Working capital: (TS)							
Use of working capital (1)	a^w_{ij}	0	-1	0	0	0	≤ 0
Limit on borrowing (1)	0	c^l_j	1	c^f_j	0	0	≤ CL
Fertiliser: (bags)							
According to type (2)	a^f_{ij}	0	0	-1	0	0	≤ 0
Balance equations:							
For each product (8)	$-a^y_{ij}$	0	0	0	+1	a^c_{ij}	= 0
Max/Min. level of activities:							
Area under cassava (1)	1**	0	0	0	0	0	≥ 0.5
Number of goats (1)	1**	0	0	0	0	0	≤ 2
Cash requirements (1) TS	0	$-c^l_j$	$-c^w_j$	$-c^f_j$	c^s_j	0	≥100,000
Accounting Equations:							
Req. of wood (1) - m^3	a^t_{ij}	0	0	0	0	0	≥ 0
Family lab. Emp. (1)	a^{tl}_{ij}	0	0	0	0	0	≥ 0
Objective Functions:							
Cash income (1)	0	$-c^l_j$	$-c^w_j$	$-c^f_j$	c^s_j	0	Max.
Economic risk (1)	Needs different specifications						Min.
Labour use variation (1)	Needs different specifications						Min.
Max lab. employment (1)	a^{tl}_j	0	0	0	0	0	Max*

*The objective of maximisation of labour employment was used in some cases for illustrative purposes only.
** a_{ij} coefficients equal unity in the columns for cassava and goat rearing activities only.
# LA and FL refer to the levels of land and family labour available at the farm. CL is the maximum limit on capital availability.

Note: Figures in the brackets refer to the number of constraints or activities.

Incorporation of the minimisation of quadratic objective functions for "economic risk" and "seasonal labour" requires explicit considerations of variance-covariance matrices (not given in the table).
The MCDM farm planning problem for the farm household can thus be stated as follows: Simultaneously optimise the following three objective functions[7],

[7] These were found to be the most relevant objectives from the point of view of individual farm household in the area of study.

(1). Maximise expected cash income $Z = \sum c_j x_j$,
(2). Minimise standard deviation of income $SDI = [\sum_j \sum_i x_j x_i s^r_{ji}]^{1/2}$,
(3). Minimise the standard deviation of seasonal labour over the 12 months, i.e., $SDL = [\sum_j \sum_i x_j x_i s^l_{ji}]^{1/2}$,
subject to the following constraints:
$\sum a_{ij} x_j$ {≤ or = or ≥) b_i (for all i, i = 1 to m)
and non negativity restrictions
$x_j \geq 0$ (for all j, j = 1 to n).
In the above relations
s^r_{ji} = the variance or covariance of per acre gross returns[8] between the j^{th} and i^{th} crop production activity when j = i or j ≠ i. Gross returns were considered only for the preceding six years, for which the relevant data were readily available.
s^l_{ji} = the variance or covariance coefficient of per unit seasonal labour use between the j^{th} and i^{th} production activity when j = i or j ≠ i. Labour use was considered for 12 months during a year.
Superscripts "r" and "l" in s^r_{jt} and s^l_{jt} refer to gross returns and seasonal labour.
b_i = the level of i^{th} constraint.
SDI = standard deviation of gross returns.
SDL = standard deviation of seasonal labour.
n = number of real activities.
m= number of constraints.

Thus two of the objective functions in this farm planning model were quadratic and were sought to be estimated as such rather than through linear approximations.

4.2 Pay-off Matrix for the Compromise programming Problem

As a first step in the use of compromise programming technique for solving a MCDM model, it is necessary to test the real degree of conflict between the different objectives. For doing so, each objective was optimised separately to compute its optimum value. Table 3 gives the pay-off matrix showing the optimum value for each objective along with the corresponding values for the remaining objectives. The ideal point, where all objectives achieve their optimum values, can be read from the main diagonal.

From the information contained in the pay-off matrix, the following conclusions can be drawn:
1. There is a strong degree of conflict between the first two objectives. Thus, when, cash income is maximised, economic risk as measured by SDI is at its worst or 'anti-ideal' value.
2. Similarly, there is a strong degree of conflict between the first and third objectives, i.e., SDL takes anti-ideal value when cash income is maximised.
3. The conflict between second and third objectives is also clear as the minimisation of one of them renders the value for the other worse.
Given the degree of conflict between the three objectives and the impossibility of obtaining the ideal solution, the use of compromise programming appears quite justified.

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[8] It would have been ideal to use gross margins instead, but due to non-availability of such data gross returns were used as a proxy. It, therefore, approximates the risk due to fluctuations in output prices and yields only and not due to variations in input prices. Given that the input and output prices in Tanzania were regulated during the period under consideration, yield fluctuations were the most important. Thus the measure of risk used in this study is rather limited as it also does not account for fluctuations in a_{ij} and b_i coefficients.

Table 3. Payoff matrix for four objective Functions

Objective Function to be Optimised	Levels of Different Objective Functions			
	Cash Income	Standard Deviation of Gross returns	Standard Deviation of Labour use	Labour Employ-ment
Cash Income (TS*)	**172,410**	90,204	55.03	406.40
Standard Deviation of Gross returns- SDI (TS)	100,000	**54,821**	45.54	450.80
Standard Deviation of Labour use- SDL (Days)	100,000	62,425	**32.75**	338.88
Labour Employment# (Days)	100,000	64,001	48.39	**471.63**

*TS stands for Tanzanian shilling.
Not considered as an objective function in all the illustrations.
Note: The figure of TS 100,000 represents a minimum annual cash income requirement constraint to meet the farm family needs.

4.3 Compromise Farm Plans

The compromise farm plans corresponding to the L_1, L_2 and L_∞ metrics for the MCDM problem under consideration (referred to as Model 1 throughout) along with the existing farm plan are given in Table 4. In order to resolve the problem in respect of the preferential weights to be assigned to the different objectives, the same were obtained through interaction with the decision makers at the time of field survey. These weights were found to be approximately in the ratio of 5:3:2 for the objectives of maximisation of cash income, minimisation of standard deviation of income and minimisation of standard deviation of seasonal labour use.

The compromise farm plan corresponding to L_∞ metric appears to be quite close to the existing farm plan being currently followed by the decision maker. The compromise farm plans corresponding to L_1 and L_2 metric, however, showed greater departures from the existing farm plan. The trade-offs between different pairs of objectives in relation to the existing farm plan are also clearly brought out in the table. For example, if the decision maker adopts compromise farm plan corresponding to L_1 metric in place of the existing plan he/she can expect to obtain TS 18,980 (12.82 per cent) higher income by accepting increased income risk, TS 7,421 (9.73 per cent) higher standard deviation, and also an increased level of standard deviation of seasonal labour by 1.04 (2.28 per cent). According to our analysis, an average farmer in Songea district did not seem to be doing too badly in planning his farm when compared with the L_∞ metric compromise farm plan.

We consider this model as the appropriate use of compromise programming technique for solving the given MCDM model under the given farm planning environment. It uses only the well thought of objective functions estimated in their proper form, without any linear approximation, using appropriate weights.

Table 4. Compromise and existing farm plans - considering only three objective Functions (two of them non-linear) with appropriate weights assigned through interaction with the DM - Model 1.

Objective function /activity, etc.	Compromise Farm Plans corresponding to			Existing Farm Plan
	L_1	L_2	L_∞	
Objective functions:				
Cash Income (TS)	166,990	155,420	147,370	148,010
Standard deviation of gross returns (TS)	83,722	79,623	75,248	76,301
Standard deviation of labour (Days)	46.70	44.45	46.39	45.66
Other parameters:				
Employment (Days)	461.50	442.28	458.37	450.87
Requirements of wood (m^3)	3.72	3.28	3.42	3.54
Working capital (TS)	11,652	10,618	10,815	11,099
Urea (Bags)	7.28	7.18	6.43	6.46
Ammonium Sulphate (Bags)	8.27	7.78	8.12	8.03
Goats (No.)	2	2	2	2
Crop Activities:				
Tobacco (Acres)	1.86	1.64	1.71	1.77
Cassava (Acres)	0.50	0.50	0.50	0.50
Paddy (Acres)	0.91	0.91	0.91	0.76
Sunflower (acres)	0.00	0.00	0.58	0.35
Groundnuts (Acres)	0.00	0.00	0.00	0.15
Maize+Beans (Acres)	3.64	3.59	3.21	3.23
Total Cropped Acres	6.91	6.64	6.91	6.76

5. Consequences of Improper Use of CP Technique

Consequences of improper use of CP technique are reflected in terms of imprecisions in the model results. A number of variations of model 1, will now be used to substantiate this view point. The solution values of different variables, objective functions and activities, for these models corresponding to L_1, L_2 and L_∞ metric compromise plans are presented in Table 5. Table 4 will be used as a standard to make all comparisons for having an idea of the extent to which the results of model 1 will change when enough care is not taken in respect of selection, weights and estimation of different objective functions.

5.1 Effect of assigning arbitrarily equal weights to all objectives

In order to investigate the consequences of such an action, model 1 was solved by arbitrarily assigning equal weights to all the three objectives (model 2).

All the results, except the level of cassava activity which was fixed at 0.50 acres, changed quite dramatically in all the three type of compromise farm plans. As greater weight was now assigned to second and third objectives in relation to the first objective, their solution values improved, i.e., decreased, at the cost of lower value for the cash income. Thus the departure between the existing and compromise solution values for the objective functions were far greater in model 2 than in model 1. Corresponding solution values for L_1, L_2 and L_∞ plans showed deterioration in income, SDI and SDL between 6.7 to 40.1, 4.3 to 26.9 and 6.1 to 29.3 per cent respectively from model 2 when compared to those from model 1.

Table 5. Compromise farm plans with alternate formulations of MCDM model for an average farm in Songea District, Tanzania.

Objective functions/ other parameters/ crop activities, etc.	Model 2			Model 3			Model 4			Model 5		
	Three objective functions - Two of them Quadratic Arbitrary equal weights			Four objective functions (including employment) -Two of them Quadratic Arbitrary equal weights			Three objective functions - Linear approximation used for two quadratic functions Arbitrary equal weights			Three objective functions - Linear approximation used for two quadratic functions Appropriate weights		
	L_1	L_2	L_∞	L_1	L_2	L_∞	L_1	L_2	L_∞	L_1	L_2	L_∞
Objectives functions:												
Cash Income (TS)	100,000	133,260	137,240	164,780	139,700	137,240	100,000	132,650	137,590	169,930	119,660	146,830
Standard Deviation of Income(SDI)	61,229	72,703	72,020	83,194	73,412	72,020	59,444	72,061	72,907	86,448	66,248	76,449
Standard Deviation of Labour (SDL)	33.04	39.34	43.58	45.80	43.76	43.58	37.45	43.27	48.07	50.54	43.48	49.74
Total absolute deviation of income (TS)	-	-	-	-	-	-	286,840	346,480	349,660	414,980	318,120	366,640
Total absolute deviation of labour (Days)	-	-	-	-	-	-	170.30	207.50	236.86	249.82	211.94	246.40
Other parameters:												
Employment* (Days)	337.01	397.29	430.46	458.77	441.60	430.46	346.37	385.17	419.68	432.94	388.65	430.18
Req. of wood (m^3)	1.75	2.49	3.27	3.12	2.22	3.27	3.86	4.76	5.10	5.72	4.58	5.31
Working capital (TS)	6,666	8,691	10,314	10,527	8,489	10,314	10617	12,882	13,784	15,411	12,412	14,315
Urea (Bags)	6.49	7.25	6.10	7.88	7.47	6.10	3.46	4.30	4.04	5.27	3.67	4.34
Ammonium Sulphate (Bags)	5.49	6.75	7.61	7.97	7.34	7.61	6.50	7.82	8.73	9.27	7.84	9.06
Goats (No.)	2	2	2	2	2	2	2	2	2	2	2	2
Crop Activities:												
Tobacco (Acres)	0.88	1.24	1.64	1.56	1.11	1.64	1.93	2.38	2.55	2.86	2.29	2.65
Cassava (Acres)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Paddy (Acres)	0.50	0.63	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Sesamum (Acres)	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.03	0.00	0.00	0.00	0.00
Sunflower (acres)	0.00	0.00	0.38	0.00	0.47	0.38	0.00	0.00	0.63	0.00	0.47	0.68
Groundnuts (Acres)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.05	0.00
Maize+Beans (Acres)	3.24	3.63	3.05	3.94	3.74	3.05	1.73	2.15	2.02	2.64	1.84	2.17
Total Cropped Acres	5.12	6.00	6.48	6.91	6.73	6.48	5.26	5.97	6.68	6.91	6.06	6.91

* Used as objective function in model 3.

Note: Following Hazell (1971), Models 4 and 5 used the minimisation of total absolute deviations (MOTAD) in respect of income (an approximation for income risk) and labour use variability objective functions. SDI and SDL for these models were obtained through the use of calculating equations.

Similarly, all the remaining solution values for model 2, including the levels of activities, were quite different for the corresponding compromise farm plans than those for model 1. For example, the area under commercial crop like tobacco declined to less than half in L_1 compromise plan. The departures in the solution values for the L_1 compromise plan were the highest followed by those for L_2 and L_∞ metric plans.

It also demonstrates that the compromise solutions can be quite sensitive to changes in the relative weights assigned to different objective functions.

5.2 Effect of incorporating objective of employment

As already pointed out in section 3, the inclusion of the objective of maximisation of labour employment in a number of MCDM models can not be justified from the point of view of a rational individual farmer. It is likely to have important repercussions, irrespective of the method of choosing the weights. What effect such an action on the part of a planner will have on the model results has, however, been demonstrated here for the case of arbitrarily chosen weights only by incorporating this objective in model 2.

While the solution values corresponding to the L_∞ metric compromise plans were identical for models 2 and 3, the same were quite different for L_1 and L_2 plans. Incidentally, the solution values for model 3 were relatively closer as compared to those from model 2 to those from model 1 being used by us as a standard for comparison. It is interesting to notice that the solution values obtained from L_1 and L_2 plans for employment in models 1 and 3 were very close. Thus leisure was not affected much by incorporating an additional objective function for maximisation of labour employment in the model. This may, however, only be a coincidence and should not be generalised.

This highlights the necessity of avoiding the use of arbitrary weights and inclusion of maximisation of family labour employment objective in the MCDM farm planning problems for an individual farmer.

5.3 Effect of linear approximation of quadratic objective functions when equal weights are assigned arbitrarily

For having an idea of linear approximation of the two quadratic objective functions on the model results, namely, for minimisation of economic risk and seasonal labour, model 2 was re-formulated as MOTAD model (model 4) following Hazell (1971). It required the addition of 18 constraints and an equal number of real activities.

Comparison of results for model 4 with those from model 2 (using similar sets of weights) show no significant difference in the solution values for the first objective of cash income in different metric plans. The solution values of SDL, as obtained through the use of calculating equations, were relatively higher. Except for L_∞ metric plan, the solution values for SDI were superior, i.e., lower than those from model 2. There were quite noticeable differences in the levels of many other variables of interest, including the levels of activities. For example, solution of model 4 gave much higher area under tobacco and reduced area under maize+beans as compared to that in model 2 for all types of compromise plans.

The results obtained by using model 4 gave entirely different levels for all the free variables as compared to that from model 1.

5.4 Effect of linear approximation of quadratic objective functions when appropriate weights are assigned

Comparisons of results contained in Table 5 with those in Table 4 bring out a number of differences, sometimes quite significant, in respect of the objective functions, activities and other variables included in the MCDM farm planning model as a result of linear approximation of the two quadratic objective functions. In the interest of precision of results, therefore, it is important to estimate the non-linear objective functions as such rather than approximate them with linear functions.

Similarly, by incorporating necessary modifications in the standard formulation of the MCDM farm planning model, it is possible to investigate the effect of inclusion of other objective functions, such as, minimisation of hired labour, minimisation of capital borrowing, etc., that have often been considered without proper justification in the context of farm planning environment faced by an individual farmer.

6. Concluding comments

Critical review of some important studies of MCDM farm planning models using compromise linear programming, show that their existing use may often seriously suffer from lack of proper specifications. While some applications have shown a tendency to incorporate objective functions rather in a mechanistic way, others have paid little attention in assigning appropriate weights to different objective functions. Besides, no attempt has been made to incorporate non-linearities in the objective functions.

Hasty applications of a technique like CP for solving MCDM models are likely not only to mislead researchers but also confuse the decision makers who are expected to be the ultimate beneficiaries. It is important for the researchers to avoid the inclusion of some objective functions in a MCDM decision making problem without proper justification. The quality of results generated by such models depends to a great extent on the judicious choice of the set of objective functions which need to conform to the economic, social, political and psychological environment faced by the individual decision maker in farming. Results of MCDM farm planning models solved by using compromise programming technique can also be highly sensitive to the weights assigned to different objectives. Efforts should, therefore, be directed in the future to devise suitable methods for assigning more realistic weights, consistent with the preferences of the decision maker, to different objectives rather than assigning arbitrary equal or unequal weights. Finally, non-linearities in the objective functions should be incorporated as such rather than their linear approximation so as to avoid distortions in model results.

Suggestions made here will greatly help exploiting the inherent potential of the CP technique for solving MCDM farm planning models and thereby improving the effectiveness of the decision making process in the future.

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