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Risk Efficient Resource Allocation in Agricultural Systems of Pakistan: A Farm Level Analysis

Shahid M. Zia

Abstract

This paper develops farm plans that can ensure optimal utilisation of available farm resources for a given level of risk. In general, farm-planning models generate a large set of farm plans. Farmers can choose the plan that suits their production environment and is congruent with their attitude towards risk. To make the decision-making process easy for the farmers, this paper attempts to reduce the decision space that risk-programming models generate. It uses compromise-programming techniques together with risk planning methods for developing the best compromise farm plans. Compromise farm plans furnish very useful information on resource allocation and risk. Through the present extension networks, the model can be applied to improve resource use efficiency. It can also be utilised for assessing environmental costs in agriculture with little adaptation.

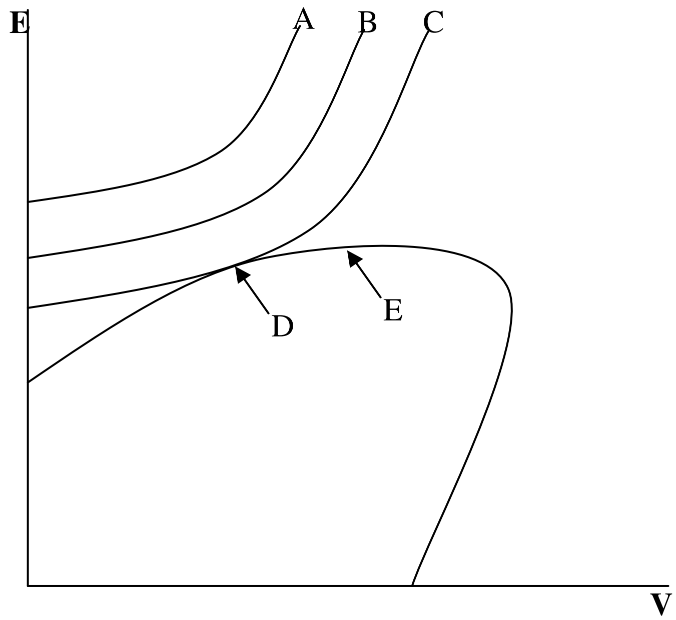
Agriculture in Pakistan is entering a new era of commercialisation. In commercial agriculture, farm managers need to base their resource allocation decisions on a combination of information on production technology and its financial implications. It becomes all the more important to know the strengths and potential weaknesses of farm business for better farm planning. It is generally noticed that with the growing complexities of farm business, coupled with increased use of capital in agriculture, the farmers realise the tremendous need for assistance in enterprise planning and farm resource management in order to achieve better efficiency and to reduce production risk. To assist farmers in evaluating and planning their business, mathematical programming techniques are widely used.

Theoretical Framework

The theoretical framework adapted for this study is the mean-variance (E-V) efficiency criteria. The E-V approach assumes the decision-maker is risk averse and has a quadratic utility function (Boisvert and McCarl, 1990). However, several linear approximations to the E-V model have been evolved. In this analysis, linear approximation the MOTAD was employed to develop a Compromise MOTAD. This approach generally assumes that the decision-maker maximises expected utility (Anderson, et al 1977). Thus, his preferences among alternative farm plans are expressed in terms of expected income and associated variance. It is assumed that the outcome distributions are distributed normally.

MOTAD and other programming models generate a large set of risk efficient farm plans. It is often left to the farmer to select one of these plans. A reliable mathematical form of the decision-maker's utility function is essentially required to find a definite and unique solution to farm problems (Hazel, 1982, Hazel and Norton, 1986). Where the E-V utility function is known, an optimal farm plan can be identified on the frontier. The set of farm plans having minimum variance for each expected level of income defines an efficient E-V frontier. Segment OE in Figure 1 describes the E-V efficient frontier. The other three curves—a, b and c in Figure 1— indicate hypothetical iso-utility curves denoting the farmer's preference between risk and income. Given these curves, point D in Figure 1 depicts the point of utility maximisation. The farm plan that is associated with point D is the optimal farm plan.

Figure.1: The optimal E-V farm plan



In practice, however, it is not always easy to establish reliable and stable utility functions for a decision-maker (Binswanger, 1980). The risk programming models, in fact, generate a range of farm plans out of which the decision-maker is required to select one that suits his production environment and is congruent with his risk attitude. Virtually, these models generate a large set of farm plans. The Compromise MOTAD model was developed to help reduce the decision space on the efficiency frontier. Compromise MOTAD assumes that the decision-maker prefers more to less in the case of the ideal objective and less to more in case of anti-ideal objective (risk).

The Compromise MOTAD Model

Traditional risk analysis models are in effect multi-objective programming (MOP) models involving two objectives. The first objective is to maximise returns from individual enterprises. The second objective of risk programming models is to minimise the variability of income expressed as variance (Freund, 1956) or mean absolute deviation (Hazel, 1971). Since an optimal solution for two or more simultaneous objectives cannot be traced, MOP models identify the set of efficient solutions.

Generally, three different methods are used to generate efficient sets in MOP models. They include: (1) the constraint method, in which one objective is optimised while other objectives are specified as constraints; (2) the weighting method, in which a weight is assigned to each objective and then their weighted sum is calculated and maximised; (3) the multi-criteria simplex method, where all efficient points are traced by moving from one efficient point to the next (Cohon, 1978; Willis and Perlack, 1980). The weighting and constraint methods are the most common techniques. The constraint method is generally preferred and used to generate efficient sets in risk programming models (Willis and Perlack, 1980, Romero, et al 1988; Romero and Rehman, 1985).

From these efficient sets, the optimal solution can be identified if the farmer's utility function is known with precision. However, as noted earlier, the available literature suggests that there are many practical difficulties in establishing mathematical forms of a decision-maker's utility functions (Dillon and Scandizzo, 1978; Romero, et al 1988). Even if the utility functions are established, they are not stable over time (Hazel, 1982, Romero, et al 1988).

Compromise programming techniques provide an answer to these difficulties, as they do not require rigid assumptions about the farmer's behaviour. These models assume that alternatives that are closer to the ideal are preferred to those that are farther away. To be as close to the ideal as possible is the rationale of human choice. Ideally, risk-averse producers would prefer to earn maximum profits with no risk. This, however, is usually infeasible. Zeleny's axiom basically states that a farmer prefers more income to less income, and less risk to more risk. With this simple and realistic assumption, compromise programming can easily be incorporated in the traditional risk programming models to generate that portion of the efficiency frontier where the tangency between the iso-utility curve and the efficient frontier occurs. This frontier will be called the Compromise MOTAD efficiency frontier and the model, the compromise MOTAD model. The beauty of this model is that it does not require any assumption about the shape of the utility curve.

The Compromise MOTAD can be solved in two steps. First, the MOTAD efficiency frontier is traced by using parametric techniques. Second, compromise programming is incorporated in the MOTAD model to define the objective function of Compromise MOTAD and the model is solved to trace the compromise MOTAD efficiency frontier. The first step has already been explained elsewhere (Zia, 1997). The second step, however, requires more description.

The ideal point is defined first. The coordinates of the ideal point are given by the optimal values of the two objective functions of MOTAD. The maximum attainable value of expected net returns from the MOTAD model and the lowest risk associated with any farm plan in the efficient set of the MOTAD model define the ideal point in the Compromise MOTAD model. The opposite of this point is called the anti-ideal point. The ideal point is usually infeasible. Since the ideal point is infeasible, the point closest to the ideal point is assumed to be preferred. That point is defined as the best compromise solution measured. The best compromise solutions are identified using distance functions.

The distance between the points, say Z_k^* (ideal point) and $Z_k(X)$ (anti-ideal) is measured by the following distance function:

$$(1) \qquad d\alpha = \left\{ \sum_{k=1}^{p} w_k \left(Z_k^* - Z_k(X)\right)^a \right\}^{1/\alpha}$$

Where $\alpha \geq 1$, p is the number of objectives, and w_k is the weight assigned by the decision-maker to kth objective function. Generally, the farmer assigns different weights to different objectives. When the objectives are measured in different units of measurement, relative deviations must be used (Romero, et al 1987). Hence, the distance function can be written as:

$$(2) \qquad d\alpha = \left\{ \sum_{k=1}^{p} w_k \left(\frac{Z_k^* - Z_k(X)}{Z_k^* - Z^*_k} \right)^a \right\}^{1/\alpha}$$

where Z*k is the anti-ideal point for the kth objective.

The metrics d_1 and d_∞ represent bounds on the distance between any two points such as:

(3) $d_\infty \geq d_\alpha \geq d_1$

Hence, metrics d_1 and d_∞ can be used to identify bounds on Compromise MOTAD efficiency frontier. The best compromise solution lies on this frontier.

When $\alpha = 1$, the compromise MOTAD model can be stated as:

(4) $$\text{Min } d_1 = \sum_{k=1}^{p} w_k \left[\frac{Z_k^* - Z_k(X)}{Z_k^* - Z_{*k}} \right]$$

subject to

(5) $$\sum_{j=1}^{n} (C_{hj} - g_j)\ X_j + Y_h^- \geq 0 \qquad h = (1\ldots s)$$

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

(7) $$X_j,\ Y_h^- \geq 0$$

where

C_{hj}	=	the gross margin for the jth activity for the hth year
g_j	=	the sample mean gross margin for the jth activity
n	=	number of activities in the model
s	=	the number of years of sample observations
X_j	=	the level of jth activity
aij	=	use of ith resource for jth activity

By solving the model, the best compromise solution for $\alpha = 1$ can be found.

When $\alpha = \infty$ only the largest deviation of the individual deviations is minimised. The best compromise solution can be found by solving the following Compromise MOTAD model:

(8) $$\text{Min } d_\infty$$

subject to

(9) $$\sum_{k=1}^{p} w_k \left[\frac{Z_k^* - Z_k(X)}{Z_k^* - Z_{*K}} \right] \leq d_\infty$$

(10) $$\sum_{j=1}^{n} (C_{hj} - g_j)\ X_j + Y_h^- \geq 0$$

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

(12) $X_j, Y_h^{-} \geq 0$

By solving Compromise MOTAD model for $\alpha = 1$ and $\alpha = \propto$, bounds of the Compromise MOTAD efficiency frontier can be defined. All other solutions for $1 \leq \alpha \leq \propto$ lie between these two points. In Compromise Programming, other points of the compromise set (Compromise MOTAD efficiency frontier) can be found by using non-linear techniques. But in Compromise MOTAD, MOTAD is used to generate an efficiency frontier and Compromise MOTAD identifies the two points (bounds) on MOTAD efficiency frontier that define the Compromise MOTAD efficiency frontier. Thus, in Compromise MOTAD we do not require non-linear techniques to identify the Compromise MOTAD efficiency frontier.

The farmer can pick any farm plan from the Compromise MOTAD efficiency frontier, and that will be his anchor point. Needless to say, different farmers will locate their anchor points at different points on the Compromise MOTAD efficiency frontier.

Data Development

The MOTAD and Compromise MOTAD models used for analysing risk efficient resource allocation, require enterprise budgets with additional information on the time series data in returns and cost of production for each enterprise in the model to develop a distribution of gross margins. The IFFS model is used for generating enterprise budgets. The deviations are computed by subtracting expected gross margin from the gross margin for each enterprise for each year in the series. This deviation matrix is the heart of MOTAD and Compromise MOTAD models and is used to compute risk.

Data on enterprise budgets are required to specify input-output coefficients for each enterprise. The resource availability and constraints must be specified. The resource constraints specified in the model developed here include land, family labour, hired labour, fertiliser use, and institutional credit. The real activities include all major crops grown in the area.

A set of representative farms was selected for analysis, with the choice being based upon the available budget information. An attempt was also made to select such farms that gave a comprehensive picture of the dominant farming systems in Punjab, Pakistan. A survey form for collecting data from each of the farms, was designed from the inputs known to be needed to use MOTAD models, as well as from consideration given to the types of information the farmers will readily have available and be willing to provide. This form was then used as a basis for conducting personal interviews with managers of selected representative farms. The data collected was first used to generate enterprise budgets, which were then used to develop MOTAD and Compromise MOTAD models.

Enterprises

One representative farm is growing almost all the traditional and non-traditional crops that are being grown in the study area. The traditional crop rotations include wheat, rice, sugarcane, sorghum and berseem. The non-traditional crops include peas, brinjal (eggplant), gourds and carrots. The non-traditional crops are labour-intensive and are, generally, grown only on the farms that have enough family labour or on farms where sharecropping arrangements are made. The weather and rotation system permits production of two crops from the same land every year.

Livestock enterprises are an integrated part of the crop rotations in the study area. Generally, livestock is raised to meet the milk consumption requirement of the family, but sometimes surplus milk is also sold to get supplemental income from livestock.

Resource Constraints

The farm has an area of 20.5 acres and the land is assumed to be homogeneous in fertility. Average crop yields are used for the computation of gross margins. Availability of surface irrigation water is a constraint on the farms where supplementary tube-well water is not available, but as the farm owns a tube-well, irrigation water is not specified as a binding constraint. The binding constraints include institutional credit and hired labour, the latter being critical during the peak periods, such as planting and harvesting. Labour inputs are specified on monthly basis. The availability of family labour, hired labour and institutional credits is specified for each season of the two-crop production seasons in Pakistan, namely *Rabi* (spring) and *Kharif* (autumn). The restrictions for the family consumption requirement are also specified. For instance, the family keeps sufficient quantity of wheat for home consumption and the rest enters the market.

Efficient Resource Allocation

Farmers, it is frequently argued, tend to maximise profits from their farming business. To look at the profit maximising resource allocation of the farm, a basic linear programming (LP) model was developed. The results of the LP model are presented in Table 1. Risk theory indicates that risk-neutral farmers will seek the LP profit-maximising plan. The expected income (Rs. 96,736) associated with this plan reflects the maximum attainable income given the existing resources of the farm. The profit-maximising plan is a high-risk plan as also ind1icated by the associated mean absolute deviation (MAD) of Rs. 32,946.

Table 1: Profit Maximising Farm Plan

Expected Income (Rs)	96,736	
Mean Absolute Deviation (MAD)	32,946	
Activity	Unit	Level of Activity
Wheat	Acre	13.68
Rice	Acre	18.18
Sorghum	Acre	2.31
Peas	Acre	2.99
Berseem	Acre	1.81
Carrot	Acre	2.00
Buffaloes	Head	3.25

Source: Survey data

The profit-maximising farm plan suggests a crop rotation with 13.68 acres of wheat, 18.18 acres of rice, 2.31 acres of sorghum, 2.99 acres of peas, 1.81 acres of berseem, and 2.0 acres of carrots. The farm plan includes 3.25 buffaloes for meeting consumption requirements of the family. Sugarcane and eggplants do not enter the optimal farm plan. However, sugarcane and eggplants are common in the present crop rotations of the study area. That implies that the profit-maximising plan does not truly represent a farmer's current behaviour. The high risk attached to the profit-maximising farm plan may explain why farmers do not adopt this profit-maximising rotation.

May-June and November-December are the peak labour requirement seasons. Labour shortage in these seasons will compel the farm manager to adopt a sub-optimal farm plan. The area under carrots was constrained at the margin by the availability of harvest labour. All the institutional credit available was used. Thus, the constraint on institutional credit is binding. Sorghum and berseem are forced in the solution for meeting the fodder requirements of livestock raised on the farm.

Risk and Best Compromise Farm Plans

In agricultural planning problems the farmers face multiple objectives, often conflicting in nature. In situations where multiple objectives are involved, the farmer is interested not in optimising a single objective but finding a compromise among several objectives. In this analysis two conflicting objectives, profit maximisation and risk minimisation, are involved. A Compromise MOTAD model was developed to identify the compromise set of risk efficient plans for these two conflicting objectives.

The MOTAD model is employed to generate risk efficient farm plans. Expected income is parameterised in arbitrary increments of Rs 5,000 to trace the efficiency frontier (Figure 16). Each point on the efficiency frontier is a unique farm plan. The farmer is provided with information about expected income of each farm plan, risk associated with each farm plan, and enterprise levels for that plan. The decision-maker can select any farm plan according to his preferences for expected income and associated risk.

Table 2 shows the set of risk efficient farm plans generated. It shows the trade-off between expected income and associated risk as measured in terms of standard deviations (SDs) or coefficients of variations (CVs). With higher expected incomes, risk is also higher. When the expected income is reduced, the associated risk is also reduced. The details of MOTAD model are discussed elsewhere (Zia, 1993).

As discussed earlier, Compromise MOTAD first identifies an ideal vector and a nadir vector. The ideal vector includes the highest feasible value of expected gross margins, Rs 96,736, and the lowest possible value of mean absolute deviations, Rs 5,340. On the other hand, the nadir vector reflects the lowest expected gross margin of Rs 50,000 and the highest value of mean absolute deviation of Rs 32,279 as shown in Table 2.

The Compromise MOTAD model was employed to identify a compromise set of farm plans. It is assumed that a decision-maker attaches equal importance to both objectives. This implies W_1 equals W_2. The compromise set is shown in Figure 2. The best compromise farm plans are given in Table 4.

Point A reflects the solution defined by the d_1 metric and point B shows the solution of the d_∞ metric. Solutions of all other metrics lie between A and B. This indicates that the area on the risk efficiency frontier between point A and point B represents the compromise set. The shaded area reflects the compromise decision space.

Table 2: Risk Efficient Farm Plans- MOTAD solution

Characteristics	Farm Plans								
	Farm Plan 1	Farm Plan 2	Farm Plan 3	Farm Plan 4	Farm Plan 5	Farm Plan 6	Farm Plan 7	Farm Plan 8	Farm Plan 9
Exp. Income	90,000.00	85,000.00	80,000.00	75,000.00	70,000.00	65,000.00	60,000.00	55,000.00	50,000.00
MAD[1]	24517.18	21134.26	17751.33	14368.41	11206.21	8836.46	7334.91	6322.76	5340.80
CV[2]	37.41	34.14	30.47	26.31	21.98	18.67	16.78	15.79	14.67
Crop Mix									
Wheat	11.31	8.24	5.18	2.11	1.72	7.68	2.72	1.34	1.34
Rice	13.21	9.69	6.17	2.64	0.00	0.00	0.00	0.00	0.00
Sugarcane	2.86	5.92	8.99	12.06	12.45	5.86	6.04	6.23	6.36
Gourd	0.00	0.00	0.00	0.00	2.19	9.63	8.38	8.41	8.47
Sorghum	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Peas	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Berseem	1.33	1.33	1.33	1.33	1.33	1.33	1.33	3.33	4.01
Carrot	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Eggplant	2.60	3.05	3.51	3.97	4.02	3.18	4.26	4.02	3.83
Buffalo	1.30	1 .33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Total Area Sown	38.14	35.06	32.01	28.94	28.54	34.51	29.56	30.16	30.84
Cropping Intensity	186.05	171.02	156.15	141.17	139.22	168.34	144.20	147.12	150.44

Note: 1 = Mean Absolute Deviations
2 = Coefficient of Variations

Figure 2: MOTAD Risk Efficiency Frontier and Compromise Set

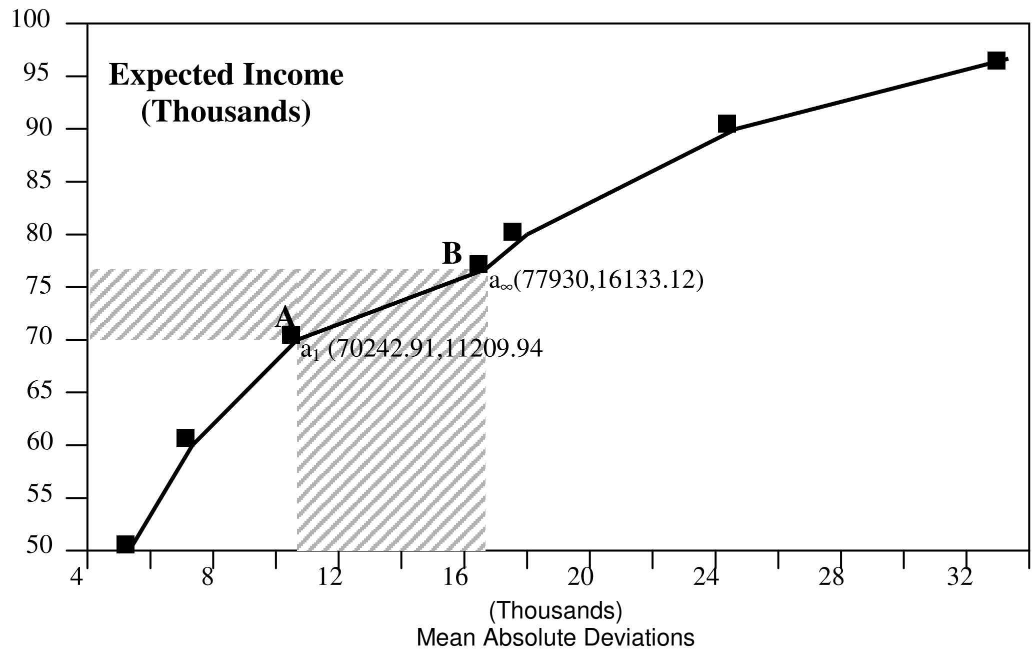


Table 3: Efficient Farm Plans, Ideal Vector and Nadir Vector

Farm Plans	Mean Absolute Deviations (Rs)		Expected Gross Margins (Rs)
Plan 1	5,340		50,000
Plan 2	6,322	Ideal Vector	55,000
Plan 3	7,334		60,000
Plan 4	8,836		65,000
Plan 5	11,206		70,000
Plan 6	14,368		75,000
Plan 7	17,751		80,000
Plan 8	21,134		85,000
Plan 9	24,517		90,000
Plan 6	32,279	Anti-Ideal Vector	96,736

Table 4: Risk Efficient Best Compromise Farm Plans

Characteristics	Farm Plans		
	Farm Plan 3	Farm Plan 4	Farm Plan 5
Exp. Income	80,000.00	75,000.00	70,000.00
MAD[1]	17751.33	14368.41	11206.21
CV[2]	30.47	26.31	21.98
Crop Mix			
Wheat	5.18	2.11	1.72
Rice	6.17	2.64	0.00
Sugarcane	8.99	12.06	12.45
Gourd	0.00	0.00	2.19
Sorghum	1.83	1.83	1.83
Peas	3.00	3.00	3.00
Berseem	1.33	1.33	1.33
Carrot	2.00	2.00	2.00
Eggplant	3.51	3.97	4.02
Buffalo	1.33	1.33	1.33
Total Area Sown	32.01	28.94	28.54
Cropping Intensity	156.15	141.17	139.22

Note: 1 = Mean Absolute Deviations
2 = Coefficient of Variations

Risk Aversion Coefficient

The information generated can also be utilised to estimate the risk aversion behaviour of the farmers.

It is intuitively clear that minimising the objective function of Compromise MOTAD is the same as maximising the following function:

$$(13) \quad \text{Max } Z(x) - \frac{(\text{Max EGM - Min EGM})}{(\text{Max MAD - Min MAD})} \bullet \frac{W_1}{W_2} \bullet \frac{1}{n} \; {}_{i=1}^{n}(\overset{-}{y} + \overset{+}{y})$$

or

$$(14) \quad \text{Max } Z(x) - \gamma \bullet \frac{W_1}{W_2} \bullet \frac{1}{n} \sum_{i=1}^{n} (\bar{y} + \overset{+}{y})$$

where $\gamma = \frac{(\text{Max EGM - Min EGM})}{(\text{Max MAD - Min MAD})}$ and EGM is the expected gross margin. The expression (14) maximises the utility function of the farmer. It can be noticed that for any conceivable form of the utility function, the point of maximum utility will lie in the compromise set.

The term $\gamma \bullet \frac{W_1}{W_2}$ can be viewed as a measure of risk aversion because it is a multiplicative factor for risk in this case. In this analysis, W_1 is assumed equal to W_2. Thus, γ represents the risk aversion coefficient of the farmer.

$$\frac{96{,}736.22 - 50{,}000}{32{,}279.50 - 5340.80} = 1.73$$

If farmer attaches a higher weight to the expected gross margin (say $W_2 = 2$) than the risk, then the value of risk aversion coefficient will decrease to 0.87.

Conclusion

There are several mathematical programming techniques available for modeling of specific agricultural systems problems. Probably, no single model is the best at farm level, but the use of MOTAD with compromise programming seems to offer a more powerful analytical instrument for agricultural systems modeling. In addition to the information that MOTAD offers (risk-efficient set of farm plans and trade-off among objectives), Compromise MOTAD furnishes the farmer with very useful information on the compromise sets of farm plans. The compromise set is a subset of the risk efficient set of farm plans identified in MOTAD. This implies that application of Compromise MOTAD helps through considerable reduction of alternatives to be considered and thus makes the decision making process easier.

In terms of the information necessary to build a systems model, Compromise MOTAD seems to be the easiest model for practical model formulation. Furthermore, Compromise MOTAD can be a very useful research tool to handle the problems of multiple objectives without introducing computational difficulties, as the model can be solved with a traditional LP algorithm.

The model can easily be applied to a wide range of farm planning problems. It can handle agricultural resource allocation issues, satisfy multiple and conflicting objectives, and environmental issues where some restrictions are required to be placed on the use of some inputs with known environmental externalities. However, to do so, we need time series data on environmental variables that quite often do not exist in the required form. The other difficulty in the use of these models is the use of weights for different objectives. The weights can be changed to reflect different values that someone attaches to selected objectives. More in-depth modeling efforts, however, hold promise of portraying the reality more accurately.

References

Anderson, J.R., J.L. Dillon, and J.B. Hardaker. (1977). *Agricultural Decision Analysis,* Ames: Iowa State University Press.

Binswanger, H.P. (1980). "Attitudes Toward Risk: Experimental Measurement in Rural India," *AJAE.* 62:395-407.

Boisvert, R.N. and B. McCarl. (1990). "Agricultural Risk Modeling Using Mathematical Programming, " Southern Cooperative Series *Bulletin No. 356.*

Cohon, J.L. (1978). *Multi-objective Programming and Planning.* New York: Academic Press.

Dillon, J.L. and P.L. Scandizzo. (1978). "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach, " *AJAE.* 60:425-35.

Freund, R.J. (1956). "The Introduction of Risk into a Programming Model, " *Econometrica.* 24:253-263.

Hazel, P.B.R. (1971). "A Linear Alternative to Quadratic and Semi-variance Programming for Farm Planning Under Uncertainty," *AJAE.* 53:53-62.

Hazel, P.B.R. (1982). "Application of Risk Preference Estimates in Firm Household and Agricultural Sector Models," *AJAE.* 384-390.

Hazel, P.B.R. and R.D. Norton. (1986). *Mathematical Programming for Economic Analysis in Agriculture.* New York: Macmillan Publishing Company.

Romero, C. and T. Rebman. (1985). "Goal Programming and Multiple Criteria Decision-Making in Farm Planning: Some Extensions," *Journal of Agricultural Economics.* 36(2).

Romero, C., F. Amador and A. Barco. (1987). "Multiple Objectives in Agricultural Planning: A Compromise Programming Application," *Am. J. of Ag. Econ.* Feb.:78-85.

Romero, C., T. Rehman and J. Domino. (1988). "Compromise Risk Programming for Agricultural Resource Allocation Problems: An Illustration," *Journal of Agricultural Economics.* 39(2):271-76.

Willis, C.E. and R.D. Perlack. (1980). "A Comparison of Generating Techniques and Goal Programming for Public Investment, Multiple Objective Decision Making," *American Journal of Agricultural Economics.* February.

Zeleny, N. (1982). *Multiple Criteria Decision Making.* New York: McGraw-Hill.

Zia, S.M. (1985). "Estimation of the Parity Prices to Serve as a Guide to Determine Support Prices for Major Agricultural Crops—Wheat, Rice, Cotton, and Sugarcane." An unpublished M.S. Thesis, Department of Agricultural Economics, University of Agriculture, Faisalabad, Pakistan.

Zia, S.M. (1992). "Economic Analysis of Rice-Wheat Farming Systems of Pakistani Punjab: A Case Study." An unpublished Ph.D. dissertation, Department of agricultural economics, Oklahoma State University, Stillwater, Oklahoma.

Zia, S.M., J.N. Trapp, and M.M. Ali. (1993). "An Analysis of Selected Economic Factors and Policies Affecting Farm Income and Risk Levels in Punjab." *Pakistan Journal of Agricultural Social Sciences,* Vol. 6 & 7 No. 1 & 2 July 1991- June 1993.

Zia, S.M., (1997). "A trade-off Between Expected Returns and Risk among Farmers of Rice-Wheat Zone of Punjab, Pakistan." *Journal of Economic Cooperation Among Islamic Countries,* Vol. 18, No. 4 October, 1997.

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