# ECONOMIC ANALYSIS OF RICE-WHEAT FARMING SYSTEMS OF PAKISTANI PUNJAB:

## A CASE STUDY

by

SHAHID MAHMOOD ZIA

Bachelor of Science (Hons)
University of Agriculture
Faisalabad, Pakistan
1982

Master of Science (Hons)
University of Agriculture
Faisalabad, Pakistan
1984

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
May, 1992

# ECONOMIC ANALYSIS OF RICE-WHEAT FARMING SYSTEMS OF PAKISTANI PUNJAB: A CASE STUDY

Thesis Approved:

James N. Trapp
Thesis Adviser

Arthur Stoecker

Dean F. Schreiner

Michael R. Edgmand

Thomas C. Collins
Dean of the Graduate College

# ACKNOWLEDGEMENTS

I wish to express my deep gratitude to all those people who helped me complete this manuscript. It is difficult to acknowledge everyone who has given me helpful advice on this study since much of the most important advice I received was delivered in different class discussions and lectures in the Department of Agricultural Economics, Oklahoma State University. Still, I have obvious debts that deserve a special word of appreciation. A continuous encouragement, apt guidance and gentle criticism from my major advisor, Dr. James N. Trapp, made it possible to complete this study. Appreciation is also expressed for his patience and counseling throughout the course of my doctoral program. I greatly appreciate my committee members, Dr. Dean F. Schreiner, Dr. Arthur L. Stoecker, and Dr. Michael R. Edgmond for their assistance, encouragement and guidance in completing this study.

A lot of thanks are extended to Dr. Ross O. Love and IFMAP staff for the help and guidance they provided in the application of IFFS model. Harry Heifner provided valuable assistance in making changes in IFFS to make it workable in Pakistani agriculture. Thanks, Harry!

Thanks are also due to the farmers who showed enough patience during lengthy interviews and provided data for this study. I also wish to thank the Department of Agricultural Economics, UA, Faisalabad, Pakistan for providing me computer facilities during the survey. Valuable discussions of Dr. Bashir Ahmad of UA, Faisalabad are also appreciated.

Betsy Little typed the entire manuscript. Her work was exceptional for both its high quality and for the speed. I am very grateful to Betsy.

On a personal note I am especially grateful for my mother, father, brothers and sisters, especially younger one, for their sacrifice, prayers, encouragement and support throughout my graduate program.

Finally, I wish to express my deep appreciation to my wife and Zeshan for their understanding, sacrifice and encouragement during this endeavor. To Ch. Muhammad Ali, my father, I dedicate this dissertation.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER I

# AN OVERVIEW OF PAKISTAN AGRICULTURE

The Pakistani economy has been and largely remains predominantly an agricultural economy. The agricultural sector plays a vital role in growth and development of the national economy. Recent estimates show that roughly one-half of the gross domestic product (GDP) is produced by the agricultural sector. Additionally, about two-thirds of the employment and three-fourths of the exports are provided by the agricultural sector (Mahmood and Walters).

The agriculture sector provides food and fiber to a rapidly growing population on the one hand, and raw material to a growing industrial sector on the other. Thus, economic activities in other sectors of the economy are critically linked with those of the agriculture sector. The results of recent studies cited in Mahmood and Walters show that a one rupee increase in farming sector production will stimulate a two rupee increase in overall business activities in the country.

A prosperous agriculture is perceived to be very important for sustained economic growth of the Pakistani economy. For this reason, development of the agricultural sector is the heart of development strategy designed for the seventh five-year plan for 1988-93. Pakistan's agricultural development strategy is based on three main priorities: (1) national food security; (2) full employment in rural areas; and (3) augmented foreign exchange earnings (Government of Pakistan). The main objective is to accelerate the growth rate of the agricultural economy and to generate greater resources for economic development.

Self-sufficiency in food has been a major priority for the last decade because food shortages pose a threat to the political and economic stability of the country, and the import of food is an unbearable burden on the country's balance of payments. Generally, past growth in wheat production has not been adequate to satisfy the rising needs of a rapidly growing population, and substantial amounts of wheat have had to be imported. However, in recent years, increased wheat production has indicated that self-sufficiency in wheat is now well within reach. Government policies are now targeting towards augmenting the production of oilseed crops to meet the increased demand for vegetable oil and reduce the import bill for vegetable oil.

## Farming Systems

Agroclimatic conditions, soil structure, and topography determine the type of crops that can successfully be grown in a region. Pakistan is divided into nine agroclimatic zones as shown in Figure 1 (Pinckney). A well-managed state-run gravity flow canal irrigation system, together with diverse agroclimatic conditions, allow the country to grow virtually almost all kinds of crops.

There are two main cropping seasons in most of Pakistan: <u>kharif</u> (April-November) and <u>rabi</u> (November-April). Rice, cotton and maize are the major kharif crops, while wheat, oilseeds, and gram are the major rabi crops. Sugarcane is a whole year crop and is grown mainly in Punjab and Sind and in some areas of NWFP and Baluchistan. Minor crops grown in different parts of Pakistan include oilseed crops, vegetables, pulses, fodder crops, tobacco, and orchards. Of the total cropped area, about 55 percent is planted in rabi season (Pinckney). Livestock is an integrated part of farming in all regions of Pakistan. The province-wise share of major crops production is shown in Table I.

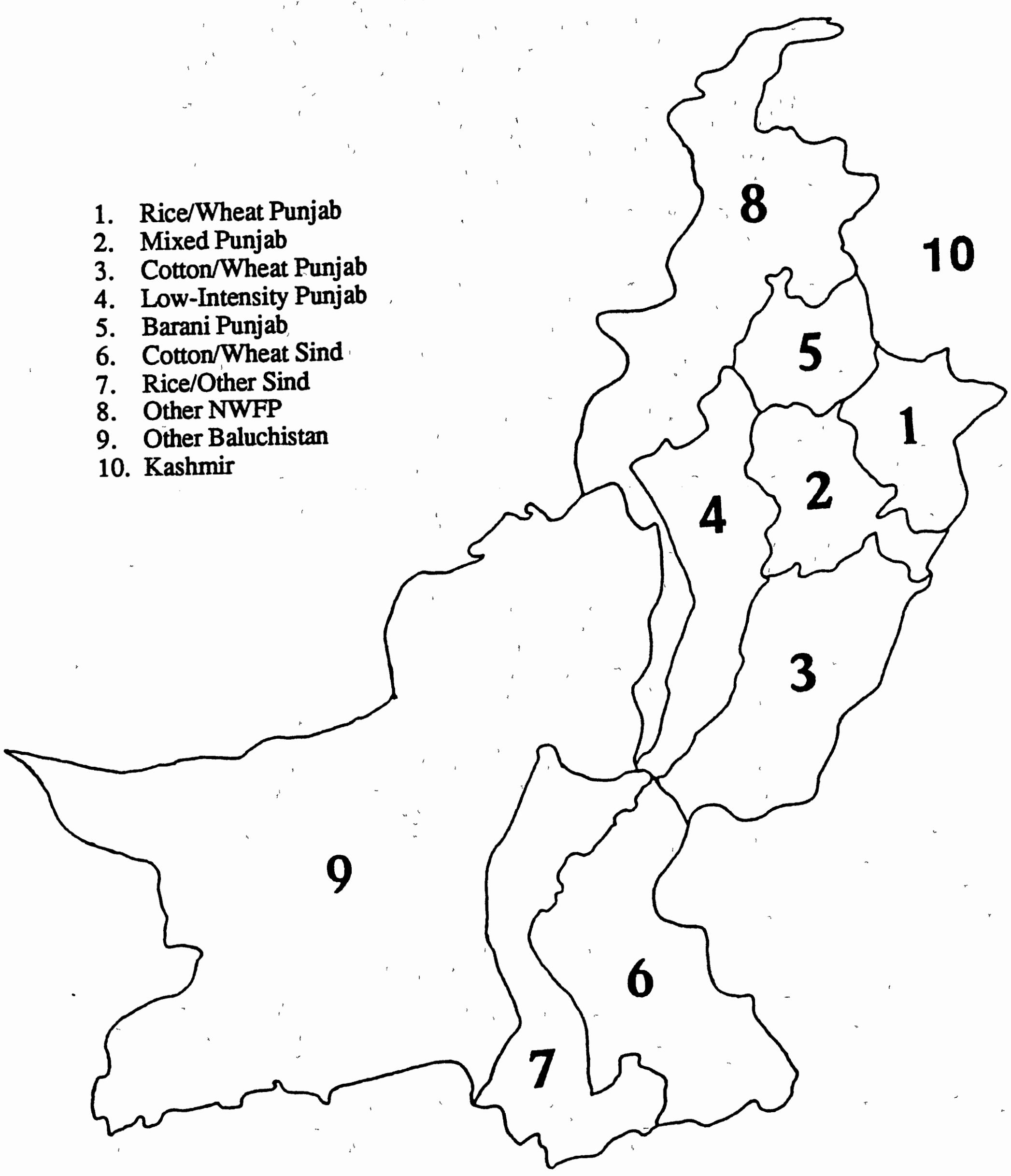


Figure 1. Agroclimatic Zones of Pakistan

TABLE I

PROVINCE-WISE SHARE OF MAJOR CROPS PRODUCTION
(share in percent)

| | Province | | | |
|---|---|---|---|---|
| Crops | Punjab | Sind | NWFP | Baluchistan |
| Wheat | 72.5 | 16.6 | 7.3 | 3.6 |
| Rice | 45.1 | 42.7 | 3.6 | 8.6 |
| Sugarcane | 58.2 | 29.6 | 12.1 | 0.1 |
| Cotton | 83.0 | 16.9 | 0.1 | – |

Source: Pakistan Economic Survey, 1990-91.

## Agricultural Resource Base

Agricultural Land. Pakistan's total geographical area is 79.6 million hectares, of which only 20.9 million hectares (ha) (26 percent) is cultivated, primarily due to the limited supply of irrigation water. Total cropped area increased from 11.6 million ha. in 1947-48 to 20.9 million ha. in 1988-89, or nearly 80 percent in 40 years. This impressive growth rate in cultivated area has slowed in the eighties.

Land use is generally influenced by rotational constraints, lack of monetary liquidity, and labor and water requirements of the crops. The area under major agricultural crops is shown in Table II.

## TABLE II

## LAND USE BY CROP FOR 1989-90

| Crop | Area (000, hectare) | Percent of Total |
|---|---|---|
| Wheat | 7845 | 37.54 |
| Rice | 2107 | 10.08 |
| Cotton | 2599 | 12.44 |
| Sugarcane | 854 | 4.09 |
| Others | 7495 | 35.85 |

Source: Pakistan Economic Survey, 1990-91.

Irrigation Water. Pakistan's gentle east to west slope has facilitated the development of the world's largest gravity-flow canal irrigation system. This irrigation system encompasses the Indus River and its tributaries, three major storage reservoirs, 19 barages, 12 link canals, and 43 primary canals and serves approximately 90,000 villages (Mahmood and Walters). The total length of the canal system is about 40,000 miles, with watercourses and field ditches running another 1.0 million miles. The total irrigation water supply at the farmgate was 112.2 million acre feet (MAF) in 1988. Table III shows the availability of irrigation water in Pakistan. Significant growth in groundwater availability over the past four years is indicated.

TABLE III

AVAILABILITY OF WATER FOR
IRRIGATION, 1984-1988
(million acre feet)

| Year | Surface Water | Groundwater | Total |
|---|---|---|---|
| 1984-85 | 59.50 | 37.83 | 97.33 |
| 1985-86 | 60.81 | 39.58 | 100.39 |
| 1986-87 | 69.69 | 40.03 | 109.72 |
| 1987-88 | 71.24 | 40.98 | 112.22 |

Source: Pakistan Agriculture, 1990.

The efficiency of canal system is deteriorating over time due to poor state of repair. Some estimates (Mahmood and Walters) show substantial losses in the process of conveying water from rivers to farmgate. Moreover, this seepage and excessive application of irrigation water is creating a problem of water-logging and salinity. The use of public and private tubewells is found helpful not only in reducing waterlogging problems, but also in augmenting the supply of irrigation water.

Labor Use. Available statistics show that the total agricultural labor force in 1988-89 was 15.29 million (Government of Pakistan). The share of labor employed by the agricultural sector declined slowly from 60 percent in 1963 to

With the steadily growing industrial sector and favorable non-farm wages, incentives are present for farm labor to migrate out of agriculture.

The agriculture sector was once considered a labor surplus sector. However, agriculture now experiences serious labor shortages at harvest time in various areas. As a consequence, farmers are compelled to reevaluate their cropping systems, keeping in view the availability of labor at critical times. A summary of past rates of growth of population, labor, and the agricultural labor force is shown in Table IV.

TABLE IV

LABOR FORCE: RATE OF GROWTH

| | 1963-64<br>1979-80 | 1970-71<br>1979-80 | 1980-81<br>1988-89 |
|---|---|---|---|
| Population | 3.03 | 3.1 | 3.05 |
| Labor Force | 2.7 | 3.45 | 2.24 |
| Total Employment | 2.54 | 3.15 | 2.35 |
| Agriculture Employment | 1.46 | 2.1 | 1.85 |

Source: Pakistan Agriculture.

## Crop Production

Wheat. Wheat, a major rabi crop, is Pakistan's major staple food and is grown in all the four provinces of Pakistan. Wheat area and production have been increasing over time. As a result of the green revolution, wheat production has increased dramatically since the mid-sixties. Recent surveys (Akhtar et al.) show that nearly all irrigated wheat and over half of the "barani" (rainfed) wheat crop are planted in high yielding varieties. In 1989-90, the area under wheat crop was 7.8 million hectares with an average yield of 1825 kg/ha.

The area and production targets for wheat for 1990-91 were set at 7.844 million hectares and 15,250 thousand tons, respectively. Table V depicts the area, production, and yield per hectare of wheat in Pakistan for the last three years.

TABLE V

AREA, PRODUCTION, AND YIELD PER HECTARE OF WHEAT

| Period | Area (000, ha) | Production (000, tons) | Yield/ha (kg) |
|---|---|---|---|
| 1988-89 | 7730 | 14419 | 1865 |
| 1989-90 | 7845 | 14316 | 1825 |
| 1990-91 | 7871 | 15105 | 1919 |

Source: Pakistan Economic Survey, 1990-91.

Rice. Rice is a very important food and cash crop during the kharif season for farmers of Punjab and Sind. Basmati rice, a fine quality, high-valued rice variety grown in Punjab, is one of Pakistan's major exports and generates a substantial amount of much-needed foreign exchange. The government purchases paddy from the growers through its compulsory procurement program at a much lower price than the international price (Zia).

Pakistan once enjoyed a monopoly in the international market for basmati rice but is now facing serious competition from India, Thailand, and the United States. Efforts are being made to improve the agronomic practices of basmati rice production. These efforts include increasing the efficiency of input use and popularize application of zinc on sodic soils to enhance production and maintain competitiveness.

A production target of 3480 thousand tons of rice was set for 1990-91. Area, production, and yield per hectare of rice for the last three years is given in Table VI.

Cotton. Cotton is a very important cash crop in Pakistan. In 1990-91, cotton was grown on 2.69 million hectares of land. Cotton occupied the second largest area of all crops grown in Pakistan. More than 80 percent of Pakistan's cotton is grown in Punjab (Table II). Significant improvement in cotton production has occurred in recent years and is attributed to favorable weather and increased productivity. Cotton productivity improvements have resulted from enhanced use of improved seed varieties and adoption of more effective plant protection measures.

Historically, cyclical patterns are observed in cotton production (Mahmood and Walters). In 1983-84, cotton growers experienced a disastrous cotton crop. Consequently, the use of pesticides and other chemicals in cotton production

## TABLE VI

## AREA, PRODUCTION, AND YIELD PER HECTARE OF RICE

| | 1988-89 | 1989-90 | 1990-91 |
|---|---|---|---|
| Area | | | |
| (000, ha) | 2042 | 2107 | 2113 |
| Basmati | 989 | 1074 | 1087 |
| Others | 1053 | 1033 | 1026 |
| Production | | | |
| (000, tons) | 3200 | 3220 | 3265 |
| Basmati | 1076 | 1160 | 1159 |
| Others | 2124 | 2060 | 2106 |
| Yield | | | |
| (kg/ha) | 1567 | 1528 | 1545 |
| Basmati | 1088 | 1080 | 1066 |
| Others | 2017 | 1995 | 2053 |

Source: Pakistan Economic Survey, 1990-91.

increased significantly. Area, production, and yield per hectare of cotton are presented in Table VII.

## TABLE VII

## AREA, PRODUCTION, AND YIELD PER HECTARE OF COTTON

| Period | Area (000, ha) | Production (000, bales) | Yield/ha (kg) |
|---|---|---|---|
| 1988-89 | 2619 | 8385 | 544 |
| 1989-90 | 2599 | 8560 | 560 |
| 1990-91 | 2692 | 9610 | 607 |

Source: Pakistan Economic Survey, 1990-91.

Sugarcane. Sugarcane is grown on a little less than a million hectares of land in Pakistan. The Punjab is a major sugarcane growing area, followed by Sind and NWFP. The per hectare yield of sugarcane in Punjab is lower than Sind and NWFP due to the short growing season in Punjab. Average yields in Pakistan are considerably lower than those realized in other countries like India (53 tons/ha) and Egypt (83 tons/ha) (Mahmood and Walters). Moreover, the yield gap between progressive farmers and common farmers suggests that there is a significant yield potential to be exploited.

To enhance cane production, sugar mills located in the cane growing area have been urged by the government to provide growers new high yielding cane varieties. However, more extension efforts are required to educate the farmers in improving agronomic practices and in the efficient use of inputs (Zia). Reported data show that area and production of sugarcane have risen by 3.5

percent and 1.4 percent respectively over the last year (Government of Pakistan, 1990). Table VIII depicts the area, production, and yield of sugarcane.

TABLE VIII

AREA, PRODUCTION, AND YIELD OF SUGARCANE

| Period | Area (000, ha) | Production (000, tons) | Yield/ha (tons) |
|---|---|---|---|
| 1988-89 | 877 | 36976 | 42.16 |
| 1989-90 | 854 | 35494 | 41.56 |
| 1990-91 | 884 | 35989 | 40.71 |

Source: Pakistan Economic Survey, 1990-91.

Other Crops. Other crops grown in various parts of the country include maize (corn), oilseeds, coarse grains (grams, sorghum, millet, etc), pulses, fruits, and vegetables. Maize is grown in both irrigated and rainfed areas and is the second most important kharif crop after rice in Punjab.

The production of oilseeds in Pakistan remained nearly stagnant for many years. The area under traditional oilseeds has registered a 0.8 percent decline from 1947 to 1988 (Mahmood and Walters). To meet the increasing demand for vegetable oil, Pakistan imports large amounts of edible oil. However, the government is making some efforts to increase production of oilseeds by supplying inputs to growers in a timely fashion, procuring their produce to ensure reasonable prices, and disseminating improved technology.

Fruits and vegetables are grown not only to meet growing domestic demand but also to earn badly needed foreign exchange through exports. The value of fruit exports rose from Rs. 111 million to Rs. 646 million from 1976 to 1988 (Government of Pakistan, 1990).

## Livestock

The primary purpose of livestock raising in Pakistan has been and largely remains to be to fulfill livestock product consumption requirements of farm families and to provide draft power. Historically, income generation from livestock enterprise has been a secondary objective in most parts of the country, especially in irrigated areas.

The crop and livestock sectors are closely integrated. The crop sector provides fodder and feed to the livestock sector, while a significant portion of the crop sectors requiring draft power is provided by livestock. Also, farmyard manure is contributed by the livestock sector to the crop sector. It is noted that with the increased use of tractors, the number of work animals has significantly declined over time from 3.2 million pairs in 1976 to 2.3 million pairs in 1984 (Mahmood and Walters). The shift from animal power to tractor power has positively affected cropping intensity, especially in rainfed areas (Sheikh et al.).

The dairy industry in Pakistan has shown considerable progress and has achieved a relatively advanced level of development. Per capita production and consumption of milk in Pakistan are greater than in a number of developing countries in South Asia (Anjum et al. cited in Mahmood and Walters). Total milk production in the country is about 13.7 million tons. More than half of the milk comes from rural small farmers.

## Study Area

The central Punjab, generally termed as the rice-wheat area of Punjab (Figure 1), was selected as the study area based on several criteria. First, it is the major agricultural area of the country. It produces a significant portion of the country's wheat, rice, and sugarcane. It also produces many other traditional and non-traditional crops and is an important producer of livestock products. Secondly, the physical environment of Punjab makes it conducive to economic analysis. It is all canal irrigated with similar weather patterns and relatively homogeneous soil and water conditions. Moreover, virtually all growers face the same general set of input and output conditions and a similar set of decision variables.

## The Problem Statement

Pakistan agriculture has advanced rapidly over the last two decades. The growth rate of agricultural production is estimated to be over 4 percent per annum throughout this period. It is generally believed that this success resulted largely from price support policies and the availability of modern inputs and subsidized input prices, including agricultural credit. At present, the main focus of the agricultural development strategy is to enhance agricultural productivity (especially for small and medium size farms) by providing farmers more access to improved inputs and agricultural credit.

New developments in agriculture continue to require Pakistani farmers to reevaluate their farming systems. With each new technological change and/or government policy, Pakistani farmers must reevaluate the viability of their current crop rotations, crop mix, forage production and livestock balances, etc. Farm families who find a need to adopt new technology and/or change their farming system have an increased need for assistance in financial planning.

The Integrated Farm Financial Statements (IFFS) program developed at Oklahoma State University provides a tool to aid farmers in financial planning. Punjab farmers need the financial planning capabilities of IFFS to project the financial consequences of changes in farm plans upon farm income and short-term as well as long-term credit needs.

It is generally argued that farmers in developing countries are "poor but efficient" (Schultz). Farmers allocate their resources efficiently in light of their life-long experiences. But with the availability of rapidly changing new crop production technologies, improved modern inputs, and ever-changing government policies, farmers are required to adjust and readjust their farm plans frequently with less information available than before. The farming business is becoming more and more sophisticated and risky. There is a common saying that "farmers are found in fields - plowing up, seeding down, rotating from, planting to, fertilizing with, spraying for and harvesting if". Fluctuations in income per acre of major agricultural crops shown in Figure 2 provide some insights of the risk and uncertainty that farmers face.

Few would disagree that agricultural production is a risky process. Available literature suggests that most farmers, especially subsistence farmers, are risk-averse and that risk aversion tends to be more common among small farmers (Dillon and Scanizzo). The inclusion of farmers' risk behavior in farm planning models is well discussed in the literature. It is generally believed that unless risk responses are adequately considered in agricultural planning models, the results generated in empirical analysis may be of little use either in

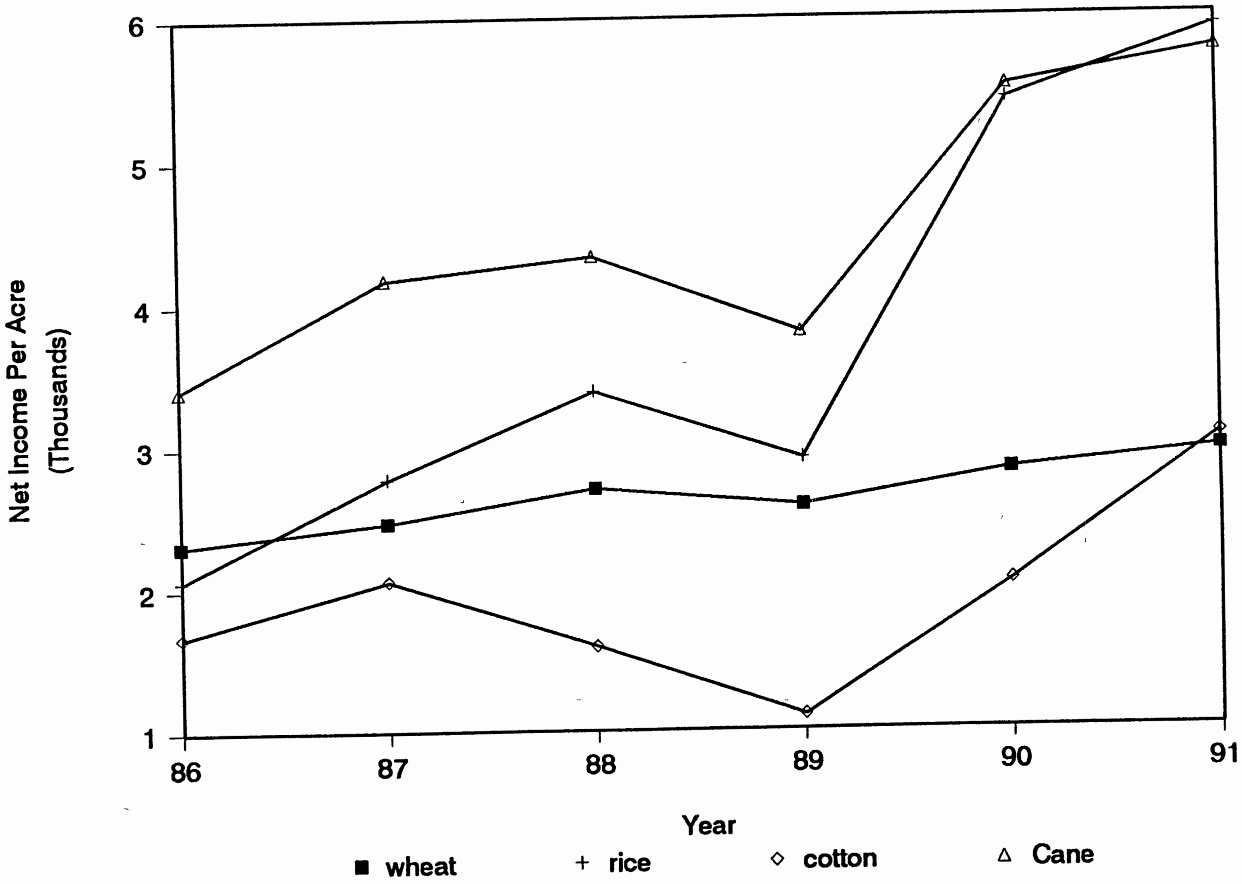


Figure 2. Income Volatility of Major Crops

direct decision making or in policy analysis (Brink and McCarl, Boisvert and McCarl). It is further stressed by Hazel (1982) that neglect of risk averse behavior of farmers can result into an overstatement of the output levels of risky enterprises and overly specialized cropping patterns. Moreover, it can lead to biased estimates of supply elasticities of individual commodities. Over-estimation of the value of farm resources such as irrigation water and land, and incorrect prediction of technology choice may also be experienced as a consequence of ignoring risk in farm planning models.

Conventional linear programming models are widely accepted as a method for determining profit maximizing resource allocation. But given the fact that they ignore risk, they can provide misleading results and result in farm plans that may not resemble the actual farm plans of the decision maker. The use of risk programming models to eliminate these problems seems desirable.

## Objectives of the Study

The main objective of this study is to analyze the financial characteristics of Pakistani farming systems and to determine risk efficient optimal farming systems given existing economic and financial conditions. This objective is achieved by conducting assessments of selected Pakistani farms. A key contribution of this study is the modification and application of IFFS to perform these assessments.

Based on the information generated from IFFS analysis, further research is undertaken to apply linear programming, risk programming, and multiple objective goal programming procedures to determine optimal farming systems. From results of the optimization analysis, conclusions and recommendations regarding resource allocation, credit needs, and price structures are made.

The specific objectives of the study are to:

1. analyze the financial problems of selected farming systems at the farm level,

2. estimate the short-term credit needs of selected existing farming systems,

3. determine profit maximizing farming systems given the current credit availability,

4. determine the optimum farm resource allocation and enterprise combinations in a risky environment, and

5. analyze the sensitivity of optimal farm plans to changes in prices, institutional credit terms and availability, and labor availability.

## Organization of the Dissertation

The rest of the dissertation is organized into five chapters. Chapter II considers the need for whole farm analysis to provide a sound basis for modeling and reviews the past developments in risk analysis. It also focuses on conceptualizing, modeling, and measuring risk in decision analysis.

Chapter III specifies the research model used in this study. It presents detailed descriptions of the objective function, activities, constraints, assumptions, and limitations. Sources of data and the details of the method used to collect data are also provided in this chapter.

Chapter IV presents the results of farming systems analysis. Applications of the IFFS model and its results are provided in this chapter. Credit needs and cash flow problems of growers are identified.

Chapter V addresses the risk analysis of farm business. Profit maximizing optimal farming systems are also identified in this chapter using linear programming techniques. Risk efficient optimal farm plans are identified by using MOTAD and Target MOTAD models, and efficient frontiers are traced through parametric solutions. Then compromise programming techniques are utilized to identify subsets of the MOTAD and Target MOTAD frontiers with superior utility levels. Identification of the subsets of alternative farming systems makes the farming systems selection process easier for the decision maker.

Chapter V also considers the application of the model for sensitivity analysis. It shows how changes in government policies regarding output prices and institutional credit can affect farming business at the farm level.

Chapter VI presents a summary of the results and findings of the analysis. Policy implications for resource allocation and future planning are discussed. Finally, areas for further research are identified and discussed.

# CHAPTER II

# CONCEPTUAL FRAMEWORK AND EMPIRICAL TECHNIQUES FOR FARMING SYSTEM ANALYSIS IN A RISKY ENVIRONMENT

Agriculture in Pakistan is entering into a new era of commercialization. In the process of transforming from traditional subsistence agriculture to commercial agriculture, farmers are required to have a good knowledge about what alternatives are available and the consequences of each alternative. Planning procedures that systematically evaluate the effect of the interaction of production, marketing and financing on the profitability of alternative farming systems are rapidly becoming a major requirement for sound decision making. It is noticed that with the increasing complexities of farm business coupled with the higher use of capital, farmers are realizing the tremendous need for assistance in financial management (Hornung and Dalsted).

This chapter reviews different techniques available for whole-farm planning. Farm budgeting is one of the most commonly used techniques in whole-farm analysis. The use of the IFFS model for whole-farm planning is discussed. The other commonly used techniques in whole-farm analysis include linear programming and risk programming models. The concept of risk is explained and sources of risk are discussed. The conceptual framework for farm decision making under risk is explained and some empirical techniques of measuring risk are discussed in this chapter.

## Farm Financial Planning Models

In commercial agriculture, farmers need to base their decisions on a combination of financial data, production data, and efficiency measures to analyze the strengths and weaknesses of their business. To assist farmers in evaluating their business, many computerized financial analysis programs have been developed. Frey and Klinefelter designed a "Coordinated set of Financial Statements" (CFS) that includes a balance sheet, an income statement, statement of owner equity, statement of change in financial position, and a cash flow statement.

Another microcomputer software package, the "Integrated Farm Financial Statements" (IFFS) program has been developed by Love et al. (1988). It provides users with a thorough description of the farm's financial health, cash flow situation, credit needs, and profitability of enterprises. The IFFS model allows users to construct simulations of farming enterprises (Wallace). The IFFS model is used extensively by Oklahoma State University and many other universities. Further details of the IFFS model are given in Chapter III.

The IFFS model, as well as most other whole-farm planning models such as FINPACK, (as mentioned by Spears) and CFS ignore the risk and uncertainty that farmers face. It uses only expected values for the two key variables, price and yield. Realizing the importance of risk in farm planning models, Spears modified IFFS to incorporate risk analysis into whole-farm planning. He added a simulation model in IFFS which provides a mechanism capable of generating correlated multivariate distributions of yield and prices. Because of this addition, Spears's IFFS Risk Analyser requires the user to provide additional data to quantify the distributions and correlations involved.

Thus better record keeping of historical yield data and identification of correlations between enterprise yields and prices are required.

The IFFS Risk Analyser provides useful information in analyzing farm business, however, it does not solve for optimal resource allocation. However, other available farm planning models that include risk generate risk efficient farm plans that can be analyzed for their consistency and for cash flow problems by using IFFS.

## Role of Risk in Farm Planning Models

In developed countries, risk issues remained relatively unimportant in farm management research until the 1950s. Prior to the 50s, more attention was given to problems like low farm incomes and misallocation of farm resources. In developing countries agriculture witnessed substantial structural changes after green revolution in the 1960s. Hence, resource allocation problems received relatively high priority in agricultural research until recently. With the improvement of farmers' income positions, risk and uncertainty issues in agriculture became prominent in farm planning. Recently, Sheikh et al. have identified the need for research on the role of risk aversion in crop and livestock production decisions in Pakistan.

## The Concept of Risk

Risk has been defined in many different ways. Risk and uncertainty have recently become interchangeable terms in the literature. In 1921, Knight suggested a distinction between risk and uncertainty on the basis of probability. Knight argues that if the probabilities are known, the problem is one of risk. In contrast, if the probabilities are unknown, the problem is one of uncertainty.

With the introduction of the subjective concept of probability, this distinction appears to no longer be applicable in agriculture. Farmers can virtually attach subjective probability to any uncertain event from their past experiences.

In applied research, risk is generally defined as variability of income or net returns. Risk is often measured by measures of dispersion such as variance, standard deviation or the coefficient of variation. Sometimes risk is defined as a chance of loss or the probability that random net income (Y) will fall below some disaster level. Algebraically it can be written as:

(2.1) $\Pr(Y < d) = \alpha$

where Y is income and d is some disaster level.

Other possible measures often discussed in literature include: (1) the standard deviation; (2) the probability of loss; (3) the expected value of loss; (4) the expected absolute deviation; and (5) the maximum loss. Freund introduced risk in farm planning models and described risk as variance of net revenues. Hazel (1971) defined risk as negative deviations from the mean. Some researchers like Roy, Telser, and Kataoka (reviewed in Robison et al.) defined risk in terms of safety first. They assume that the probability of not achieving some critical value of gross margin together with the expected income are the crucial elements of the decision objective.

In this analysis, risk is defined as the negative deviation of net farm income from its expected value. It is assumed that farmers do not attach any disutility to positive deviations from the mean income. Risk of net farm income falling below a critical level is also considered in this study.

## Sources of Risk in Agriculture

The biological nature of crop and livestock production is the most often cited source of risk in agriculture. In general, other businesses do not face this source of risk. Sonka and Patrick identify five major sources of business risk in agriculture: "(1) production or technical risk; (2) market or price risk; (3) technological risk; (4) legal and social risk; and (5) human sources of risk".

According to Barry, farmers' total risk includes business risk and financial risk. Barry shows that business risk (BR) and financial risk (FR) together determine total risk (TR) in a multiplicative way:

$$(2.2)\quad TR = BR * FR$$

where TR is expressed by the coefficient of variation for equity holders and BR is the coefficient of variation for risky assets.

$$(2.3)\quad FR = TR/BR$$

$$(2.4)\quad FR = \frac{S_a P_a}{r_a P_a - i_d P_d} / \frac{S_a}{r_a}$$

$$(2.5)\quad FR = \frac{r_a P_a}{r_a P_a - i_d P_d}$$

$$(2.6)\quad TR = \frac{S_a}{r_a} * \frac{r_a P_a}{r_a P_a - i_d P_d}$$

where $S_a$ is the standard deviation of return to the risky assets, $r_a$ is the expected return to the risky assets, $i_d$ is the interest rate on debt, $P_a$ is the proportion of risky assets in the portfolio, and $P_d$ is the proportion of the risk-free asset (debt) in the portfolio (Pederson and Bertelson).

## Farm Decision Making Under Risk

Farmers face the problem of ranking farm plans on the basis of their income distributions and to select the one that provides maximum utility. Utility is derived from the consumption. Consumption, in turn, is a function of income (Freund, and Kaiser and Boehlje). Farmers' utility function can then be described as:

(2.7) $U = f(Y)$

where Y is the income earned by using a specific farm plan. A functional form of utility function is required that accurately describes the farmer's behavior. Because theory predicts that risky alternatives will be ranked by their expected utility, the choice of functional form describes the risk preferences of the farm decision maker.

If it is assumed that a farmer's utility function is best described by the quadratic function and that the income earned by using a farm plan is uncertain, the utility function of the farmer may then be written as follows:

(2.8) $U(Y) = a + \alpha Y + \beta Y^2$

where a, $\alpha$ and $\beta$ are constants (Hazel and Norton,1986; Kaiser and Boehlje; and Dillon). As farmers rank their farm plans on the basis of their expected utility, taking the expected value of (2.8):

(2.9) $E[U(Y)] = a + \alpha E[Y] + \beta E[Y^2]$

(2.10) $E[U(Y)] = a + \alpha E[Y] + \beta E[Y^2] - \beta E[Y]^2 + \beta E[Y]^2$

(2.11) $E[U(Y)] = a + \alpha E[Y] + \beta V[Y] + \beta E[Y]^2$

where E[Y] is the mean of income and V[Y] denotes the variance of income. Equation (2.11) above shows that the farmer's utility function can be specified in terms of mean and variance such that:

(2.12) $U = f(E, V)$

where E denotes mean income and V equals variance of expected income. By keeping U constant at $U^o$, E-V indifference curve can be traced and be plotted in E, V space.

For a rational producer, ∂U/∂ E[Y] must be positive over the relevant range of a quadratic utility function, i.e. if the variance of income is constant, utility increases with the increase in mean income. Producers will prefer farm plans with higher income and lower variance. If the two farm plans have the same variance, the plan with higher income will be preferred.

A farmer's attitude towards risk is inferred from the shape of his utility function. If ∂U/∂ V[Y] = β is positive, it implies that the decision maker is a risk preferrer and variability of income is desired. When β > 0, it shows that greater income variances are associated with greater utility. On the other hand, if β is negative, it implies that the decision maker is a risk averter and that variability of income is disliked (Dillon, 1971; Kaiser and Boehlje). A decision maker is considered to be risk neutral if β =0.

Graphically, when utility is made a function of income, a function concave to the origin implies risk aversion, a linear utility function implies risk neutrality, and a convex function implies risk preference. A decision maker may also have a utility function with both concave and convex segments indicating changes in risk attitudes for different income levels. Figure 3 presents examples of all three risk/utility relations.

Unique optimal farm plans can be found by maximizing expected utility if farmer's preferences are known. Available literature shows that it is hard to measure individual utility functions with precision. Utility functions are unique to decision makers and may not be stable over time because they vary with the income level and other socioeconomic conditions of the household (Dillon and Scandizzo; Binswanger).

Attitude literature suggests that due to cognitive biases the typical methods of elicitation may not yield accurate utility functions and subjective probability functions. Moreover, eliciting an individual farmer's utility functions is expensive

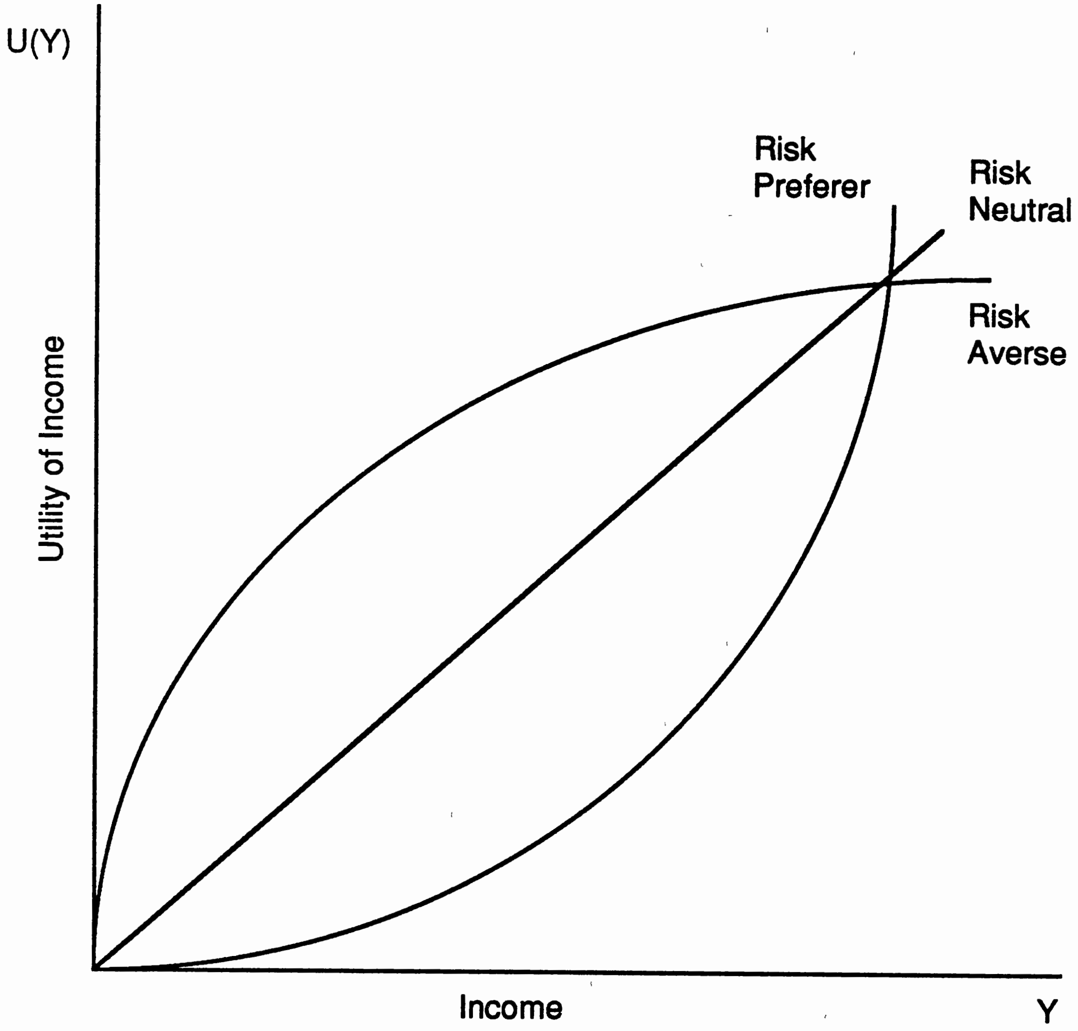


Figure 3. Three Functional Forms of Utility Function

and time consuming. Hazel (1982) concluded that direct elicitation of utility function approach will never be widely adopted in farm planning.

## Risk Efficiency Criterion

Another approach that is based on the expected utility maximization framework but does not require full specification of the utility function is called Risk Efficiency Analysis. Given specific restrictions on decision maker's preferences, the Risk Efficiency criterion will provide a partial ordering of choices. The Mean-Variance (E-V) analysis is perhaps the most widely used efficiency criterion. The E-V approach assumes the decision maker is risk averse and has a quadratic utility function. Outcome distributions are also assumed to be normally distributed. The E-V criterion can be stated as: if A is an outcome distribution with mean EA and variance VA and B is another outcome distribution with mean EB and variance VB, then A is preferred to B only if $EA \geq EB$ and $VA \leq VB$ and at least one inequality strictly holds.

## Mathematical Analysis Techniques for Risk Analysis

In risk programming models, it is important to identify the key elements of risk to be studied. The problem of risk and uncertainty may stem from: a) the uncertainties in activity costs, yields and prices (objective function risk); b) the changes in production technology (technical coefficient risk); and c) the uncertainties in the availability of resources (right hand sides risk). Most risk programming models deal with objective function coefficient uncertainty. Farm prices and yields are major sources of risk that affect the objective function. In many studies the two sources of risk are combined to consider only variability in gross margins for individual crop and livestock enterprises. Quadratic programming has been considered as a useful method to incorporate risk in farm planning models.

## Quadratic Programming

The general formulation of a quadratic programming (QP) model as developed by Freund is as follows:

(2.13) $\text{Max } E\,[U(Z)] = X'U - \phi X'\sigma X$

subject to

(2.14) $A\,X \leq B$

(2.15) $X \geq 0$

where X is a vector of activity levels, U is vector of expected returns, B is a vector of resource constraints, $\sigma$ is a variance covariance matrix, and $\phi$ is a risk aversion coefficient.

An alternative form of quadratic programming model reported by Hazel and Norton (1985) is:

(2.16) $\text{Min } V = \sum_{j=1}^{n} \sum_{k=1}^{n} X_j X_k \sigma_{jk}$

such that

(2.17) $\sum_{j=1}^{n} F_j X_j = \lambda$ ($\lambda$ = 0 to unbound)

and

(2.18) $\sum_{j=1}^{n} a_{ij} X_j \leq b_i$ (for all i, i = 1 to m)

(2.19) $X_j \geq 0$ (for all j, j = 1 to n)

where $F_j$ denotes the expected gross margin of the jth activity and $\lambda$ is a scaler.

The major difference between these two formulations is the specification of $\phi$ and $\lambda$. The advantage of using Freund's formulation is that it directly determines the risk aversion parameter associated with each point on the frontier (Boisvert and McCarl).

Quadratic programming assumes that a farmer's utility is a function of expected income E and associated income variance V. QP further assumes that the farmer is a risk averter (Hazel, 1971). The E-V frontier can be traced by parameterizing $\lambda$.

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 OB in Figure 4 describes the E-V efficient frontier. The other three curves in Figure 4 denote hypothetical iso-utility curves denoting the farmer's preference between risk and income. Given these curves, point A in Figure 4 depicts the point of utility maximization. The farm plan that is associated with point A is the optimal farm plan.

Quadratic Programming is considered an effective tool of analysis in farm planning under risk. It is particularly attractive for farm management research. The major advantage of Quadratic Programming technique is that the criterion is consistent with the separation theorem and given a riskless option it allows a more general solution to the farm diversification problem (Johnson).

Despite its considerable potential, problems do arise in applying Quadratic Programming due to the limited availability of QP computer software, computational difficulties and doubts about the performance of the available packages. These programs tend to suffer severely from rounding errors. Unfortunately, any two solution packages seldom perform the same (Hazel, 1971; McCarl and Tice). With the development of new powerful non-linear

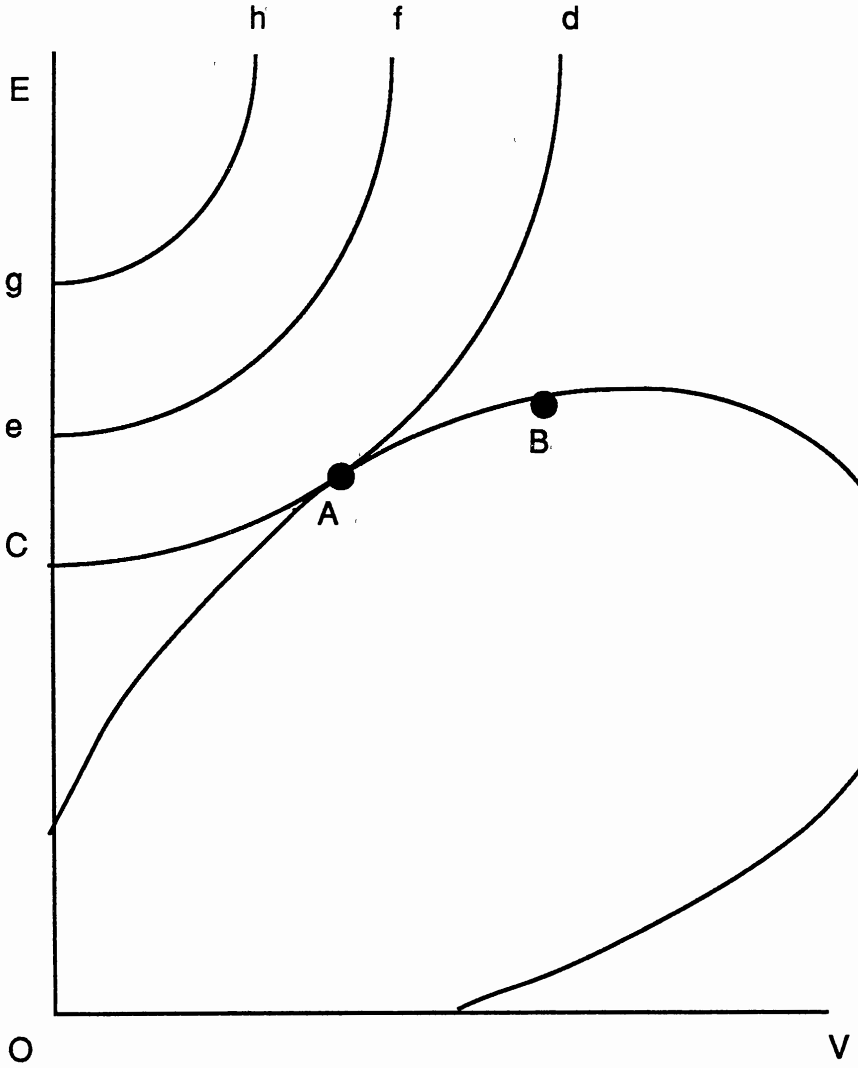


Figure 4. The Optimal E-V Farm Plan

programming algorithms, it is argued that computational difficulties are now less important (Boisvert and McCarl). Moreover, problems can also arise when the variance-covariance matrix is only semi-definite rather than positive definite (Johnson). Some other limitations of QP include the difficulty in the choice of the risk aversion coefficient and general problems of accuracy in data on income variance and covariances (Anderson et al., 1977).

## MOTAD – A Linear Approximation

Several linear approximations to E-V model have evolved (Hazel, 1971; and others as reviewed in McCarl and Tice, 1982). Only MOTAD is discussed here because it is extensively used (Hazel, 1971; Hazel and Seandizo; Schurle and Ervin, 1979; Mapp et al.) in the literature and is considered to be a reasonable substitute for quadratic risk programming (Anderson et al., p. 211; Hazel, 1971).

The acronym MOTAD stands for Minimization of Total Absolute Deviation. The MOTAD model is formulated to identify a set of risk efficient farm plans based on expected income and mean absolute income deviation. In a MOTAD model, risk is measured by absolute deviation from mean returns rather than by the variance of total returns. The mean absolute deviation (MAD) of income is defined as:

$$(2.20) \quad A = \frac{1}{S} \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (C_{hj} - g_j) X_j \right|$$

where

A = an unbiased estimator of the population mean absolute income deviation

S = the number of years of sample observation

n = the number of activities

$C_{hj}$ = the gross margin for the jth activity for the hth year

$g_j$ = the sample mean gross margin for the jth activity

$X_j$ = the level of jth activity

Because the sum of negative gross margin deviations from the mean must equal the sum of the positive gross margins deviations from the mean, the MOTAD model can be reduced to minimize only the sum of absolute values of the negative total gross margin deviations. The total negative gross margin deviations can be defined as:

$$(2.21) \quad Y^{-}_{h} = \left| \sum_{j=1}^{n} (C_{hj} - g_j)\ X_j \right|$$

where $\sum_{j=1}^{n} (C_{hj} - g_j)\ X_j$ is negative if $(C_{hj} - g_j) < 0$ and zero otherwise. The MOTAD model can be written in the following mathematical programming model.

$$(2.22) \quad \text{Min} \sum_{h=1}^{s} Y^{-}_{h}$$

subject to

$$(2.23) \quad \sum_{j=1}^{n} (C_{hj} - g_j)\ X_j + Y^{-}_{h} \geq 0 \qquad h = (1\text{---}S)$$

$$(2.24) \quad \sum_{j=1}^{n} F_j X_j = \lambda \qquad \lambda = (0 \text{ to unbound})$$

$$(2.25) \quad \sum_{j=1}^{n} a_{ij} X_j \leq bi \qquad i = (1\text{----}m)$$

$$(2.26) \quad X_j,\ Y^{-}_{h} \geq 0$$

where

$Y^{-}_{h}$ = absolute total negative gross margin deviations

n = number of activities in the model

$F_j$ = the expected gross margin for the jth activity

$\lambda$ = the expected total gross margin.

The model can be solved parametrically for various values of $\lambda$ to trace out an E-A frontier.

Anderson et al. (1977) suggested an alternative formulation for MOTAD where expected returns are maximized with a parametric constraint on the sum of negative deviations. In mathematical programming, the model can be written as:

$$(2.27) \quad \max \sum_{j=1}^{n} F_j X_j$$

such that

$$(2.28) \quad \sum_{j=1}^{n} (C_{hj} - g_j) X_j + Y^{-}_{h} \geq 0$$

and

$$(2.29) \quad \sum_{j=1}^{n} a_{ij} X_j \leq bi$$

$$(2.30) \quad \sum_{h=1}^{s} Y^{-}_{h} \leq \lambda \qquad \lambda = 0 \text{ to } \lambda \text{ max}$$

$$(2.31) \quad X_j, Y_h \geq 0$$

Even though the MOTAD model has been used extensively in agricultural research, some researchers have criticized it. They have argued that it may prove misleading if the decision maker's utility function is not quadratic or the distribution of returns is not normal (Okunev and Dillon). In contrast, Second Degree Stochastic Dominance (SSD) technique is theoretically more appealing because it is less restrictive. Though SSD is theoretically ideal for risk averse decision makers, in the context of portfolio-type problems it has significant disadvantages compared to the MOTAD and E-V approaches (Okunev and Dillon). The MOTAD and E-V approaches help in optimizing resource allocation. Sensitivity analysis allows examination of the impacts of different alternatives on farm income and risk while SSD helps only in ranking the alternatives. Tauer developed a modification of MOTAD that is generally called Target MOTAD that provides solutions which are also SSD efficient.

### Target MOTAD

The concept of Target MOTAD formulation is based on the assumption that decision makers often wish to maximize expected returns but are concerned only about net returns falling below a critical target level. In Target MOTAD, expected returns are maximized with a restriction on the level of negative deviations from the target. Mathematically, the model is stated as:

$$(2.32) \quad \max \sum_{j=1}^{n} f_j x_j$$

subject to

$$(2.33) \quad \sum_{j=1}^{n} aij\ xj \leq bi$$

$$(2.34) \quad \sum_{j=1}^{n} C_{hj} x_j + Y^-_h \geq T$$

$$(2.35) \quad \sum_{h=1}^{s} P_h Y^-_h = \lambda$$

$$(2.36) \quad xj, Y^-_h \geq 0$$

where

$T$ = target level of return

$P_h$ = probability that state of nature or observation h will occur

$Y^-_h$ = negative deviation of income under the hth state of nature below the target income

$\lambda$ = maximum amount of the average income shortfall permitted ($\lambda = 0$ to m)

m = a large number.

All other definitions are defined for the MOTAD model.

The Target MOTAD model maximizes expected income subject to the resource constraints and two additional constraints. First, the relationship between income under the hth state of nature and a target level of income is established in equation (2.34). If the income in any one year is more than the target, $Y^-_h$ will be zero. On the other hand, if the revenue is less than the target T the difference is transferred to equation (2.35) via variable $y^-h$. Second, the constraint in equation (29) requires the average shortfall to be more than a parameter $\lambda$. In fact, the target MOTAD has two parameters, $\lambda$ and T, to specified and parameterized to get different risk solutions.

## Compromise MOTAD

Like MOTAD, target MOTAD also generates a subset of all the risk efficient farm plan. It is often left with the farmer to select one of these plans. Some researchers consider that this is only the first stage in the solution process and the decision maker may be interested in obtaining a definite solution (Berbel, 1988) or at least a smaller subset of efficient plans to choose from. For a definite solution, a reliable mathematical form of the decision maker's utility function is required. In practice, it is difficult to establish a reliable and stable utility function for a farmer (Dillon and Scandizzo). Attitude literature further argues that elicited utility functions are valid only in the context of a particular decision. By using compromise programming techniques, this difficulty can be mitigated considerably (Romero et al., 1988; Zelenly, 1982). Compromise programming helps identify the bounds of that portion of the efficient set where the tangency between the iso-utility curve and the E-A frontier occurs without having any assumptions on the shape of these curves (Romero et al., 1988). This technique is also helpful in finding a compromise among conflicting objectives such as maximizing returns while minimizing risk at the same time (Romero et al., 1987). Compromise programming can be incorporated in the MOTAD model to overcome the above mentioned difficulties. The proposed mathematical programming model is a modification of MOTAD defined here as "Compromise MOTAD". General mathematical formulation of Compromise MOTAD is as follows:

$$(2.37) \quad \text{Min } L_1 = \sum_{k=1}^{p} W_k \left[ \frac{Z_k^* - Z_k(x)}{Z_k^* - Z_{*k}} \right]$$

subject to

$$(2.38) \quad \sum_{j=1}^{n} (C_{hj} - g_j)\, x_j + Y^-_h \geq 0$$

$$(2.39) \quad \sum_{j=1}^{n} a_{ij}\, x_j \leq b_i$$

$$(2.40) \quad x_j, Y^-_h \geq 0$$

where $Z_k^*$ is the highest value and $Z_{*k}$ is the lowest value for the kth objectives, and $W_k$ is the weight associated with kth objective. All other definitions are the same as defined for the MOTAD model. Further details of Compromise MOTAD model are given in Chapter III.

## Some Applications of Risk Programming Models

Risk programming models are widely used for analysis of risk management strategies for farming business. Quadratic Programming (QP) and the MOTAD model are the most commonly used programming models. QP is used as an alternative to the portfolio theory of Markowitz. Freund (1956) used QP for minimizing portfolio variance at different levels of expected income. Realizing the computational difficulties of QP models, Hazel (1971) suggested a linear programming alternative. The MOTAD approach has been used in many studies. Tauer (1983) developed a modified MOTAD, the Target MOTAD. Some researchers applied Compromise Programming with MOTAD. Some selected applications of MOTAD, Target MOTAD, and Compromise Programming are discussed below. (For a detailed survey of applications of risk programming models, see Boisvert and McCarl.)

Brink and McCarl (1978) specified a MOTAD model for each of 38 corn belt crop farmers. The model formulation used was:

(2.41) $\max \overline{C}X - \varepsilon KLd$

subject to

(2.42) $AX \leq B$

(2.43) $DX + Id \geq 0$

and

(2.44) $X, d \geq 0$

where X, A, B and $\overline{C}$ respectively represent activity levels, resource uses, resource availabilities, and gross margin expectations. D is a matrix of gross margin deviation, d denotes yearly total negative deviations, L is a row vector of ones, k is a constant, and ε is a risk aversion coefficient. Parameterization of ε generates a set of efficient farm plans. The farmer's risk aversion coefficient was identified as that value of ε which minimized the difference between associated plan in the efficient solution set and the farmer's present plan.

Schurl and Erven (1979) studied the issue of sensitivity of efficient frontiers developed by using MOTAD. They constructed a MOTAD model for a 600 acre representative farm. The sensitivity of the frontier was checked by excluding selected enterprises one by one. All of the new frontiers were found to lie to the right of the original frontier, indicating increased risk due to the different enterprise combinations.

Mapp et al. (1979) developed a MOTAD model for a representative farm in Oklahoma. They generated efficient farm plans by using MOTAD and then used a simulation model to evaluate the feasibility of those plans under alternative economic scenarios. They found that the MOTAD model demonstrated the ability to reduce relative variability through diversification.

Kaiser and Boehlje (1980) developed a multiperiod MOTAD model to analyze the risk and return of a farm's investment, production, and marketing plans. The results showed evidence of the benefits of enterprise diversification. Other means used to reduce risk included off-farm employment, share-cropping, and limited use of credit.

Held and Zink (1982) applied MOTAD to evaluate enterprise combinations for an irrigated farm in Wyoming, considering income and risk. They also studied the effects of excluding livestock feeding from the farm plans on farm income and its variability. To obtain detailed information on crop production practices, a group interview approach was followed. Their results confirm that higher income crop mixes are achieved only at the cost of additional income risk.

Tauer (1983) developed a Target MOTAD model. He demonstrated that the Target MOTAD model is second degree stochastically dominate (SSD). He analyzed three crop activities with net revenue data for five years. Stochastic dominance analysis was conducted with the data using frequency intervals. The results demonstrated that Target MOTAD solutions were efficient by SSD, but MOTAD results were not necessarily first degree stochastically dominate (FSD) or SSD.

Watts et al. (1984) provided a comparison of Target MOTAD to MOTAD. They showed that comparing risk based upon different risk reference points such as the mean is undesirable. They argued that minimizing negative deviations from a target is congruent with the actual behavior of decision makers and stochastic dominance relationships. They derived risk-income frontiers using MOTAD and Target MOTAD for a representative farm in Wyoming. They used a six-year period of historical net return data to develop an income series. Their results show that the Target MOTAD model is a more plausible approach and is more consistent with recent risk literature.

Zimet and Spreen (1986) used Target MOTAD to analyze an optimal farm organization for a typical crop and livestock farm in Florida. Their results suggest that farmers allocate their resources by considering the income risk involved. The results of a deterministic linear programming model did not resemble the actual resource allocation at the farm level. The results of a Target MOTAD model were closer to the actual farm situation and suggest that the persistence of cow-calf production, despite its low net returns, may be explained by its stabilizing influence on income.

Helmers et al. (1986) used a MOTAD and a Target MOTAD model to analyze the risk-income performance of three corn varieties, four soybean varieties, and four wheat varieties using historical yield variability data, product prices, and variable costs for each crop. MOTAD and Target MOTAD efficient frontiers were generated. The Target MOTAD solutions contained higher levels of Cumberland soybeans, Pella soybeans, and Cargill corn relative to the MOTAD solutions.

Pederson and Bertelsen (1986) used Target MOTAD and simulation methods to analyze the opportunity to reduce whole-farm risk in a diversified cash farm crop. Forty possible activities were specified in the model. Results of a Target MOTAD showed that risk reduction was achieved through traditional enterprise diversification. Risk-efficient strategies derived from the Target MOTAD model were simulated to monitor farm financial performance.

McCauley and Kliehenstein (1987) presented a method to identify the complete set of Target MOTAD solutions. They described Target MOTAD as a two-parameter model, and the complete set of Target MOTAD solutions can be identified by parametric programming. They also described a method to identify the lower and upper boundary for $\lambda$.

Curtis et al. (1987) employed a Target MOTAD model to determine an efficient marketing strategy for soybeans. Due to the increased price volatility associated with soybeans, they realized the need for identifying risk-reducing marketing strategies for farmers. They examined the expected returns and variation in returns of 103 soybean marketing strategies available to farmers from 1978 to 1983. They derived risk efficient frontiers of marketing portfolios associated with specified target income levels.

Romero et al. (1988) used a MOTAD model to generate an efficiency frontier and then applied a compromise programming model to identify the best-compromise solution closest to an ideal point. They named this approach compromise risk programming. An ideal point is defined. Then distance functions are used to identify a point on the efficient frontier that is closest to the ideal point. By using different distance functions, a subset of the efficient frontier can be traced that is called the compromise solution set. Romero et al. (1987) provides a detailed description of compromise programming and its applications in agricultural planning.

Berbel (1988) used a modified Target MOTAD model and named it the "mean-partial absolute deviation (mean-PAD) model". The structure of the mean-PAD model is:

(2.45) Eff (GM, PAD)

(2.46) $GM = GX$

(2.47) $PAD = \sum_{i=1}^{m} P_r(i)\ N(i)$

subject to

(2.48) $AX \leq b$

(2.49) $S(i)X + N(i) \geq t$ for $i = 1, ..., m$

where Eff means the efficient set, GM = gross margin, G = vector of expected gross margins per unit of activity level, A = matrix of technical coefficients, X = vector of activity levels, PAD = probability - weighted sum of negative deviation from t for the m years (states of nature), S(i) = vector of gross margin for the m years, N(i) = vector of negative deviations, t is a parameter (scalar). An efficiency frontier has been traced parametrically. For identifying a superior solution on the frontier, compromise programming is proposed.

The role of options in soybean marketing was examined by Frank et al. (1989). They used the Target MOTAD algorithm to generate efficient portfolios of marketing strategies. Results indicated that options strategies are important components in efficient portfolios of marketing activities.

Novak et al. (1990) applied Target MOTAD to assess the risks and returns of sustainable cotton crop rotations. The Universal Soil Loss Equation (USLE) was used to calculate potential annual soil losses from sheet and rill erosion under the six cropping systems. Ten years of crops data were used to analyze the profitability of six rotations. Risk-returns for permitted soil loss (three tons/acre/year) were analyzed using a Target MOTAD model. The study results suggest that diversification in rotations results in the least risk for a given level of target income.

Misra and Spurlock (1991) developed a Target MOTAD model to analyze intra-year impacts on profit due to the variations in timing of planting and harvesting as well as to capture inter-year impacts on profit that arise from fluctuations in weather and economic factors. Delays in field work may occur due to unfavorable weather or due to the limited capacity of the planting or harvesting equipment. The loss in profit due to less timeliness is considered in the model. Even though earliness showed significant benefits, a combination of maturity management practices performed better than a single practice.

Paxton, Vandeveer and Lavergne (1992) evaluated the potential benefits of irrigation using a Target MOTAD model. They used subjective yield expectations data for developing enterprise gross margin series. Yield estimates for both dryland and irrigated conditions were obtained from the farmers using a direct interview method. The target income used in the model was an expected income level that allowed the farm to meet all of its financial obligations. Results showed that irrigation offers substantial potential to increase farm income and to reduce relative risk.

In Pakistan, none of the risk programming models discussed have been applied to analyze farm resource allocation problems or to assist in agricultural planning. Results of this study will provide useful information to agricultural producers, extension workers, and policy makers. Hopefully, this study will stimulate further research in this important area.

# CHAPTER III

# THE MODEL AND DATA DEVELOPMENT

In this study, analysis is done in three sections. In the first section, farming systems are analyzed using IFFS to visualize a clearer picture of alternative farming systems. The resources available with the farm are determined and cash flow problems are identified. The second part of the analysis deals with risk analysis. Risk analysis is performed under two scenarios: 1) it is assumed that farmers allocate their resources in a way that minimizes the variability of portfolio income; and 2) farmers maximize their expected net returns, but they are concerned about their income falling below a target income. In the third part of the analysis, Compromise MOTAD techniques are applied to help the decision maker in picking a farm plan from the efficient set.

## The IFFS Model

The Integrated Farm Financial Statements (IFFS) model is a whole farm financial planning template designed to facilitate the financial analysis of farms or ranches. IFFS requires a working knowledge of Lotus 1-2-3 by the user. It operates around three independent Lotus 1-2-3 worksheet files: CLBUD, AI, and MULTSTAT. The Crop and Livestock Budget Management (CLBUD) and Additional Information (AI) file can be used to build Cash Flow Statement from enterprise budgets. The Multiple Year Integrated Statements (MULTSTAT) file can be used to generate a Cash Flow Statement, Net Worth Statement, Debt

Worksheet, Income Statement, and a set of Financial Ratios. These financial statements are constructed by a combination of direct keyboard entries of data and transfer of data from other worksheets within IFFS. Figure 5 illustrates the operational relationships between the different components of IFFS.

The flow of information between the respective worksheet files is shown in the flow chart. The arrows indicate the direction of flow of information within each worksheet and between worksheets. The boxes and ovals indicate where direct keyboard entry is made by the user and where the computer is processing data, respectively.

CLBUD is a crop and livestock budget file. It uses menus to guide the user, and macros to perform various functions such as loading, saving, and printing of budgets. CLBUD contains specific enterprise budgets for almost all enterprises. Each enterprise budget is particularly designed for that enterprise to include the type of units, common revenue items, expense items, and timing of cash flows associated with that enterprise. Each enterprise budget is saved under a unique name to be used in the Cash Flow Statement.

Each enterprise budget contains information about revenues and expenses and can be printed separately. For more accurate information, timing of expenses and revenues must be entered by the user. The main purpose of CLBUD is to construct enterprise budgets which will in turn be used in constructing cash flow statements. A commonly used file showing expenses and revenues is given in Figure 6.

The Additional Information (AI) worksheet supplements CLBUD in the creation of cash flow statement. The AI worksheet provides information on farm and non-farm revenues and expenses that are not directly attributable to any one crop or livestock activities, such as non-farm income, family living

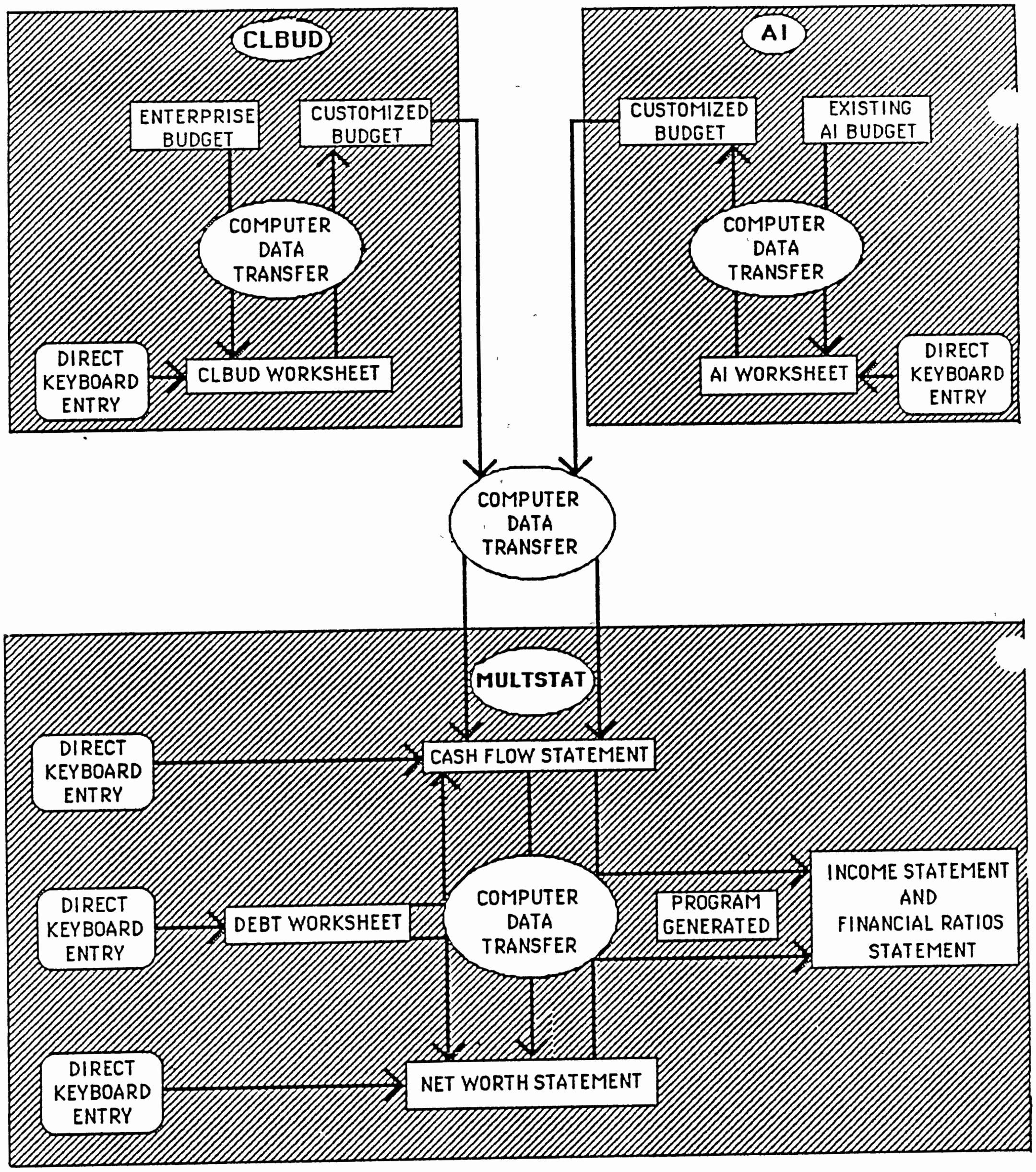


Figure 5. Relationship Among the Components of Integrated Farm Financial Statements (IFFS)

<<ENTERPRISE BUDGET WORKSHEET>> NAME: NOOR AHMAD DATE: FIELD: File: RICE
Enterprise: RICE OWN

| | | | | | |
|---|---|---|---|---|---|
| Number of acres: | 4 | Quantity stored: | 14 Md. | | |
| Acres Harvested | 4 | | | | |
| Yield: per acre | 47.00 Md/ac | | | | |
| Price: per Md | RS 138/Md. | | | Percent change in costs | 0.00% |
| Operator's share | 100.0% | | | | |
| Gov't Pymts | RS 0 | Interest rate | 0.00% | Error Check | 0 |

| | PER UNIT | TOTAL | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <<OPERATING RECEIPTS>> | | | | | | | | | | | | | | |
| Crop sales· | | | | | | | | | | | | | | |
| Description unit price quan. | | | | | | | | | | | | | | |
| RICE Md 138 47 | 6003 00 | 24012 | | | | | | | | | | | | 24012 |
| | 0 00 | 0 | | | | | | | | | | | | |
| Govt. payments (totals) | 0.00 | 0 | | | | | | | | | | | | |
| Other farm income (totals) | 0.00 | 0 | | | | | | | | | | | | |
| (totals) | 0.00 | 0 | | | | | | | | | | | | |
| TOTAL CASH OPERATING RECEIPTS | 6003 00 | 24012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24012 |
| <<OPERATING EXPENSES>> | | | | | | | | | | | | | | |
| Hired Labor | 0 00 | 0 | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | |
| Repairs | 0.00 | 0 | | 0 | | | | 0 | 0 | 0 | 0 | | | |
| Feed | 0 00 | 0 | | | | | | | | | | | | |
| Seeds, Plants | 150.00 | 600 | | | | | | 600 | | | | | | |
| Fertilizer, Lime, Chemicals | 452.50 | 1810 | | | | | | | 597 | 615 | 597 | | | |
| Farmyard Manure | 0 00 | 0 | | 0 | | | | | | | 0 | | | |
| Machine Hire (tractor) | 0 00 | 0 | | | | | | 0 | | | | | | |
| Threshing | 648.60 | 2594 | | | | | | | | | | | 2594 | |
| Harvesting | 0.00 | 0 | | | | 0 | | | | | | | | |
| Vet Medicine | 0.00 | 0 | | 0 | | | | 0 | 0 | 0 | 0 | | | |
| Fuel, Oil, Lubricants | 75.00 | 300 | | | | | | | | 75 | 75 | 75 | 75 | |
| Taxes | 85.00 | 340 | | | | 340 | | | | | | | | |
| Irrigation (water & labor) | 250.00 | 1000 | | | | | | 1000 | | | | | | |
| Rents, Leases | 0.00 | 0 | | | | | | | | | | | | |
| Utilities | 0.00 | 0 | | | | | | | | | | | | |
| Freight, Trucking | 0.00 | 0 | | | | | | | | | | | | |
| Other | 0 00 | 0 | | | | | | | | | | | | |
| TOTAL CASH OPERATING EXPENSES | 1661.10 | 6644 | 0 | 0 | 0 | 340 | 0 | 1600 | 597 | 690 | 672 | 75 | 2669 | 0 |
| NET OPERATING (Rec-Exp) | 4341.90 | 17368 | 0 | 0 | 0 | -340 | 0 | -1600 | -597 | -690 | -672 | -75 | -2669 | 24012 |
| Operating Interest Expense | 0 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Net Operating after Interest | 4341.90 | 17368 | 0 | 0 | 0 | -340 | 0 | -1600 | -597 | -690 | -672 | -75 | -2669 | 24012 |
| Cont to Other Enterprise | | 0 | | | | | | | | | | | | |
| Cont. of Other Enterprise | | 0 | | | | | | | | | | | | |
| Net After Contribution | 4341.90 | 17368 | 0 | 0 | 0 | -340 | 0 | -1600 | -597 | -690 | -672 | -75 | -2669 | 24012 |
| Land or Other Fixed Charges | | | | | | | | | | | | | | |
| Net After Charges | 4341.90 | 17368 | 0 | 0 | 0 | -340 | 0 | -1600 | -597 | -690 | -672 | -75 | -2669 | 24012 |

Figure 6. Rice Cost and Return Budget

expenses, capital purchases, and sales. These revenues and expenses are entered into the Cash Flow Statement through the AI worksheet. An example of the cash flow of a set of additional information entries is depicted in Figure 7.

The acronym MULTSTAT is for Multiple Year Integrated Statement. MULTSTAT is composed of the Cash Flow Statement, Net Worth Statement, Income Statement, Debt Worksheet, and a Financial Ratio section.

The Cash Flow Statement is an important component of IFFS. It is used to build the Income Statement and it calculates operating interest. In addition to revenues and expenses, the Cash Flow Statement shows capital sales and purchases, inflows from wages and salaries, family living expenses, and scheduled debt payments. The program subtracts cash outflows from cash inflows each month to determine the cash position of the farm each month. All payments are made at the end of each month automatically if funds are available. The Cash Flow Statement can be constructed by direct keyboard entries. Creating it using CLBUD and the AI worksheets exhibits significant advantages in analyzing changes in the farm organization (Mapp and Love). An example Cash Flow Statement is shown in Figure 8.

The Net Worth Statement is another basic component of MULTSTAT. The accounting method used depends on whether the producer views assets at their historical cost or current market value. The user specifies beginning and ending values for the assets. The difference between these values determines the depreciation or appreciation in value of the assets. Though Net Worth Statement is built by direct keyboard entries, most of the data on current, intermediate, and long-term liabilities are transferred to the Net Worth Statement from the Debt Worksheet and the Cash Flow Statement. Figure 9 depicts a Net Worth Statement.

CASHFLOW OF ADDITIONAL INFORMATION NAME: DATE: Error check 0

| | TOTALS | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <<OPERATING RECEIPTS>> | | | | | | | | | | | | | |
| 7. Other Farm Income | 0 | | | | | | | | | | | | |
| 8. | | | | | | | | | | | | | |
| <<CAPITAL SALES>> | | | | | | | | | | | | | |
| 10 Breeding Livestock | 0 | | | | | | | | | | | | |
| 11. Mach., Equip., Vehicles | 0 | | | | | | | | | | | | |
| 12. Buildings & Land | 0 | | | | | | | | | | | | |
| <<OTHER INFLOWS>> | | | | | | | | | | | | | |
| 13 Wages and Salaries | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 Investments | 0 | | | | | | | | | | | | |
| 15 | 0 | | | | | | | | | | | | |
| <<OPERATING EXPENSES>> | | | | | | | | | | | | | |
| 17, Hired Labor | 0 | | | | | | | | | | | | |
| 28. Taxes-R.E | 0 | | | | | | | | | | | | |
| 29 Insurance | 0 | | | | | | | | | | | | |
| 30 Utilities | 0 | | | | | | | | | | | | |
| 31. Cash Rents & Leases | 0 | | | | | | | | | | | | |
| 33 Miscellaneous | 0 | | | | | | | | | | | | |
| 34. | 0 | | | | | | | | | | | | |
| <<CAPITAL EXPENSES.. (Total Cost) | | | | | | | | | | | | | |
| 37. Breeding Livestock | 0 | | | | | | | | | | | | |
| 38 Mach., Equip., Vehicles | 0 | | | | | | | | | | | | |
| 39 Buildings & Land | 0 | | | | | | | | | | | | |
| <<OTHER OUTFLOWS>> | | | | | | | | | | | | | |
| 40. Family Living | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41. Income Tax | 0 | | | | | | | | | | | | |
| 42. Investments | 0 | | | | | | | | | | | | |
| 43. | 0 | | | | | | | | | | | | |
| <<NEW BORROWING-INTERMEDIATE>> | | | | | | | | | | | | | |
| 49 Int rt. 0 00 | 0 | | | | | | | | | | | | |
| 49a. Int rt. 0 00 | 0 | | | | | | | | | | | | |
| <<NEW BORROWING-LONG TERM>> | | | | | | | | | | | | | |
| 50 Int rt. 0 00 | 0 | | | | | | | | | | | | |
| 50a. Int rt 0 00 | 0 | | | | | | | | | | | | |
| <<PAYMENTS NEW BORROWING-INT>> | | | | | | | | | | | | | |
| 44. Interest for loan 49 | 0 | | | | | | | | | | | | |
| 45 Principal for loan 49 | 0 | | | | | | | | | | | | |
| 44a. Interest for loan 49a | 0 | | | | | | | | | | | | |
| 45a. Principal for loan 49a | 0 | | | | | | | | | | | | |
| <<PAYMENTS NEW BORROWING-LT>> | | | | | | | | | | | | | |
| 46 Interest for loan 50 | 0 | | | | | | | | | | | | |
| 47 Principal for loan 50 | 0 | | | | | | | | | | | | |
| 46a. Interest for loan 50a | 0 | | | | | | | | | | | | |
| 47a. Principal for loan 50a | 0 | | | | | | | | | | | | |
| ANNUAL PAYMENT FOR NEW LOAN ON LINE | | 49=) | | 49a=) | | 50=) | | 50a=) | | | | | |

Figure 7. Cash Flow of Additional Information (AI)

WHOLEFARM CASHFLOW STATEMENT NAME: DATE:

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <<OPERATING RECEIPTS>> | | | | | | | | | | | | | | |
| 1 | Livestock Sales. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2. | Sale of Livestock Products | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3. | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Crop Sales | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5. | | | | | | | | | | | | | | |
| 6. | Government Payments | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Other farm income. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8. | | | | | | | | | | | | | | |
| 9. | TOTAL CASH RECEIPTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <<CAPITAL SALES>> | | | | | | | | | | | | | | |
| 10 | Breeding Livestock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Machinery, Equipment, Vehicles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12. | Buildings, Land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <<OTHER INFLOWS>> | | | | | | | | | | | | | | |
| 13. | Wages and Salaries | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | Investments | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | | | | | | | | | | | | | | |
| 16 | TOTAL CASH INFLOW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <<OPERATING EXPENSES>> | | | | | | | | | | | | | | |
| 17. | Hired Labor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18. | Repairs: Mach. & Equip. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | Buildings & Fences | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20. | Feed Purchased | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21. | Seeds, Plants | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22. | Fertilizer, Lime, Chem. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23. | Machine Hire | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | Supplies | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | Vet , Medicine, Breeding Fees | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | Fuel, Oil, Lubricants | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27. | Storage, Warehousing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | Taxes.E & Pers Prop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | Insurance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | Utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | Cash Rents & Leases | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32. | Freight, Trucking | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33. | Miscellaneous | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34. | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35. | Livestock Purchases | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | TOTAL CASH EXPENSES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <<CAPITAL EXPENSES (total cost)>> | | | | | | | | | | | | | | |
| 37 | Breeding Livestock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38. | Machinery, Equipment, Vehicles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | Buildings, Land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <<OTHER OUTFLOWS>> | | | | | | | | | | | | | | |
| 40 | Family Living | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | Income Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42. | Investments | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | | | | | | | | | | | | | | |

Figure 8. Cash Flow Statement

| NET WORTH STATEMENT | Beginning Balance | Ending Balance | Net Change |
|---|---|---|---|
| ----------CURRENT ASSETS---------- | | | |
| 1 Cash & Checking | 0 | 0 | 0 |
| 2. Savings & Time Certificates | | | 0 |
| 3. Marketable Bonds & Securities | | | 0 |
| 4 Accounts Receivable | | | 0 |
| 5. Cash Value Life Insurance | | | 0 |
| Market Livestock & Products | | | |
| 6. Raised Livestock | | | 0 |
| 7 Purchased Livestock | | | 0 |
| 8. Stored Crops, Feed, Supplies | | | 0 |
| 9. Cash Investment Growing Crops | | | 0 |
| 10 Prepaid Expenses | | | 0 |
| 11 Other Current Assets | | | 0 |
| 12. TOTAL CURRENT ASSETS | 0 | 0 | 0 |
| ----------INTERMEDIATE ASSETS---------- | | | |
| 13 Notes Receivable | | | 0 |
| Breeding Livestock | | | |
| 14 Raised Livestock | | | 0 |
| 15 Purchased Livestock | | | 0 |
| 16 Vehicles | | | 0 |
| 17. Machinery & Equipment | | | 0 |
| 18 Securities Not Readily Mktable. | | | 0 |
| 19 Other Intermediate Assets | | | 0 |
| 20 TOTAL INTERMED. ASSETS | 0 | 0 | 0 |
| ----------FIXED ASSETS---------- | | | |
| 21. Contracts & Notes Rec | | | 0 |
| 22. Buildings & Improvements | | | 0 |
| 23 Cropland | | | 0 |
| 24. Pasture | | | 0 |
| 25 | | | 0 |
| 26 Other Long Term Assets | | | 0 |
| 27 TOTAL FIXED ASSETS | 0 | 0 | 0 |
| 28 TOTAL ASSETS | 0 | 0 | 0 |

| NAME DATE | Beginning Balance | Ending Balance | Net Change |
|---|---|---|---|
| ----------CURRENT LIABILITIES---------- | | | |
| 29 Accounts Payable | | | 0 |
| 30 Notes Payable | 0 | 0 | 0 |
| 31. Interest Due Current | 0 | 0 | 0 |
| 32. Intermediate | 0 | 0 | 0 |
| 33. Long Term | 0 | 0 | 0 |
| Taxes Due: | | | |
| 34. Real Estate & Personal Prop. | | | 0 |
| 35 Employee Payroll Withholding | | | 0 |
| 36. Personal & Self-Employment | | | 0 |
| 37. Other Accrued Expenses | | | 0 |
| 38 Contingent Tax Liability | | | 0 |
| Principal Due in 12 months | | | |
| 39. Intermediate Liabilities | 0 | 0 | 0 |
| 40 Long Term Liabilities | 0 | 0 | 0 |
| 41. Other Current Liabilities | | | 0 |
| 42. | | | 0 |
| 43. TOTAL CURRENT LIABILITIES | 0 | 0 | 0 |
| ----------INTERMEDIATE LIABILITIES---------- | | | |
| 44. Notes Payable | 0 | 0 | 0 |
| 45. Contingent Tax Liability | | | 0 |
| 46. Other Intermediate Liabilities | | | 0 |
| 47. | | | 0 |
| 48. TTL INTERMED. LIABILITIES | 0 | 0 | 0 |
| ----------LONG TERM LIABILITIES---------- | | | |
| 49 Mortgages & Notes Payable | 0 | 0 | 0 |
| 50 Contingent Tax Liability | | | 0 |
| 51 Other Long Term Liabilities | | | 0 |
| 52. | | | 0 |
| 53. TOTAL LONG TERM LIAB | 0 | 0 | 0 |
| 54 TOTAL LIABILITIES | 0 | 0 | 0 |
| 55. NET WORTH | 0 | 0 | 0 |
| 56 TOTAL LIAB. & NET WORTH | 0 | 0 | 0 |

Figure 9. Net Worth Statement

The Debt Worksheet is designed to facilitate specification of the debt situation for a farm operation. The interest and principal payments of debt are calculated in the Debt Worksheet. The user specifies the source of the loan, payment month, interest rate, payment amount, and current balance. These payments are transferred to the Cash Flow Statement. The beginning values are transferred to the Net Worth Statement. The impacts of changing debt factors can easily be evaluated by changing the Debt Worksheet and recalculating the MULTSTAT spreadsheet. Figure 10 shows an example of the Debt Worksheet.

DEBT WORKSHEET NAME: DATE:

| DESCP. OF NOTE | PAYMENT MONTH | INTEREST RATE | PAYMENT AMOUNT | INTEREST ACCRUED | INTEREST PAST DUE | CURRENT BALANCE | INTEREST DUE | PRINCIPAL DUE | ENDING BALANCE | INT DUE NEXT YR | PRIN DUE NEXT YR | NEXT END BALANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPERAT-ING LOANS: | | | | | | | | | | | | |
| | XXXXX | | XXXXX | | XXXXX | | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX |
| | XXXXX | | XXXXX | | XXXXX | | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX |
| OTHER SHORT TERM LOANS: | | | | | | | | | | | | |
| | | | | | | | | | 0 | | | 0 |
| | | | | | | | | | 0 | | | 0 |
| | | | | | | | | | 0 | | | 0 |
| | | | | | | | | | 0 | | | 0 |
| INTER-MEDIATE LOANS | | | | | | | | | | | | |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| NEW LOAN | | 0 | 0 | XXXXX | XXXXX | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NEW LOAN | | 0 | 0 | XXXXX | XXXXX | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LONG TERM LOANS. | | | | | | | | | | | | |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| | MONTHLY | | | | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 |
| NEW LOAN | | 0 | 0 | XXXXX | XXXXX | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NEW LOAN | | 0 | 0 | XXXXX | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | TOTALS | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Figure 10. Debt Worksheet

The Income Statement, shown in Figure 11, is calculated from the other worksheets and does not require direct entry of data by the user. Revenues and cash farm expenses are transferred to the Income Statement from the Cash Flow Statement. The net farm income is computed by subtracting the farm expenses from the cash farm receipts and then making adjustments to income as appropriate. Net farm income is considered as the amount of money available for investment, debt payments, and family living.

The Financial Ratios Section, shown in Figure 12, is calculated from information transferred from the Financial Statements. The ratios calculated are used to measure liquidity, credit worthiness, solvency, risk bearing ability, and profitability. The Financial Ratios Section also measures cash available for debt payments and for new investment and risk. Cash flow problems can also be identified by evaluating the Cash Flow Statement. Data in the Financial Ratios Section presents an overview of the farm's financial condition.

After completion of the financial plan for one year, the producer can use the summary data for the following year. The user can select an option from a menu to save ending balances from one year and transfers these values into the beginning balances of the next year. Once the statements for next year are complete, financial progress can be evaluated by examining changes in net worth, net farm income, net cash flow and the financial ratios. The MULTSTAT main menu is shown in Figure 13.

**INCOME STATEMENT** NAME: DATE:

| A. OPERATING RECEIPTS | |
|---|---|
| Livestock Sales & Products: | |
| Livestock sales | 0 |
| Livestock products | 0 |
| Other livestock sales | 0 |
| Subtotal: | 0 |
| Crop Sales | 0 |
| | 0 |
| Subtotal. | 0 |
| Other Farm Income: | |
| Government payments | 0 |
| Custom Work, Cash Rent, Other | 0 |
| Dividends, Refunds, Other | 0 |
| Subtotal | 0 |
| GROSS RECEIPTS FROM FARMING | 0 |

| B. CASH FARM EXPENSES | |
|---|---|
| Hired Labor | 0 |
| Mach. & Equip. Repairs | 0 |
| Building & Fence Repairs | 0 |
| Cash Interest | 0 |
| Feed Purchased | 0 |
| Seed, Plants | 0 |
| Fertilizer, Lime, Chemicals | 0 |
| Machinery Hire | 0 |
| Supplies | 0 |
| Vet, Medicine, Breeding Fee | 0 |
| Gas, Fuel, Oil, Lubricants | 0 |
| Storage, Warehousing | 0 |
| Taxes: Real Est. & Pers. Prop | 0 |
| Insurance | 0 |
| Utilities (farm share) | 0 |
| Cash Rent & Leases | 0 |
| Freight, Trucking | 0 |
| Miscellaneous Expenses | 0 |
| | 0 |
| Lvstk. purchased for resale | 0 |
| TOTAL CASH EXPENSES | 0 |

C. NET CASH INCOME FROM OPERATIONS 0

D. ADJUSTMENTS FOR ACCRUED ITEMS AND INVENTORY CHANGES:

1 Accounts & Notes Receivable.

| | Accounts | Notes | Other |
|---|---|---|---|
| Ending Inventory | 0 | 0 | 0 |
| Beginning Inventory | 0 | 0 | 0 |
| Change | 0 | 0 | 0 |

Change in Accounts & Notes Receivable 0

2. Accounts Payable & Accrued Expenses:

| | Accounts | Taxes | Interest | Other |
|---|---|---|---|---|
| Beginning Inventory | 0 | 0 | 0 | 0 |
| Ending Inventory | 0 | 0 | 0 | 0 |
| Change | 0 | 0 | 0 | 0 |

Change in Accounts Payable & Accrued Expenses 0

3. Prepaid Expenses:

| Ending Inventory | | Beginning Inventory | | |
|---|---|---|---|---|
| 0 | - | 0 | = | Change in Prepaid Expenses 0 |

4 Inventories:

| | Mkt. Livestock & Products | Stored Crops, Feed & Supplies | Growing Crops |
|---|---|---|---|
| Ending Inventory | 0 | 0 | 0 |
| Beginning Inventory | 0 | 0 | 0 |
| Change | 0 | 0 | 0 |

Change in Inventories 0

E ADJUSTMENTS FOR CAPITAL ITEMS:

| | Breeding Lvstk | Mach, Equip vehicles | Bldgs & Land | Other |
|---|---|---|---|---|
| Ending Inventory | 0 | 0 | 0 | 0 |
| Sales | 0 | 0 | 0 | |
| Subtotal: | 0 | 0 | 0 | 0 |
| Beginning Inventory | 0 | 0 | 0 | 0 |
| Purchases | 0 | 0 | 0 | |
| Subtotal: | 0 | 0 | 0 | 0 |
| Change | 0 | 0 | 0 | 0 |

| | |
|---|---|
| Change in Capital Items | 0 |
| F. VALUE OF FARM PRODUCTS USED IN THE HOME | 0 |
| G. NET FARM INCOME | 0 |

---

Figure 11. Income Statement

| FINANCIAL RATIOS | | NAME: | | Beginning | Ending | BENCHMARK |
|---|---|---|---|---|---|---|
| Current Ratio | = | $\frac{\text{Current Assets}}{\text{Current Liabilities}}$ | = | 0 000 | 0 000 | |
| Working Asset Ratio | = | $\frac{\text{Current + Int. Assets}}{\text{Current + Int Liabilities}}$ | = | 0 000 | 0.000 | |
| Leverage Ratio | = | $\frac{\text{Total Liabilities}}{\text{Net Worth}}$ | = | 0 000 | 0 000 | |
| Debt to Asset Ratio | = | $\frac{\text{Total Liabilities}}{\text{Total Assets}}$ | = | 0.000 | 0 000 | |
| Percent Equity | = | $\frac{\text{Net worth * 100}}{\text{Total Assets}}$ | = | 0 00% | 0 00% | |

---

| | | | |
|---|---|---|---|
| A. | Cash Farm Receipts<br>(total cash receipts + capital sales) | = | 0 |
| B | Total Cash Expenses | = | 0 |
| C. | Nonfarm Expenses (Family Living = 0) | = | 0 |
| D. | Nonfarm Income | = | 0 |
| E. | Cash Available for Debt Service | = | 0 |
| F. | Scheduled Interest & Principal Payments | = | 0 |
| G | New Borrowing (Except Operating Note) | = | 0 |
| H. | Projected (Actual) Interest Pay. Operating Note | = | 0 |
| I. | Projected Cash for New Investment and Risk | = | 0 |
| J. | Projected Capital Expenditures | = | 0 |
| K. | Net Cash Flow | = | 0 |

Operating Note Summary

| Begin. Balance | End Balance | Change |
|---|---|---|
| 0 | 0 | 0 |

| Maximum Projected Balance | Minimum Projected Balance |
|---|---|
| 0 | 0 |

Cash Flow Sensitivity

| | |
|---|---|
| Net Cash Flow as a % of Cash Farm Receipts | 0 00% |
| Net Cash Flow as a % of Cash Op. Expenses | 0 00% |
| Interest Paid as a % of Cash Farm Receipts | 0.00% |

---

Rate of Return on Equity =

$$\frac{\text{Net Farm Income - Oppor. Return to Labor \& Mg't * 100\%}}{\text{Beginning Equity (Net Worth)}} = 0.00\%$$

INPUT DATA

Opportunity Return to
Labor and Management
0

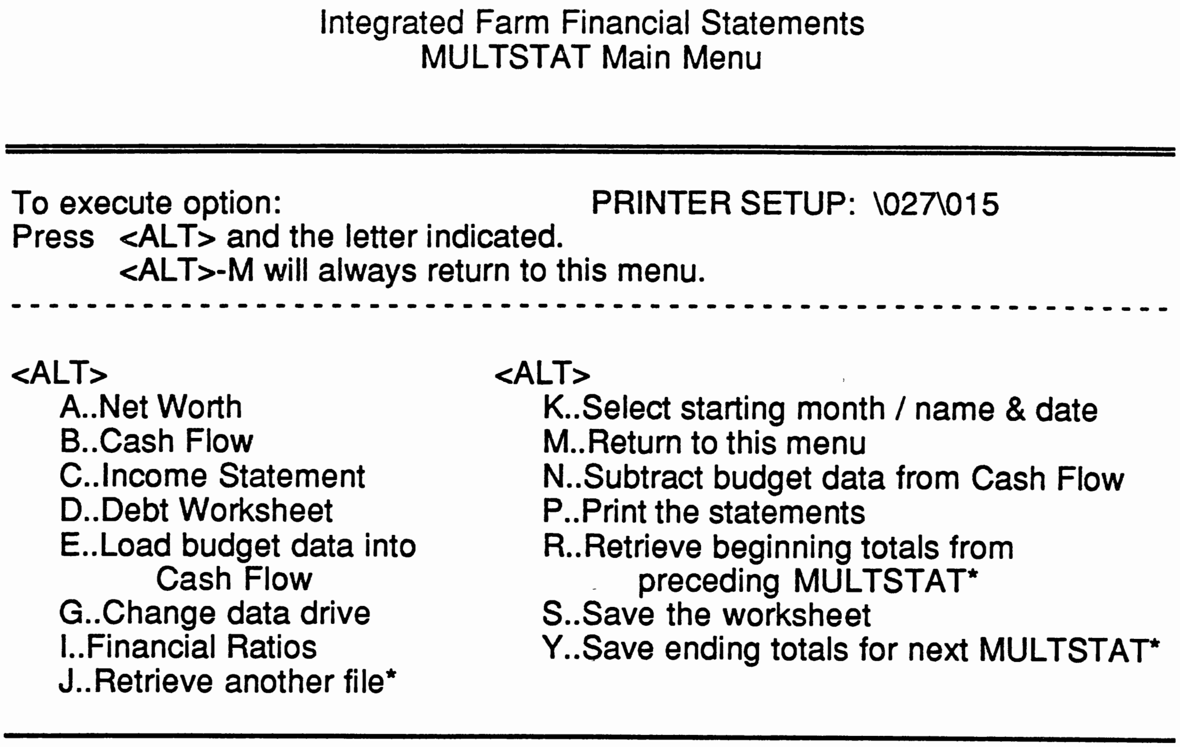
Rate of Return on Investment =

$$\frac{\text{Net Farm Inc + Int Pd - Oppor. Ret'n to Labor \& Mg't * 100\%}}{\text{Beginning Total Assets}} = 0.00\%$$

Average Interest Rate on Debt =

$$\frac{\text{Interest Paid + Change in Interest Due * 100\%}}{\text{Average Total Debt Outstanding}} = 0.00\%$$

Figure 12. Financial Ratios



```
                 Integrated Farm Financial Statements
                         MULTSTAT Main Menu
========================================================================
To execute option:                     PRINTER SETUP: \027\015
Press  <ALT> and the letter indicated.
       <ALT>-M will always return to this menu.
------------------------------------------------------------------------
<ALT>                            <ALT>
   A..Net Worth                     K..Select starting month / name & date
   B..Cash Flow                     M..Return to this menu
   C..Income Statement              N..Subtract budget data from Cash Flow
   D..Debt Worksheet                P..Print the statements
   E..Load budget data into         R..Retrieve beginning totals from
         Cash Flow                        preceding MULTSTAT*
   G..Change data drive             S..Save the worksheet
   I..Financial Ratios              Y..Save ending totals for next MULTSTAT*
   J..Retrieve another file*
________________________________________________________________________
```

*You may wish to save this worksheet first.
==>> Press PgDn to look at the files loaded or subtracted <<==

Figure 13. MULTSTAT Main Menu

## Linear Risk Programming Models

### The MOTAD Model

In this study, it is assumed that farmers bear the risk associated with income fluctuations over time. It is further assumed that farmers are risk averters and that they try to minimize the variability of portfolio income. An adaptation of Hazel's MOTAD model is used for analyzing farmer's resource allocation problems under risk. The basic objective for using the MOTAD model is to generate risk efficient farm plans with which to help farmers in decision making. The objective of the MOTAD model is to minimize the summed total absolute deviation of net revenue over all years considered, subject to a set of linear constraints on resources and expected gross margins.

In matrix notation, the MOTAD model can be written in the following linear programming model:

(3.1) Minimize $L\bar{d}$

(3.2) Subject to $AX \substack{\geq \\ \leq} B$

(3.3) $DX + I\bar{d} \geq 0$

(3.4) $\bar{c}X = \lambda$

and

(3.5) $X, \bar{d} \geq 0$

where

$X$ = a column vector of activity levels;

$A$ = a matrix of technical input coefficients;

$B$ = a column vector of available resources;

$L$ = a row vector of ones;

$\bar{d}$ = a vector of total negative deviations summed over all risky enterprises;

$D$ = a deviation matrix depicting the difference between actual and expected gross margins in a specific year;

$I$ = an identity matrix of the number of years in the study period;

$\bar{c}$ = a row vector of expected gross margins;

$\lambda$ = a scalar used to parameterize the expected total gross margin constraint level ($\lambda = 0$ to unbounded).

An example tableaux of the model is shown in Table IX.

The model can be solved by conventional linear programming codes with a parametric option. The risk efficiency frontier can be generated by solving the model for various values of $\lambda$. The maximum value of $\lambda$ is the value of the basic LP solution. The basic MOTAD model solutions provide total negative deviations (TND) associated with the each expected total gross margin. The TND value is transformed into mean absolute deviation (MAD) by multiplying by $\frac{2}{S}$ where S is the number of years. By using the MAD values derived, an E-A frontier can be generated.

If it is desired to measure risk in terms of variance or standard deviation, then TND can be converted into an estimation of standard deviation. A constant K is calculated based on the work of Hazel, Brink and McCarl, and Carlos and Simons.

$$(3.6) \quad K = \frac{2}{S} \sqrt{\frac{S * \pi}{2\ (S-1)}}$$

where $\pi$ is a mathematical constant (Hazel, 1986) and S is the number of years in the series. The Standard Deviation (SD) can be calculated by multiplying TND with the constant K as:

$$(3.7) \quad SD = TND * K$$

where $\frac{2}{S}$ converts TND into mean absolute deviation and the square root transforms it into an estimate of the standard deviation (Carlos and Simons). These transformations allow the researchers to present the model results in different forms such as E-A frontier as in MOTAD, E-TND frontier as in Brink and McCarl, or E-V frontier as in Hazel and Scandizzo. These efficiency frontiers help decision makers in understanding the risk trade-offs associated with each

# TABLE IX

## THE INITIAL TABLEAUX OF THE MOTAD MODEL

| Resources or Restrictions | $X_1$ | $X_2$ | $X_3$ | ----- | $X_m$ | $\bar{d}_1$ | $\bar{d}_2$ | ---- | $\bar{d}_t$ | Constraints |
|---|---|---|---|---|---|---|---|---|---|---|
| Objective | | | | | | 1 | 1 | ---- | 1 | maximize |
| Resource 1 | $a_{11}$ | $a_{12}$ | $a_{13}$ | ------ | $a_{1n}$ | | | | | $\leq B_1$ |
| Resource 2 | $a_{21}$ | $a_{22}$ | $a_{23}$ | ------ | | | | | | $\leq B_2$ |
| Resource M | $a_{m1}$ | $a_{m2}$ | $a_{m3}$ | ------ | $a_{mn}$ | | | | | $\leq B_m$ |
| Year 1 | $D_{11}$ | $D_{12}$ | $D_{13}$ | ------ | $D_{1n}$ | 1 | | | | $\geq 0$ |
| Year 2 | $D_{21}$ | $D_{22}$ | $D_{23}$ | ------ | $D_{2n}$ | | 1 | | | $\geq 0$ |
| ⋮ | ⋮ | ⋮ | ⋮ | | | | | | | |
| year t | $D_{t1}$ | $D_{t2}$ | $D_{t3}$ | ------ | $D_{tn}$ | | | | 1 | $\geq 0$ |
| Gross Margin | $C_1$ | $C_2$ | $C_3$ | ------ | $C_n$ | | | | | $= \lambda$ |

farm plan. Then, depending on a farmer's attitude towards risk, he can select a farm plan from the set of farm plans that will maximize his utility.

Assumptions of MOTAD. All the assumptions of a conventional farm planning deterministic linear programming model hold in a MOTAD model, with the exception of the assumption that the decision maker has perfect knowledge about resource supplies, input-output coefficient, and prices of activities and resources. Other assumptions implicitly related with a MOTAD model are: (1) gross margins of activities are assumed to have a normal distribution; (2) the decision maker's utility function is assumed to be quadratic and can be expressed in terms of expected income E and variance V associated with the income as:

(3.8) $U = f(E,V)$

and (3) the decision makers are risk averse. Thus the indifference curves resulting from the above utility function are convex with positive slopes.

## The Target MOTAD Model

It is generally argued that farmers do not consider higher income a problem; it is always lower income that poses a threat. Hence, it seems logical to consider negative deviations a source of risk. However, it is very difficult to view positive deviations as a source of risk. A target MOTAD model is a particularly useful planning technique because it considers net returns that fall below a critical target as the risk associated with a farm plan. In this analysis, a target MOTAD model is used to generate a risk-return frontier. It is assumed that the information generated will be particularly useful for decision makers who wish to maximize expected returns while keeping negative income deviations above a critical target.

The Target MOTAD model is defined by Tauer as a two-attribute risk and return model. The optimal farm plans depend on target level T, and level of expected short fall from T as defined by λ. The Target MOTAD model is a two-parameter parametric programming problem which has a linear objective function and linear constraints and can be solved with the conventional linear programming algorithms. The solution procedure for Target MOTAD model is similar to that for a MOTAD model.

In vector notation, the Target MOTAD model is specified as:

(3.9) $\text{Max } E(C)X = \bar{C}X$

subject to

(3.10) $A X \overset{\geq}{<} B$

(3.11) $C X + \bar{d} \geq T$

(3.12) $p \bar{d} \leq \lambda$

(3.13) $X, \bar{d} \geq 0$

where X is an nx1 vector of activity levels; C is an mxn matrix of returns for each activity $\bar{C}$ is a 1xn vector of expected returns for each activity; A is a kxn vector of resource requirements; B is a kx1 vector of resource constraints; $\bar{d}$ is a mx1 vector of negative deviations from target; T is a mx1 vector of the target income; P is a1xm vector of probabilities for each observation; λ is a scalar parameter; n is the number of activities; m is the number of observations, and k is the number of constraints.

Equation (3.9) is the objective function of the model used in this analysis. Equations (3.10) through (3.13) represent the constraints in the model. Equations (3.11) and (3.12) are the heart of the Target MOTAD model where deviations from a specified target and weighted sum of deviations are calculated respectively. The solution vector will be the expected-return-maximizing mixture, whenever (3.12) is not an effective constraint. The Target MOTAD risk-efficient set is traced by parameterizing $\lambda$ for a specified target income T.

Assumptions of Target MOTAD. Because Target MOTAD has a linear objective function and linear constraints, the assumptions of linear programming model also hold in Target MOTAD. Some simplifying assumptions associated with Target MOTAD are: (a) the solution to (3.9), (3.10), and (3.13) is a unique vector; (b) the Target MOTAD model provides a unique solution for each combination of $\lambda$ and T whenever (3.12) is an effective constraint; and (c) each state of nature is assumed to be equally likely. The last assumption is made only because the data on probability distribution of states of nature are not required. However, the model generally can accommodate unequal probabilities.

### The Compromise MOTAD Model

Traditional risk analysis models are in effect multi-objective programming (MOP) models involving the two objectives. The first objective is to maximize returns from individual enterprises. The second objective of risk programming models is to minimize the variability of income expressed as variance (Freund) 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 optimized 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 maximized; (3) the multi-criterion simplex method, where all efficient points are traced by moving from one efficient point to the next (Cohon; Willis and Perlack). 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; Romero et al., 1988; Romero and Rehman, 1985).

From these efficient sets, the optimal solution can be identified if the decision maker'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 decision maker's utility functions (Dillon and Seandizzo, 1978; Romero et al., 1988). Even if the utility functions are established, they are not stable over time.

Compromise programming techniques provide an answer to these difficulties. Compromise programming does not require any rigid assumption about the decision maker's behavior. According to Zeleny's axiom of choice, "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 want maximum profits with no risk. This, however, is usually infeasible. Zeleny's axiom basically states with regard to point income and risk that the decision maker prefers more income to the less income, and he prefers less risk to more risk. With this simple realistic assumption, compromise programming can easily be incorporated in the traditional risk programming models. Compromise programming, together with MOTAD (from now on defined as Compromise MOTAD), will generate that portion of the MOTAD 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. The beauty of the Compromise MOTAD model lies in the fact that it does not require any assumption on the shape of the utility curve.

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. However, the second step demands more description.

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

$$(3.14) \quad d\alpha = \left\{ \sum_{k=1}^{p} w_k \, (Z_k^* - Z_k(X))^{\alpha} \right\}^{1/\alpha}$$

where $\alpha \geq 1$, p is the number of objectives, and $w_k$ is the weight assigned by the decision maker to each objective function according to its importance for him. 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:

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

where $Z_{*k}$ is the anti-ideal point for the kth objective.

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

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

Hence, metrics $d_1$ and $d_2$ 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:

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

subject to

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

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

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

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 minimized. The best compromise solution can be found by solving the following Compromise MOTAD model:

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

subject to

$$(3.22)\quad \sum_{k=1}^{p} w_k \left[ \frac{Z_k^* - Z_k(X)}{Z_k^* - Z^*{}_K} \right] \leq d_\infty$$

$$(3.23)\quad \sum_{j=1}^{n} (C_{hj} - g_j)\, X_j + Y_h^- \geq 0$$

$$(3.24)\quad \sum_{j=1}^{n} a_{ij}\, X_j \leq b_i$$

$$(3.25)\quad X_j,\ Y_h^- \geq 0$$

By solving Compromise MOTAD model for $\alpha = 1$ and $\alpha = \infty$, bounds of the Compromise MOTAD efficiency frontier can be defined. All other solutions for $1 \leq \alpha \leq \infty$ lie between these two points. In Compromise Programming, other points of the compromise set (Compromise MOTAD efficiency frontier) can be found by using nonlinear 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 need nonlinear techniques to identify the Compromise MOTAD efficiency frontier.

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

## Data Requirement

The IFFS model used for farming system analysis requires data on yield, price, and variable cost of production for each enterprise to generate enterprise budgets. Additional information on living expenses of the farm family, off-farm income, appreciation and depreciation of farm assets, loans and other liabilities are also required to analyze the cash flow situation of the farm.

The MOTAD, Target MOTAD, and Compromise MOTAD models used for analyzing risk efficient resource allocation require the same set of data as that of IFFS with additional information on the time series data on returns and cost of production for each enterprise in the model to develop a distribution of gross margins. 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 labor, hired labor, fertilizer use, and institutional credit. The real activities include all major crops grown in the area.

## Sources of Data

A set of nine representative farms was selected for analysis. This selection was based upon existing budget information. An attempt was made to select farms that give a comprehensive picture of the dominate farming systems in Punjab, Pakistan. A survey form was designed for use in collecting data from each of these farms. This form was designed from the inputs known to be needed to use IFFS and MOTAD models, as well as from considerations given to the types of information farmers will readily have available and will be willing to provide. The survey form was then used as a basis for conducting personal interviews with managers of the selected representative farms. All interviewing was done personally. No surveyors/interviewers were used. All surveys were conducted by the author. Initial survey results were used to develop IFFS financial analysis of each farm. Follow-up interviews were conducted to complete unknown information and to provide feedback to the farmers about the initial analysis results obtained from using their data. This feedback was found useful in validating the correctness and consistency of the information given. Early in the process, surveying was done sequentially; that is, one farm was surveyed and its responses were analyzed before the next farm was surveyed. Thus, the first two farms surveyed were actually test cases as well as research cases.

The data collected was first used to generate enterprise budgets using the IFFS computer program as modified for use in Pakistan. The generated enterprise budgets were then used to develop MOTAD, Target MOTAD, and Compromise MOTAD models.

The cost of production series for each farm was not available for all the years in the study. However, prices of agricultural inputs and outputs are announced by the government. It is assumed that announced indices of prices paid by the farmer and prices received by the farmers are highly correlated with actual farm prices (Zia). Fertilizer cost is a major input cost in crop production. Moreover, it is the only input a complete price series is available for. All other production costs except fertilizer cost and labor cost were aggregated into cost of production. The cost of production series was adjusted over time to the changes in the fertilizer price series and prices received by the farmer. The index of prices paid by the farmer was not available for this period. The computed cost of production series is then used to develop a series of gross margins.

# CHAPTER IV

# THE FARMING SYSTEMS ANALYSIS

Integrated Farm Financial Analysis (IFFS) is employed to analyze the financial performance of selected farming systems of Pakistani Punjab. IFFS, as previously discussed, generates enterprise budgets and combines these budgets with other pertinent financial information regarding a farm's liabilities and available assets. Thus, the IFFS model provides the user with a concise description of the farm's financial performance. The IFFS model also provides information on profitability of enterprises and the farm's cash flow situation. This information plays a vital role in farm planning.

It is generally accepted that the overall financial performance of the farm can be judged by using three key financial indicators, namely profitability, liquidity, and solvency of the farm. The IFFS model is designed to analyze the profitability of individual enterprises as well as the farm's profitability as a unit, liquidity, and solvency position of the farm on an annual basis.

## Enterprise Budgets

An enterprise budget is a complete listing of all returns and expenditures associated with a specific farm activity. IFFS requires the timing of input use and cash receipts be recorded for each enterprise on a monthly basis. From this information a cash flow statement can be developed. IFFS also requires an

Additional Information (AI) budget that describes the inflows and outflows that cannot be generally associated with a particular farm enterprise.

The budgets for all crop and livestock enterprises as well as AIs are developed for all the nine farms included in the study. A summary of the budgets for two major crops, wheat and rice, is presented in Table X and Table XI, respectively. The quantity of wheat and rice reported as stored is wheat and rice used for family consumption. Consequently, the stored commodities were not considered for computing net cash income per acre of enterprise. Computed net cash income is utilized in the cash flow statement for analyzing the cash flow situation of each farm. However, the contribution of wheat and rice as inputs to the livestock enterprise is included for profitability and cash flow analysis purposes.

### Wheat Budget

Wheat is a major *Rabi* crop in Punjab. The summary of wheat crop budgets (Table X) indicates that on an average 4.25 acres of wheat were grown on each farm with an average per acre return of Rs. 2212.71 and a standard deviation of Rs. 856.35. Wheat is a staple food in Pakistan. A major portion of the crop produced is stored on the farm for home consumption and for seed for next year's crop. The average quantity of wheat stored for family consumption was found to be 65.93 md with a coefficient of variation 52.77. Consequently, cash generated per acre of wheat grown was much lower than the net returns per acre. Most of the expenses were incurred in the months of November, December and February, and cash receipts were available in May when farmers need cash for buying inputs for their rice crop.

## TABLE X

## SUMMARY OF WHEAT CROP BUDGETS

| Farm No. | Size of Farm (Acres) | Acres of Wheat | Quantity Stored (Md)[1] | Returns per Acre (Rs)[2] | Expenses per Acre | Cash Income per Acre (Rs)[3] |
|---|---|---|---|---|---|---|
| 1 | 20 | 6.50 | 100.0 | 3870.77 | 1394.62 | 2239.96 |
| 2 | 8 | 4.50 | 76.5 | 2317.56 | 1388.44 | 515.50 |
| 4 | 10 | 3.75 | 112.5 | 2004.80 | 1161.07 | -1161.06 |
| 5 | 8.5 | 5.00 | 60.0 | 1824.00 | 1144.00 | 552.00 |
| 6 | 8.0 | 2.50 | 25.0 | 1814.40 | 1365.60 | 754.50 |
| 8 | 5.0 | 3.00 | 20.0 | 2533.00 | 1707.00 | 1826.33 |
| 9 | 7.75 | 4.50 | 67.5 | 1124.44 | 465.36 | -465.50 |
| Mean | 9.60 | 4.25 | 65.93 | 2212.71 | 1232.29 | 841.18[4] |
| S.D. | 4.82 | 1.33 | 34.79 | 856.35 | 386.20 | 869.82 |
| C.V. | 50.18 | 31.31 | 52.77 | 38.70 | 31.34 | 103.40 |

n = 7

[1] Md = 40 kg.

[2] Returns include value of quantity stored

[3] Approximately twenty-five Pakistani Rupees (Rs) equal one U.S. dollar

[4] Mean = $\frac{1}{n} \sum_{i=1}^{n}$ max (0, $CINC_i$) where CINC is cash income per acre

In addition to the wheat production that is sold, the wheat crop provides food for household consumption and roughage for livestock. Wheat roughage provides a substantial portion of livestock feed in the periods of green fodder shortage. The value of wheat roughage produced per acre of wheat crop is calculated as a contribution to livestock enterprises. This reflects the importance of the wheat crop for the household and livestock enterprises.

# TABLE XI

## SUMMARY OF RICE CROP BUDGETS

| Farm No.[1] | Size of Farm (Acres) | Acres of Rice | Quantity Stored (Md)[2] | Returns per Acre (Rs)[3] | Expenses per Acre | Cash Income per Acre (Rs) |
|---|---|---|---|---|---|---|
| 1 | 20.00 | 4.00 | 14 | 4825.00 | 1661.00 | 4341.90 |
| 2 | 8.00 | 3.50 | 0 | 1153.82 | 1208.57 | 1153.82 |
| 4 | 10.00 | 1.50 | 12 | 740.00 | 2164.00 | -346.00 |
| 5 | 8.50 | 3.00 | 4 | 2179.00 | 1846.33 | 1994.93 |
| 6 | 8.00 | 0.50 | 11 | 1638.00 | 1398.00 | -1397.00 |
| 8 | 5.00 | 0 | 0 | 0 | 0 | 0 |
| 9 | 7.75 | 2.75 | 10 | 1685.82 | 808.73 | 1184.10 |
| Mean | 9.60 | 2.54 | 8.50 | 2036.94 | 1514.44 | 1445.79[4] |
| S.D. | 4.82 | 1.31 | 5.36 | 1451.75 | 481.39 | 1613.90 |
| C.V. | 50.18 | 51.57 | 63.03 | 71.27 | 31.79 | 111.63 |

[1] $n = 6$

[2] Md = 40 kg.

[3] Includes value of quantity stored

[4] Mean $= \frac{1}{n} \sum_{i=1}^{n} \max(0, CINC_i)$ where CINC is cash income per acre

The wheat crop is considered to be a relatively less risky crop in irrigated Punjab. Because wheat prices and input prices remain relatively stable, yield fluctuations cause most of the variability in net returns. The variability of net returns per acre of wheat across the farms as indicated by the coefficient of variation is shown in Table X.

The downside variability is measured using a semivariance statistic. Specifically, variability of revenue per acre of wheat is measured by the Standard Semideviation, which is defined as

$$S_R = \sqrt{\frac{\sum_{i=1}^{n} 2 \cdot (\max\{0, \bar{R} - R_i\})^2}{n-1}}$$

where n is the number of observations, R is the revenue per acre of wheat and $\bar{R}$ represents the mean revenue per acre of wheat. The 2 serves as a double counter. The Standard Semideviation provides a measure of variability of revenue per acre of wheat below its expected value. It implies that risk is measured as only negative deviations from expected returns. For the study area, revenue variability measured in Standard Semideviation is Rs 715.85 per acre of wheat.

## Rice Budget

Rice is the most important *Kharif* crop in the study area. Table XI depicts a summary of rice crop budgets. On an average, 2.54 acres of rice were grown on each farm considered in the study, with a standard deviation of 1.31 acres. Availability of irrigation water constrained the acreage under rice crop, especially on the farms where supplemental irrigation water from private tubewells was not available.

Rice is the second most important constituent of Pakistani food. A substantial portion of rice produced is stored and is consumed on the farm. Table XI shows that average quantity of rice stored for household consumption was 8.5 md with a standard deviation of 5.36 md. In addition to meeting the household consumption requirements, the rice crop also produces hay for livestock. Albeit rice hay is considered a low quality roughage, it helps in case of fodder shortages.

Rice yields are highly correlated with weather conditions. Favorable weather results in high and stable yields. In contrast, poor weather conditions result in reduced and unstable yields. The variability of net returns per acre of rice as shown in Table XI by the coefficient of variation indicates that rice is a relatively high risk crop. Expected net returns per acre of rice were found to be Rs 2036.94 with a coefficient of variation of 71.27.

Risk involved in rice production measured in terms of deviations below the expected revenue is also calculated using the Standard Semideviation Statistic. The level of variability of revenue per acre of rice given by this measure is estimated to be Rs 1047.74. That shows the downside revenue loss typically experienced by rice producers in the study area.

Fertilizer, chemicals, and tubewell irrigation constitute the major portion of expenditures involved in rice production. Most of these expenditures are incurred from June to September. The growers received sale proceeds in December, at a critical time when farmers need cash for purchasing inputs for the next wheat crop.

## Sugarcane Budget

Sugarcane is another important cash crop in the area. Four out of seven farms produced about two acres of sugarcane (Table XII). The expected net returns per acre of sugarcane grown were found to be Rs 3647.88 with a coefficient of variation of 30.25. The relatively lower coefficient of variation indicates that sugarcane is comparatively a low risk crop. Generally, sugarcane harvest starts in December and continues until March. It implies that the sugarcane crop generates cash flows in a period when cash is critically needed by the farm for purchasing inputs for *Rabi* crop.

## TABLE XII

## SUMMARY OF OTHER CROP BUDGETS

| Crop | No. of Farms Grown | Mean Acres | Expected Returns/Acre (Rs) | Expected Expenses/ Acre (Rs) | Expected Cash Sales/ Acre (Rs) |
|---|---|---|---|---|---|
| Sugarcane | 4<br>(Farms1,2,4,8) | 1.88<br>(50.34)* | 3647.88<br>(30.25) | 1664.63<br>(55.33) | 3147.88<br>(54.38) |
| Peas | 3<br>(Farms 1, 2, 6) | 1.75<br>(11.66) | 2253.67<br>(45.68) | 2038.00<br>(43.25) | 2253.67<br>(45.68) |
| Cotton | 2<br>(Farms 1, 6) | 1.00<br>(50.00) | 3295.13<br>(32.02) | 904.88<br>(50.29) | 3295.13<br>(32.02) |
| Gourd | 3<br>(Farms 1, 2, 6) | 1.17<br>(19.73) | 2563.75<br>(33.41) | 702.92<br>(69.98) | 2563.75<br>(33.41) |
| Eggplants | 2<br>(Farms 1, 4) | .75 | 1320.50 | 2430.00 | 1320.50 |
| Carrot | 1<br>(Farm 1) | 0.375 | 4332.00 | 193.00 | 4332.00 |

*Figures in the parenthesis are the coefficient of variation.

In addition to generating critical cash flow, the sugarcane crop contributes to the household to satisfy their demand for sweeteners, and to the livestock enterprise in terms of fodder. A part of sugarcane output is consumed on the farm as sweeteners. The value of the quantity of sugarcane output stored on the farm is computed at current prices and is included in the net returns. The price for sugarcane fodder was not available because it is generally not sold, thus, the value of fodder contributed to livestock is not included in net returns.

## Pea Budget

Peas compete with wheat for land in *Rabi* season. Peas were not very common in the area until the recent past, perhaps due to its higher vulnerability to weather fluctuations and, thus, risk involved in its production. Recent higher pea prices have attracted producers in the area. Three out of seven farmers considered in the study were growing 1.75 acres of peas on average with a coefficient of variation of 11.66.

The expected returns per acre of peas were estimated to be Rs 2253.67 with a coefficient of variation of 45.68 (Table XII). The coefficient of variation of expected returns of peas is higher than that of wheat. This implies that the pea crop is relatively more risky than the wheat crop.

## Other Budgets

Other crops grown in the area include cotton, gourds, eggplants, carrots, fodder crops, etc. Expected acreage, expected returns per acre, and expected expenses per acre of cotton, gourds, eggplants, and carrots are depicted in Table XII. The fodder crops are generally grown for feeding livestock and are not sold. The value of fodder contributed to the livestock enterprise is computed in the fodder crop budgets.

Gourds, eggplants, and carrots are labor-intensive crops. Only farms which have sufficient family labor were growing these crops. Another common practice for these crops in the area was the share cropping system. The landlord provides land and inputs, and the tenant provides labor. In this case, the farm owner will receive 50 percent of the produce. Sometimes farmers hire labor on a contract basis for sowing, hoeing, and harvesting vegetable crops.

However, only a limited number of acres of vegetable crops can be grown due to the shortage of contract labor in the area.

Gourds, eggplants, and carrots are considered very risky crops (Table XII). Farmers mentioned during the survey that the gourd and eggplant growers face both yield and price risk, while carrot growers face only price risk because carrot yields are fairly stable. Gourds and eggplants are relatively vulnerable to weather fluctuations. Insects and pests are the other major factors that cause yield fluctuations. The labor shortage, coupled with high yield risk, are the major determinants of acreage under these vegetable crops.

## Cash Flow Situation

The farm business, like other businesses, is required to generate cash in order to meet cash demands as they occur and to provide for unanticipated events. In Pakistan, most of the farm assets are "locked in", i.e. fixed assets. These assets cannot quickly be converted into cash through sales. Generally, only sales of marketable surplus from crops and sales of livestock and livestock products provide the required cash. Most of the items used for production and for family consumption are acquired with cash outlays. Since the seasonal pattern of cash inflows generally varies from that of cash outflows, seasonal cash deficits and/or cash surpluses arise. The deficits must be met somehow, and surpluses need to be managed.

The month-by-month cash flow conditions depicted in Table XIII indicate that most of the farmers do not face cash flow problems with their present crop rotations. Farm number five needs to borrow in the months of April, September, and November, and the farm manager barely made both ends meet in the month of October. The results of cash flow statements show that in the month just cited cash inflows declined on most of the farms except farm number eight and farm number nine, where the income increased in these months due to the increase in sales of livestock products. The reason cash flow typically declines in these months lies in the present crop rotations. Generally, no crop is harvested in these months.

## TABLE XIII

## A SUMMARY OF CASH FLOW SITUATION ON SELECTED FARMS

| Farm No. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14201 | 20077 | 48361 | 44610 | 92966 | 93387 | 90093 | 90895 | 90894 | 87364 | 84762 | 107624 |
| 2 | 3020 | 6745 | 4906 | 1310 | 8147 | 5388 | 5284 | 6847 | 6562 | 5764 | 6213 | 13370 |
| 4 | 160 | -716 | -7411 | -4439 | 9777 | 44915 | 41748 | 39763 | 39996 | 41611 | 42503 | 43157 |
| 5 | 4366 | 5537 | 1877 | -1786 | 44351 | 2892 | 1355 | 728 | -1826 | 29 | -1965 | 9315 |
| 6 | 3430 | 583 | 2071 | 386 | 12145 | 3948 | 4600 | 5527 | 1953 | 2020 | 1882 | 15381 |
| 8 | 1574 | 3307 | 4032 | 1998 | 11710 | 12293 | 12451 | 12900 | 13661 | 14865 | 15335 | 18813 |
| 9 | 1380 | 2482 | 3832 | 4703 | 5865 | 7010 | 8130 | 9028 | 10517 | 12674 | 13550 | 20108 |

Declining cash inflows in November, especially negative inflow as in the case of farm number five (Figure 14), suggest that farmers may face a problem in purchasing inputs for the next *Rabi* crop, particularly wheat. The lending institutions need to carefully plan their lending policies to meet the increased demand in the periods when there are cash flow problems at farms. Farmers may also need to borrow in the months of March and April, as shown in the case of farms number four and five, but that credit will mostly be needed for meeting family living expenditure requirements.

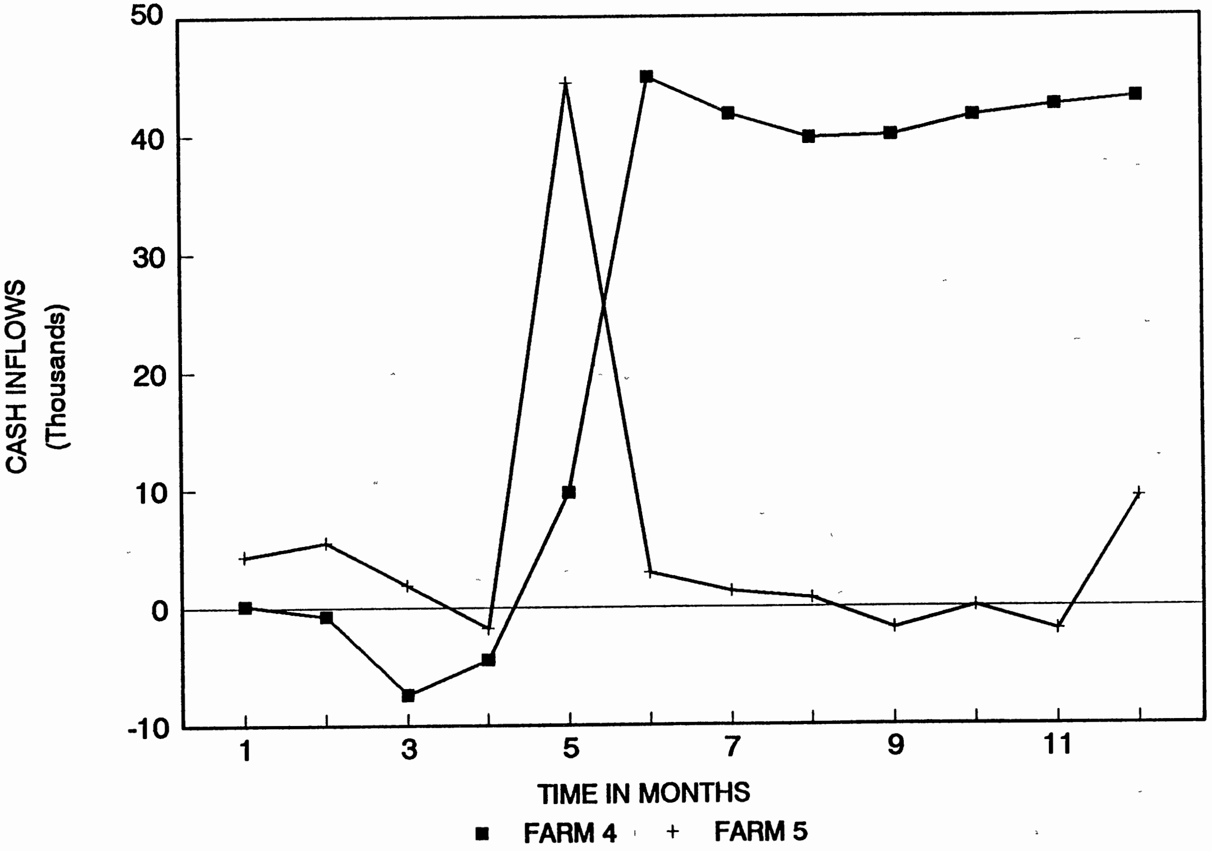


Figure 14. Month-by-Month Cash Flow Situation for Farm Number 4 and Farm Number 5

It was found that in the months of May, June, and December, farmers realized most of their farm income. In these months, farmers will have cash available for debt payments. Lending institutions need to keep this fact in view while formulating their loan policies. If loan repayments are scheduled in May-June or in December, it would be easier for farmers to make the payments.

Farm number eight and farm number nine are of particular interest because their cash inflow does not exhibit the usual cycle. Rather it shows an increasing trend over the year (Figure 15). The reason for their increased cash inflow through the year was found to be an increase in the sale of livestock products. This implies that with the present crop rotations, a carefully managed livestock enterprise can bridge the gaps between cash inflows.

## Farm Profitability

The success and failure of any business depends upon its ability to sustain annual profits. The Income Statement reflects a farm's profit over a specified accounting period. In agriculture, the accounting period is generally one year. Profits are computed on a per acre basis to make them comparable between farms. Farm number 3 and farm number 7 were dropped fro the analysis because of some data problems. A comparison of profits between farms is depicted in Table XIV.

Profits on farm numbers one, four, and five are significantly higher than the other farms. These farms have incorporated non-traditional vegetable crops into traditional crop rotations. These non-traditional crops require more labor and capital. Table XIV shows that farm expenses of these farms were also higher than that of other farms.

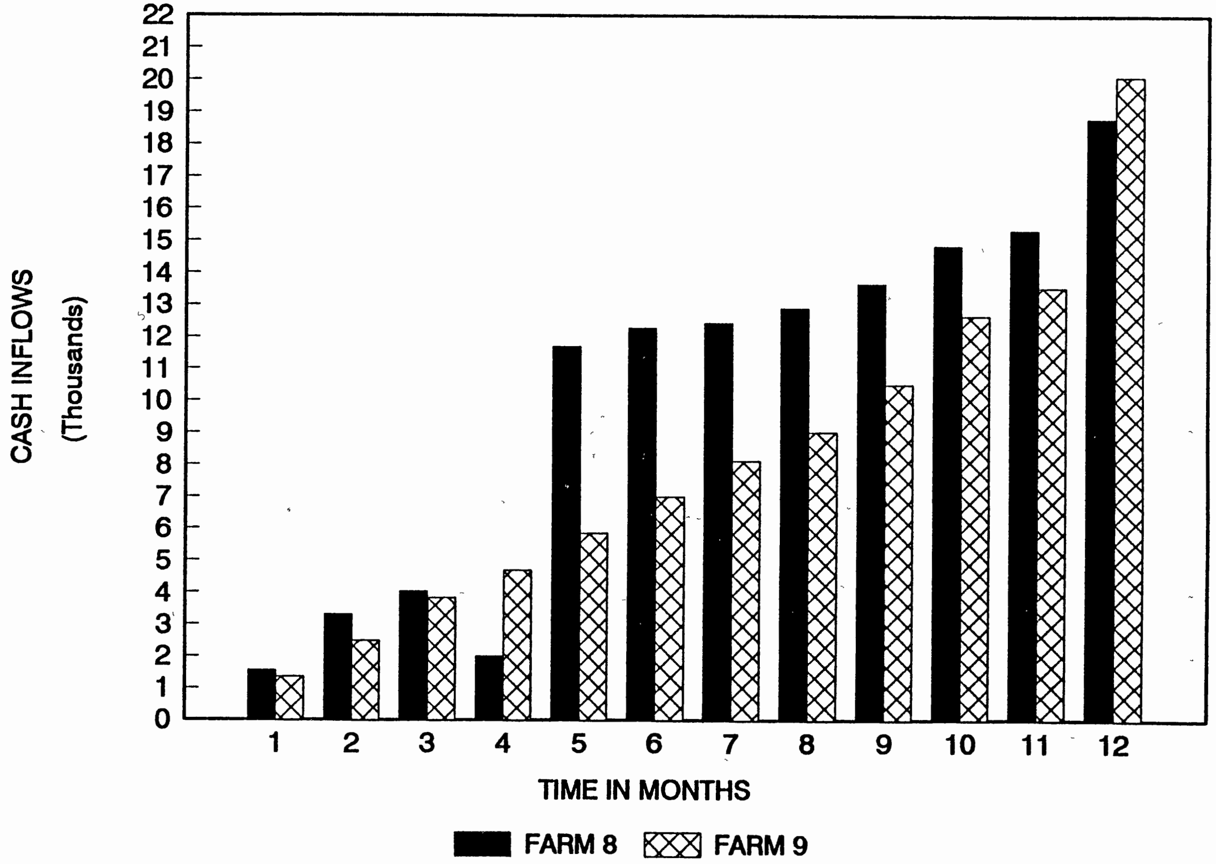


Figure 15. Month-by-Month Cash Flow Situation for Farm Number 8 and Farm Number 9

## TABLE XIV

## A SUMMARY OF FARM PROFITABILITY

| Farm No. | Gross Farm Receipts (Rs) | Farm Expenses (Rs) | Net Farm Profit (Rs) | Profit/Acre (Rs) |
|---|---|---|---|---|
| 1 | 163146 | 48922 | 114224 | 5711.20 |
| 2 | 44337 | 24966 | 19370 | 2421.25 |
| 4 | 124754 | 59997 | 64757 | 6475.70 |
| 5 | 73179 | 24826 | 48353 | 5688.59 |
| 6 | 41585 | 28204 | 13381 | 1672.63 |
| 8 | 33015 | 14703 | 18313 | 3662.60 |
| 9 | 13990 | 6882 | 7108 | 917.16 |
| Mean Profit | | | | 3792.73 |
| Standard Deviation | | | | 2203.58 |
| Coefficient of Variation | | | | 58.10 |

A wide gap between highest returns per acre of land cultivated (Rs 6475.70) and lowest returns per acre of land cultivated (Rs 917.16) suggests that there is a great potential to improve the profitability of small farms through better resource allocation. Further research on resource allocation can generate useful information for tailoring policies to bridge this gap. The resource allocation analysis is taken up in Chapter V.

### Financial Performance

In financial performance analysis, the important measure is the change in equity. Change in equity reflects the changes occurring in total assets and total liabilities and describes the farm's ability to continue in business. Other measures used to evaluate the financial performance of the farm business include the rate of return on equity, net farm income, net cash flow as a percentage of cash operating expenses, and net cash flow.

The changes in equity as depicted in Table XV show positive changes for all farms. This implies that small farms are viable and are capable of continuing in the farm business. The change in equity on the farms considered in the study range from as low as Rs 2053 for farm number five to as high as Rs 99824 for farm number one. The reason for very low change in equity at farm number five was that a debt was payable during the year analyzed.

The rate of return on equity is calculated in IFFS using the following formula:

$$\text{Rate of Return on Equity} = \frac{\begin{bmatrix}\text{Net}\\ \text{Farm}\\ \text{Income}\end{bmatrix} - \begin{bmatrix}\text{Opportunity}\\ \text{Return to}\\ \text{Labor \& Mgmt.}\end{bmatrix}}{\text{Beginning Equity}} * 100$$

The difference between the values of total assets and total liabilities results in a beginning equity. Table XV indicates that rate of return on equity was positive on all the farms except farm number two and farm number six. Farm number two did not own farm assets. Their assets are provided through an arrangement with a landlord. Because farm number two's beginning equity is zero, its rate of return on equity is undefineable. In the case of farm number six, family living expenses of Rs 29000 are more than net farm income of Rs 13381. This results in a negative rate of return on equity. However, a non-farm income of Rs 36000 helped to meet the family's living expenss and to generate a positive cash flow of Rs 20381.

Net cash flow as a percentage of cash operating expenses reflect the farm's ability to generate cash relative to actual operating expenses. As indicated in Table XV, returns on actual cash operating expenses are fairly

## TABLE XV

## FINANCIAL PERFORMANCE OF FARM BUSINESS

| Farm No. | Change in Equity | Rate of Return on Equity (%) | Net Cash Flow as a % of Cash Op. Expenses (%) | Net Farm Income | Net Cash Flow |
|---|---|---|---|---|---|
| 1 | 99824 | 3.48 | 219.99 | 114224.00<br>(5711.20)* | 107624.00<br>(5381.20)* |
| 2 | 13370 | 0 | 53.55 | 19370.00<br>(2421.25) | 13370.00<br>(1671.25) |
| 4 | 30407 | 2.09 | 71.93 | 64757.00<br>(6475.70) | 43157.00<br>(4315.70) |
| 5 | 2053 | 5.08 | 223.77 | 48353.00<br>(5688.59) | 55553.00<br>(6535.65) |
| 6 | 16881 | -18.58 | 72.27 | 13381.00<br>(1672.63) | 20381.00<br>(2547.63) |
| 8 | 35613 | 8.23 | 127.95 | 18313.00<br>(3662.60) | 18813.00<br>(3762.60) |
| 9 | 26108 | 16.55 | 292.20 | 7108.00<br>(917.16) | 20108.00<br>(2594.59) |

*Figures in parentheses are net farm income and net cash flow on per acre basis.

high. That is also a healthy sign for small farm business. But a wide range returns to cash expenses from 53.55 to 292.20 percent reflects the risk involved in farming.

Net farm income and net cash flow are the other important indicators of the financial performance of the farm businesses considered. Table XV shows net farm income and net cash flow for each farm. Figures in parentheses are net farm income and net cash flow per acre of land managed. Net farm income per acre of land managed ranges from Rs 917.16 to Rs 6475.70. This range suggests that there is room for improvement of net farm incomes, and it also reflects the risky nature of farming businesses. The net cash flow per acre of land managed is significantly higher than the net farm income per acre of land because net cash flow includes off-farm income and income from custom work, etc.

## Sensitivity Analysis

To examine the impact of different assumed prices, policies, and crop rotation changes on a typical Punjabi farm (farm number 1), an analysis was conducted using the IFFS model. The alternatives studied include: 1) a 2 percent increase in wheat price; 2) an increase in acreage under carrots; and 3) a 2 percent tax on agricultural income.

Effects of a Change in Wheat Price. It is assumed that the government will increase the price of wheat by 2 percent for the next wheat crop. The evidence from the last several years provides the rationale for this assumption. The government has been increasing wheat prices every year for the last few years. The analysis shows that a 2 percent change in wheat price, other things remaining the same, will result in an increase of Rs 472 in total cash income of the farm. The net farm income will increase by Rs 682.5. It will improve the ratio of farm income to net cash flow by 0.63 percent.

Effects of a Change in Area Under Carrots. Through personal discussions with the farmers in the study area, it was revealed that farmers would tend to increase the area under carrots provided labor for its harvesting is available.

The impact of producing two more acres of carrots is studied. It is assumed that carrots will replace wheat in the present crop rotation. The analysis shows that increasing two acres under carrots will increase the net cash income by Rs 608 (Table XVI). The rate of return on equity will also be increased by 0.03 points from 3.46 percent to 3.49 percent. Operating cash expenses will be decreased by Rs 1952, and thus the ratio of net cash flows to operating cash expenses will be improved by 10.45 points from 219.99 percent to 230.44 percent.

TABLE XVI

EFFECTS OF INCREASING AREA UNDER CARROTS TO TWO ACRES

| | Present Plan | New Plan | Net Change |
|---|---|---|---|
| Net Cash Income (Rs) | 107624.00 | 108232.00 | 608.00 |
| Rate of Return on Equity (%) | 3.46 | 3.49 | 0.03 |
| Net Cash Flow as % of Cash Farm Receipts (%) | 65.97 | 66.89 | 0.92 |
| Net Cash Flow as % of Cash Op. Expenses (%) | 219.99 | 230.44 | 10.45 |
| Operating Cash Expenses (Rs) | 48922.00 | 46970.00 | -1952.00 |
| Agricultural Income Tax (@ 2% on net farm income) (Rs) | 1804.48 | 1816.72 | 12.24 |

Agricultural Income Tax. In Pakistan, it is being argued that a tax should be levied on agricultural income. The tax could be on land owned, a particular crop, or agricultural income. A tax on any particular enterprise may result in shifting resources away from that enterprise and may cause undesirable changes in crop rotations.

A tax on agricultural income seems to be a more desirable alternative. A 2 percent tax on agricultural income is assumed to calculate income tax for the original plan and the new farm plan (with two acres of carrots). A 2 percent tax on net farm income will cost Rs 1804.48 to the farmer with the present plan and Rs 1816.72 with the new farm plan (Table XVI). A 2 percent tax on crop sales will cost Rs 1794.92 to the farmer with the present farm plan and Rs 1568.12 with the new farm plan.

## Summary

In this chapter a financial analysis of Pakistani farming systems is conducted by using an IFFS model. The results show that small farms are viable and are capable of continuing in the farming business. Analysis of the cash flow situation revealed that cash inflows declined in the months of March and April in the *Rabi* season and in October and November in *Kharif* season. In some cases, farmers needed to borrow in these months. The high income months were found to be May and December when the wheat and rice crops are harvested, respectively. The sensitivity analysis shows that bringing more acreage under carrots will result in an increase in net farm income with the present crop rotations.

# CHAPTER V

# WHOLE FARM RISK ANALYSIS

## Purpose

To generate risk efficient farm plans for the study area, risk programming models were developed. A MOTAD model was developed to identify the farm plans which minimized the risk involved. Risk was measured in terms of negative deviations from expected income. A Target MOTAD model was used for generating farm plans that provide maximum income at a given level of risk. The risk was measured as negative deviations from a target income. Both MOTAD and Target MOTAD generate a large set of farm plans for the decision-maker to choose from. The Compromise MOTAD model was developed to help reduce the decision space considerably by identifying a subset of MOTAD generated risk efficient farm plans that are more relevant to the decision-maker. In the end, sensitivity analysis was conducted using MOTAD for examining impacts of potential policy and resource base changes on farm structure.

### The Farm

A typical farm (farm number 1) with 20 acres of land is selected for analysis. Out of 20 acres, 13 acres are cultivated by the landlord, and seven acres are cultivated by a sharecropper. According to the sharecropping terms, the landlord provides land and half of the inputs, and the tenant provides labor and half of the inputs. Vegetables are labor-intensive crops and generally landlords rely on share-croppers to raise vegetable crops. The farm manager owns a tractor and has a private tube-well for supplemental irrigation water.

Income series were developed for all the crops grown over a six-year period (1986-1991). Though a longer time period may be desirable, it is assumed that a six-year period adequately captures long-term price fluctuations. It is observed that using information from a limited number of historical periods is congruent with the farmer's behavior since farmers tend to discard information from more distant periods when forming price expectations.

### Enterprises

The farm is growing almost all the traditional and non-traditional crops being grown in the study area. The traditional crop rotations include wheat, rice, sugarcane, sorghum, and berseem. The non-traditional crops include peas, bringle, gourds, and carrots. The non-traditional crops are labor-intensive crops and are, generally, grown only on the farms which have enough family labor or which can make some sharecropping arrangements. The weather and rotation system permit 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 satisfy the consumption requirement of the family. Sometimes surplus milk is also sold to get supplemental income from livestock. The farm raised buffaloes for meeting the consumption requirement of the family.

### Resource Constraints

The farm had an area of 20 acres. 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 in the area. However, because the farm owns a tubewell, irrigation water is not specified as a binding constraint. The binding constraints include institutional credit and hired labor. Hired labor is critical during the peak use periods, such as planting and harvesting. There are two crop production seasons in Pakistan, namely *Rabi* and *Kharif*. The availability of family labor, hired labor and institutional credits is specified for each season. The restrictions for the family consumption requirement are also specified. It is assumed that Rs 10,000 will be available as institutional credit at the current interest rate.

## Profit Maximizing Farm Plan

It is generally argued that farmers tend to maximize profits from their farming business. To look at the profit maximizing resource allocation of the farm, a basic linear programming (LP) analysis was conducted. The results of the LP model are presented in Table XVII. Risk theory indicates that risk-neutral decision makers will seek the LP profit maximizing plan. The expected income (Rs 96736.22) associated with this plan reflects the maximum attainable income given the existing resources of the farm. The profit maximizing plan is a high risk plan. It has an absolute deviation (MAD) of Rs 32,946.16, a standard deviation (SD) of Rs 44,326.65, and a coefficient of variation (CV) 45.82.

The profit maximizing 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 has 3.25 buffaloes for meeting milk consumption requirements of the family. Sugarcane and eggplants do not enter the profit maximizing farm plan. However, sugarcane

## TABLE XVII

## PROFIT MAXIMIZING FARM PLAN

| | |
|---|---|
| Expected Income (Rs) | 96736.22 |
| Total Negative Deviations (TND) | 96838.49 |
| Mean Absolute Deviation (MAD) | 32946.16 |
| Standard Deviation (SD) | 44326.65 |
| Coefficient of Variation (CV) | 45.82 |

| 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 |

and eggplants are common in the present crop rotations of the study area. That implies that the profit maximizing plan does not truly represent farmers current behavior. The high risk attached to the profit maximizing farm plan may explain why farmers do not adopt this profit maximizing rotation.

The profit maximizing farm plan utilized Rs 10,000 of institutional credit, 50 bags of urea, 36 bags of DAP, and hired labor as shown in Table XVIII. May-June and November-December are the peak labor requirement seasons. Labor shortage in these seasons will compel the farm manager to adopt a sub-optimal farm plan. All the institutional credit available was used . Thus, the constraint on institutional credit is binding.

## TABLE XVIII

## RESOURCE USE FOR PROFIT MAXIMIZING PLAN

| Resources | Unit | Plan Requirement |
|---|---|---|
| Hired Labor | | |
| January-February | Mandays | 51.13 |
| March-April | Mandays | 63.13 |
| May-June | Mandays | 123.47 |
| July-August | Mandays | 97.05 |
| September-October | Mandays | 73.32 |
| November-December | Mandays | 213.32 |
| Fertilizer | | |
| Urea | Bags | 50.22 |
| DAP | Bags | 36.69 |
| Institutional Credit | Rs. | 10,000.00 |

The area under carrots was constrained at the margin by the availability of harvest labor. Sorghum and berseem are forced in the solution for meeting the fodder requirements of livestock raised on the farm. In *Kharif* season, rice is the only cash crop grown. In *Rabi* season, wheat is the major crop, followed by peas and carrots.

### Risk Minimizing Farm Plans

The MOTAD model is employed to generate risk efficient farm plans. Expected income is parameterized in arbitrary increments of Rs 5,000 to trace the efficiency frontier (Figure16). Each point on the efficiency frontier is a unique farm plan. The decision maker 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 XIX shows the set of risk efficient farm plans generated. It shows the tradeoff 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 first plan was specified to have an expected income of Rs 90,000 and has the highest variability associated with it. It has a SD of Rs 33,667.33 and CV of 37.41. The enterprises included in this farm plan are: wheat (11.31 acres), rice (13.21 acres), sugarcane (2.86 acres), sorghum (1.83 acres), peas (3.0 acres), berseem (1.33 acres), carrots (2.0 acres), eggplant (2.60 acres), and buffaloes (1.33 heads). This plan shows many similarities with the profit maximizing plan in crop mixes and level of enterprises. The only major difference in crop mixes is that the risk efficient farm plan includes 2.60 acres of eggplant and 2.86 acres of sugarcane. These acreages are achieved with some reduction in other crop acreages, primarily rice and wheat.

When the specified expected income is decreased from Rs 90,000 to Rs 80,000 (plan 3) and a risk minimizing strategy derived, a dramatic change in the levels of wheat, rice, and sugarcane is noticed. The area under wheat and rice is reduced from 11.31 acres and 13.21 acres to 5.18 acres and 6.17 acres, respectively. In contrast, the area under sugarcane showed an exorbitant rise of 215 percent from 2.86 acres to 8.99 acres. Other enterprise levels remained the same except the area under eggplants increased from 2.60 acres to 3.51 acres. The associated risk with this plan as measured by SD and CV was found

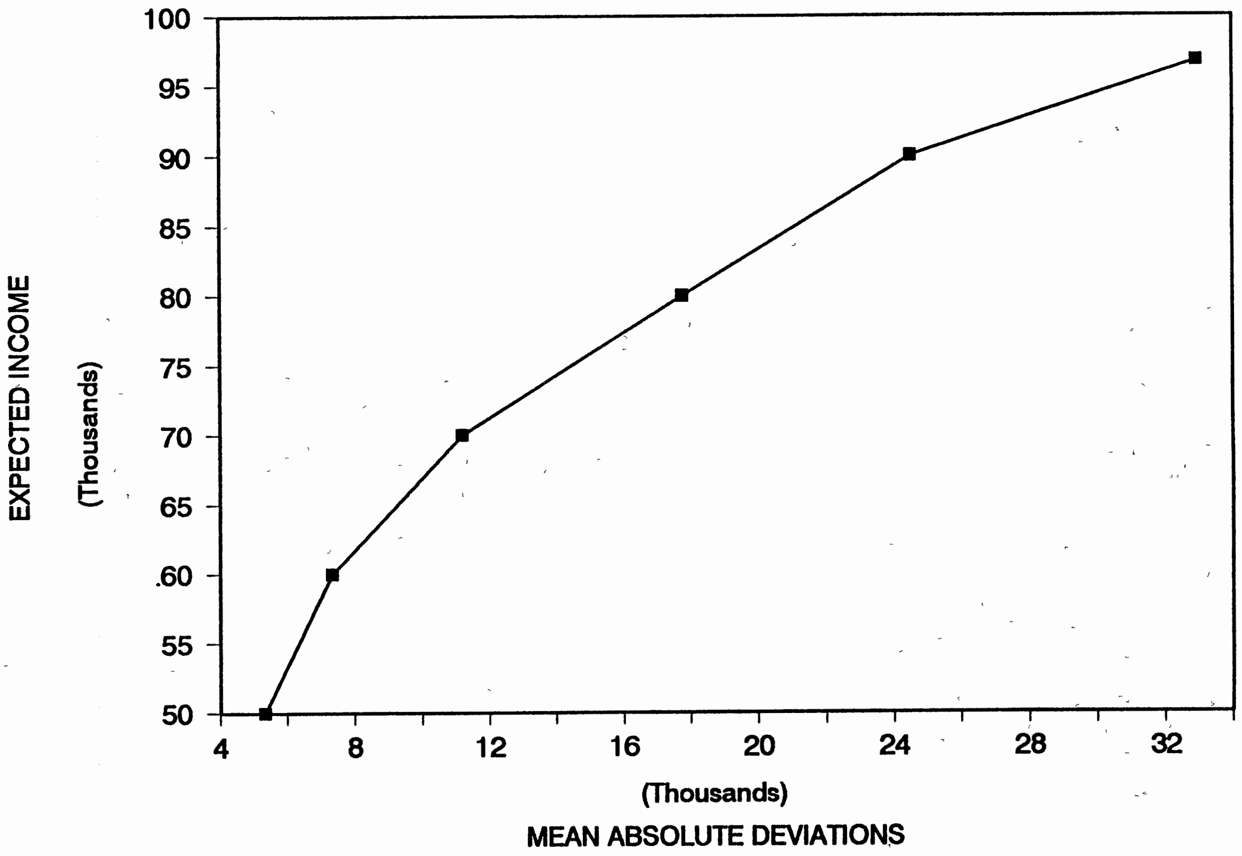


Figure 16. MOTAD Risk Efficiency Frontier

# TABLE XIX

## 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 |
| TND[1] | 73551.54 | 63402.77 | 53254.00 | 43105.23 | 33618.62 | 26509.38 | 22004.74 | 18968.27 | 16022.41 |
| MAD[2] | 24517.18 | 21134.26 | 17751.33 | 14368.41 | 11206.21 | 8836.46 | 7334.91 | 6322.76 | 5340.80 |
| SD[3] | 33667.33 | 29021.85 | 24376.38 | 19730.90 | 15388.52 | 12134.35 | 10072.40 | 8682.50 | 7334.06 |
| CV[4] | 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 |

[1] Total Negative Deviations
[2] Mean Absolute Deviations
[3] Standard Deviations
[4] Coefficient of Variations

to be Rs 24,376.38 and 30.47, respectively. The coefficient of variation declined about 7.0 percent.

In plan 5, expected income is further reduced to Rs 70,000. The standard deviation and coefficient of variation are also reduced to Rs 15,388.52 and 21.98, respectively. The enterprises associated with this plan include 1.72 acres of wheat, 12.45 acres of sugarcane, 2.19 acres of gourds, 1.83 acres of sorghum, 3.0 acres of peas, 1.33 acres of berseem, 2.0 acres of carrots, 4.02 acres of eggplants, and 1.33 head of buffaloes. Rice is not included in the plan, and the area under wheat is reduced significantly. Gourds come into the solution at the level of 2.19 acres. The area under sugarcane increases to 12.45 acres. These changes result in a lower standard deviation and coefficient of variation. This implies that high income variability is associated with rice production.

The hired labor, institutional credit, and fertilizer requirement for each farm plan are given in Table XX. For instance, if a decision maker decides to select farm plan 4, he will have to hire 277 Mandays of labor in January-February and 251 Mandays in November-December. Labor requirement in other periods are not very high as shown in Table XX. He will also have to purchase 77 bags of urea and 21 bags of DAP. Institutional credit required for this plan is estimated to be Rs 10,000. Institutional credit requirements for each farm plan remains the same. No significant change in fertilizer requirement is noticed between the different farm plans.

The tradeoff between expected income and risk is shown in Figure 16. The risk efficiency frontier depicts the alternative risk efficient farm plans and risk associated with them. Any movement from left to right along the efficiency frontier will result in increased expected income and a higher risk associated

# TABLE XX

# RESOURCE USE FOR RISK EFFICIENT FARM PLANS

| | | Farm Plans | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Resources | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 | Plan 7 | Plan 8 | Plan 9 |
| Expected Income | Rs | 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 |
| Hired Labor | Mandays | | | | | | | | | |
| Jan.-Feb. | Mandays | 94.04 | 155.05 | 216.06 | 277.08 | 284.86 | 153.89 | 159.13 | 162.22 | 164.14 |
| Mar. - Apr. | Mandays | 48.88 | 48.56 | 48.23 | 47.91 | 47.96 | 48.77 | 50.31 | 49.49 | 49.02 |
| May-June | Mandays | 93.06 | 87.52 | 81.99 | 76.46 | 74.22 | 80.18 | 75.24 | 73.85 | 73.84 |
| July-Aug. | Mandays | 58.21 | 42.88 | 27.54 | 12.21 | 14.63 | 62.48 | 59.04 | 58.13 | 57.68 |
| Sep.-Oct. | Mandays | 54.10 | 50.25 | 46.40 | 42.55 | 57.39 | 117.18 | 103.82 | 102.15 | 102.38 |
| Nov.-Dec. | Mandays | 204.96 | 220.29 | 235.62 | 250.96 | 239.78 | 159.66 | 149.08 | 147.07 | 148.40 |
| Inst. Credit | Rs | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 |
| Fertilizer Used | | | | | | | | | | |
| Urea | Bags | 67.67 | 70.87 | 74.07 | 77.26 | 77.67 | 71.14 | 73.96 | 74.08 | 73.89 |
| DAP | Bags | 31.73 | 28.19 | 24.67 | 21.14 | 20.69 | 27.50 | 21.46 | 39.52 | 66.75 |

with it. In contrast, movement from right to left along efficiency frontier would mean less risk and lower expected income.

The analysis shows that less risk-lower income farm plans include more area under sugarcane and gourd. On the other hand, wheat and rice are the dominant crops in plans with higher expected income and high risk. Sugarcane remained an important component of all farm plans. Production of carrots and peas are constrained by the scarcity of labor. Levels of sorghum and berseem in farm plans are dictated by the fodder requirements of the livestock enterprises. The magnitude of livestock enterprises is largely determined by family consumption requirements. Cropping intensity for each farm plan is also shown in Table XIX. Cropping intensity is defined as the ratio of planted acres to available land. Double cropping allows the ratio to exceed 100 percent. Cropping intensity ranged from 139 percent to 186 percent. Cropping intensity for rainfed areas of Punjab is reported to be as high as 131 percent (Sheikh et al.). Thus, a cropping intensity between 139 percent and 186 percent for irrigated Punjab seems reasonable.

## Profit Maximizing Low Risk Farm Plans

Some researchers argue that farmers do not intend to minimize risk, rather farmers maximize farm profit but they are concerned about farm income falling below a specified level. To generate farm plans consistent with this type of decision making, the Target MOTAD technique is applied. A target income is specified for the farm. Risk is measured as the expected short fall ($\lambda$) from the target. The parameter $\lambda$ was initially set at a large value. In this case, the Target MOTAD model was equivalent to the deterministic linear programming. As $\lambda$ was reduced, solutions that varied from the deterministic LP occurred. At each change in λ, the corresponding expected income and optimal solution were recorded for each target level of income considered.

The optimal cropping plan, expected net returns, and corresponding values of λ for a target income of Rs 60,000 are shown in Table XXI. Expected net returns ranged from Rs 96,736 when negative income deviations were ignored to Rs 94,998 when negative income deviations were not permitted.

### TABLE XXI

### OPTIMAL NET RETURNS AND PRODUCT MIX FOR VARYING LEVELS OF RISK FOR TARGET INCOME Rs. 60,000

| | | Farm Plans | | | |
|---|---|---|---|---|---|
| Characteristics | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 |
| Target Income | Rs | 60000.00 | 60000.00 | 60000.00 | 60000.00 |
| λ | Rs | 0.00 | 2000.00 | 6000.00 | 11000.00 |
| Obj. Function | Rs | 94998.43 | 95342.41 | 96028.88 | 96736.22* |
| Crop Mix: | | | | | |
| Wheat | Acre | 14.09 | 14.00 | 13.85 | 13.68 |
| Rice | Acre | 6.77 | 17.05 | 17.61 | 18.18 |
| Sorghum | Acre | 1.91 | 1.99 | 2.15 | 2.31 |
| Peas | Acre | 3.00 | 3.00 | 2.99 | 3.00 |
| Berseem | Acre | 1.41 | 1.49 | 1.65 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 1.81 | 1.45 | 6.73 | 6.00 |
| Buffalo | Heads | 1.64 | 1.96 | 2.60 | 3.25 |

*LP Solution

For λ greater than 11,000, the Target MOTAD model was equivalent to a deterministic linear programming model. The optimal solution in this case has already been discussed in the beginning of this chapter. On the other extreme, when λ equals zero, 1.81 acres of eggplants were brought into the solution. The area under rice declined to 6.77 acres, and the area under wheat experienced a slight increase. Other crops in the solution remained the same. The number of buffaloes was also decreased. Thus, the areas under fodder crops, sorghum, and berseem, also declined. Surprisingly, sugarcane was not included in any farm plan.

As λ was decreased, keeping the target income at the same level, crop plans were altered. The area under wheat increased, while the area under rice, sorghum, and berseem declined. The area under sorghum and berseem declined because fodder requirement was reduced due to the decrease in the number of buffaloes. These results imply that rice is the high risk crop included in the solution. Peas and carrots were included in each plan at their upper limit.

The optimal solutions for target income of Rs 70,000, Rs 80,000 and Rs 90,000 are reported in Tables XXII, XXIII, and XXIV, respectively. The analysis shows that variations in λ have similar effects on crop mixes at all target income levels. At target income levels higher than Rs 60,000, the zero risk (λ=0) option was not feasible. Higher minimum feasible values of λ were associated with higher levels of target income.

# TABLE XXII

# OPTIMAL NET RETURNS AND PRODUCT MIX FOR VARYING LEVELS OF RISK FOR TARGET INCOME Rs. 70,000

| | | Farm Plans | | |
|---|---|---|---|---|
| Characteristics | Units | Plan 1 | Plan 2 | Plan 3 |
| Target | Rs | 70,000.00 | 70,000.00 | 70,000.00 |
| λ | Rs | 11,000.00 | 15,000.00 | 20,500.00 |
| Obj. Function | Rs | 94786.94 | 95895.40 | 96736.22* |
| Enterprise Mix: | | | | |
| Wheat | Acres | 14.13 | 13.89 | 13.68 |
| Rice | Acres | 16.60 | 14.47 | 18.18 |
| Sorghum | Acres | 1.86 | 2.11 | 2.31 |
| Peas | Acres | 3.00 | 2.99 | 2.99 |
| Berseem | Acres | 1.36 | 1.61 | 1.81 |
| Carrots | Acres | 2.00 | 2.00 | 2.00 |
| Eggplant | Acres | 2.04 | .92 | 0.00 |
| Buffalo | Head | 1.45 | 2.44 | 3.25 |

*LP Solution

# TABLE XXIII

## OPTIMAL NET RETURNS AND PRODUCT MIX FOR VARYING LEVELS OF RISK FOR TARGET INCOME Rs. 80,000

| | | Farm Plans | | | |
|---|---|---|---|---|---|
| Characteristics | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 |
| Target Income | Rs | 80000.00 | 80000.00 | 80000.00 | 80000.00 |
| λ | Rs | 32000.00 | 35000.00 | 40,000.00 | 43,000.00 |
| Obj. Function | Rs | 93287.00 | 95019.68 | 96152.28 | 96736.00 |
| Crop Mix: | | | | | |
| Wheat | Acre | 16.80 | 14.09 | 13.82 | 13.68 |
| Rice | Acre | 16.02 | 16.72 | 17.71 | 18.18 |
| Sorghum | Acre | 1.83 | 1.89 | 2.17 | 2.31 |
| Peas | Acre | 0.36 | 3.00 | 2.99 | 3.00 |
| Berseem | Acre | 1.33 | 1.39 | 1.68 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 2.65 | 1.91 | 0.61 | 6.00 |
| Buffalo | Heads | 1.33 | 1.58 | 2.71 | 3.25 |

## TABLE XXIV

## OPTIMAL NET RETURNS AND PRODUCT MIX FOR VARYING LEVELS OF RISK FOR TARGET INCOME Rs. 90,000

| | | Farm Plans | | |
|---|---|---|---|---|
| Characteristics | Units | Plan 1 | Plan 2 | Plan 3 |
| Target Income | Rs | 90000.00 | 90000.00 | 90000.00 |
| $\lambda$ | Rs | 65000.00 | 70000.00 | 72,500.00 |
| Obj. Function | Rs | 94928.07 | 96152.28 | 96736.22 |
| Crop Mix: | | | | |
| Wheat | Acre | 14.10 | 13.82 | 13.68 |
| Rice | Acre | 16.72 | 17.71 | 18.18 |
| Sorghum | Acre | 1.90 | 2.17 | 2.31 |
| Peas | Acre | 3.00 | 3.00 | 3.00 |
| Berseem | Acre | 1.40 | 1.68 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 1.88 | 0.61 | 0.00 |
| Buffalo | Heads | 1.58 | 2.71 | 3.25 |

The Target MOTAD frontiers associated with the results in Tables XXI through XXIV were traced for each level of target income and are reported in Figure 17. The Target MOTAD frontiers were quite flat as the expected income from all solutions vary only slightly. In almost all cases, the expected income from farm plans over the range of $\lambda$s tested were quite close to the expected income from the deterministic LP plan.

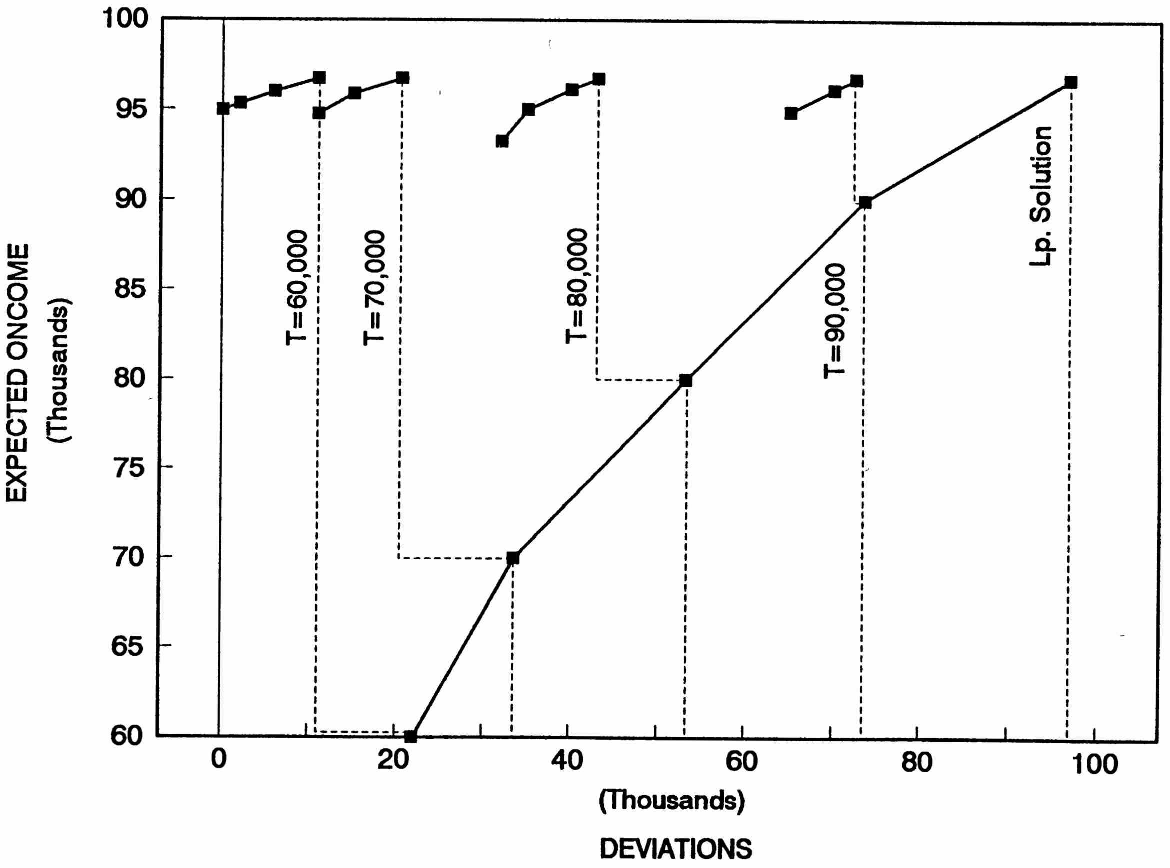


Figure 17. A Comparison of MOTAD & Target MOTAD

## MOTAD and Target MOTAD – A Comparison

For comparison, the Target MOTAD solutions were generated by using the MOTAD expected income as a target. Expected shortfall ($\lambda$) was parameterized to trace an efficiency frontier. When $\lambda$ was set at the same level as the negativedeviations of the corresponding MOTAD solution, it always generated the deterministic LP solution. The comparison of MOTAD and Target MOTAD solutions is depicted in Figure 17.

Target MOTAD solutions always generated higher expected income with negative deviations less than those in the corresponding MOTAD solutions. If risk is conceived as deviations below target income, Target MOTAD solutions resulted in lower negative deviations and, thus, less risk. Moreover, the Target MOTAD efficiency frontiers are above the MOTAD efficiency frontier everywhere. This implies that Target MOTAD solutions have higher expected income than MOTAD solutions in all situations. Therefore, Target MOTAD solutions were found to be clearly superior to MOTAD solutions. Similar corroborative results were also found by Watts et al. and Helmers et al.

Figure 18 depicts a three-dimensional surface for Target MOTAD analysis. The horizontal axis represents expected income that decreases from left to right. Deviations from target incomes are shown by the vertical axis as heights. The "side" axis reflects target incomes. The diagonal set of columns (from the front corner to back corner) where expected income equals target income represents the MOTAD frontier. The LP solutions are shown in the far left column for the cases where $\lambda$ is not a binding constraint in the Target MOTAD solution.

As expected income is increased for a specified target, negative deviations decline and then increase. This positively sloped part of the surface represents the decision area. It can clearly be seen from the surface that the decision area

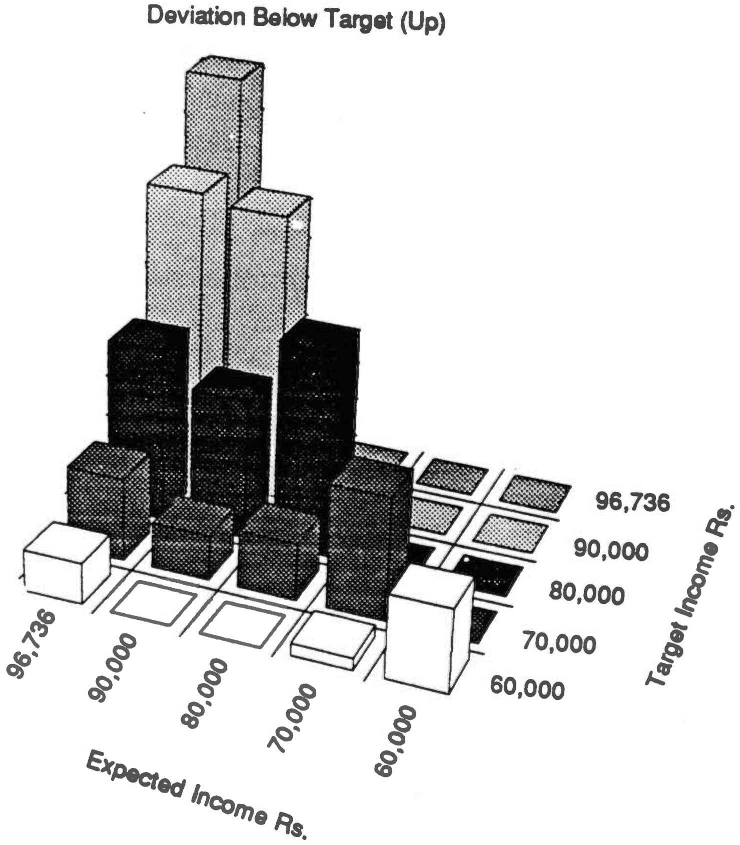


Figure 18. Target MOTAD Surface for Resource Allocation Analysis

is substantially away from the MOTAD frontier, indicating that Target MOTAD solutions are superior to MOTAD solutions.

Best Compromise Farm Plans

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

As discussed earlier, Compromise MOTAD first identifies an ideal vector and 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 32279 as shown in Table XXV.

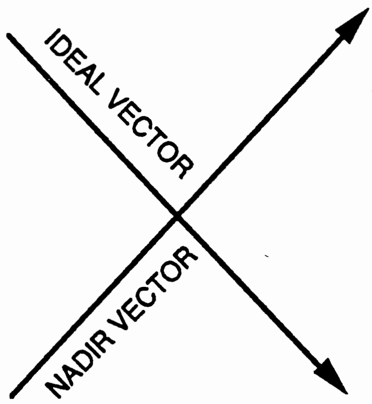
The traditional MOTAD model was used for tracing the risk efficiency frontier. The Compromise MOTAD model was then employed to identify a compromise set of farm plans. It is assumed that decision the maker attaches equal importance to both objectives. This implies $W_1$ equals $W_2$. The compromise set is shown in Figure 19.

Point A reflects the solution defined by the $\alpha_1$ metric and point B shows the solution provided by the $\alpha_2$ metric. Solutions of all other metrics lie between A and B. This implies that the area on the risk efficiency frontier between point A

## TABLE XXV

## EFFICIENT FARM PLANS, IDEAL VECTOR, AND NADIR VECTOR

| Farm Plans | Mean Absolute Deviations (Rs) | Expected Gross Margins (Rs) |
|---|---|---|
| Plan 1 | 5340.80 | 50,000.00 |
| Plan 2 | 7334.91 | 60,000.00 |
| Plan 3 | 11206.21 | 70,000.00 |
| Plan 4 | 17751.33 | 80,000.00 |
| Plan 5 | 24517.18 | 90,000.00 |
| Plan 6 | 32279.50 | 96736.22 |



and point B represents the compromise set. The shaded area reflects the compromise decision space.

It is intuitively seen that minimizing the objective function of Compromise MOTAD is the same as maximizing the following function:

$$(5.1) \qquad \text{Max } Z(x) - \frac{(\text{Max EGM} - \text{Min EGM})}{(\text{Max MAD} - \text{Min MAD})} \bullet \frac{W_1}{W_2} \bullet \frac{1}{n} \sum_{i=1}^{n} (\overline{y} + \overset{+}{y})$$

or

$$(5.2) \qquad \text{Max } Z(x) - \gamma \bullet \frac{W_1}{W_2} \bullet \frac{1}{n} \sum_{i=1}^{n} (\overline{y} + \overset{+}{y})$$

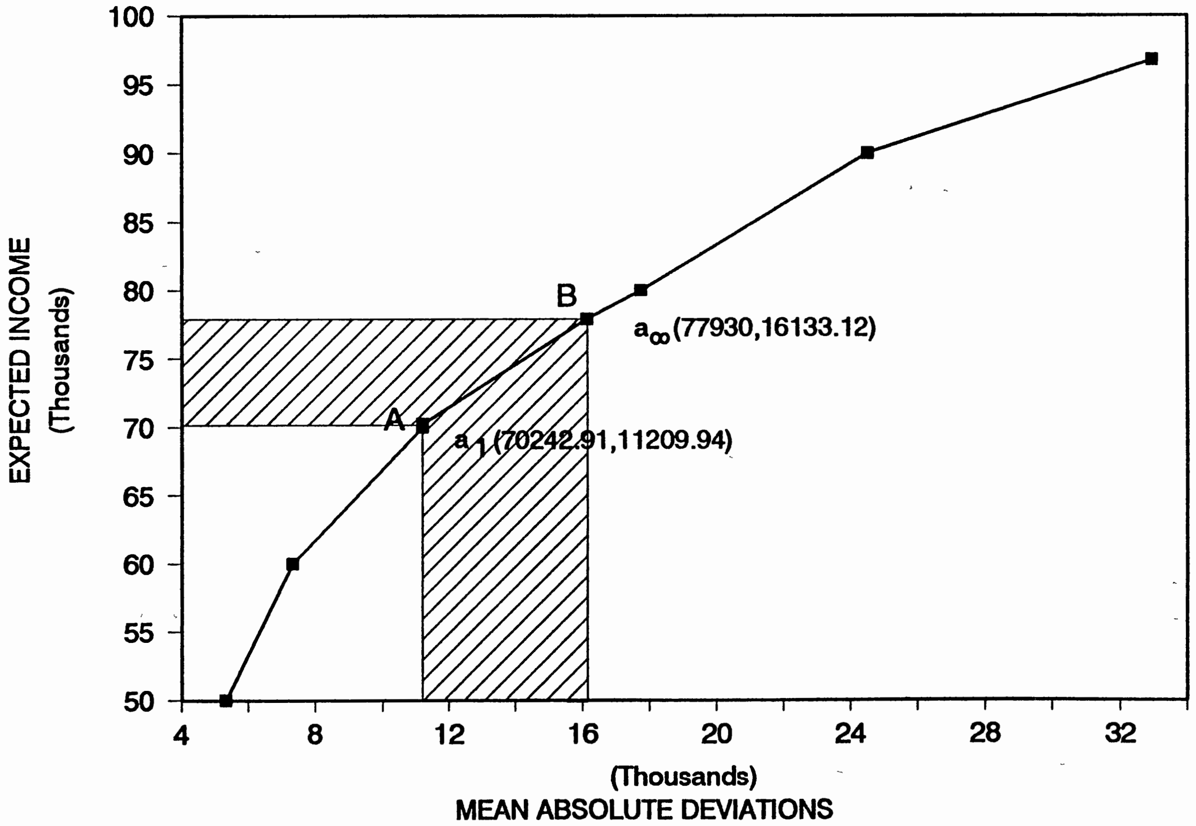


Figure 19. MOTAD Risk Efficiency Frontier and Compromise Set

where $\gamma = \frac{(\text{Max EGM - Min EGM})}{(\text{Max MAD - Min MAD})}$ and EGM is the expected gross margin. The expression (5.2) maximizes the utility function of the decision maker. 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 $\gamma \cdot \frac{W_1}{W_2}$ can be viewed as a measure of risk aversion because it is the multiplicative factor for risk. In this analysis $W_1$ is assumed equal to $W_2$; thus $\gamma$ represents the risk aversion coefficient of the decision maker.

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

If decision maker 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.

In addition to the information that MOTAD and Target MOTAD offer ( i.e. a risk efficient set of farm plans and trade-off among objectives) Compromise MOTAD furnishes the decision maker 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 farm plan alternatives to be considered and thus makes the decision making process easier. Further more, 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.

## Sensitivity Analysis

Risk programming models can be usefully applied for analyzing the impacts of different structural and policy changes. The MOTAD model discussed earlier was applied for estimating the effects of increasing the availability of institutional credit, decreasing the availability of labor, increasing the price of wheat, increasing institutional credit while decreasing labor availability, and allowing domestic prices to adjust with international prices freely. The rationale for the assumptions made for each sensitivity analysis is discussed below.

The Government of Pakistan is making strenuous efforts to make more funds available to meet the growing demand for institutional credit. The assumption of an increase in institutional credit stems from the fact that the government has allocated more budget for agricultural credit every year for the last several years. So the assumption is congruent with the government policy. It is assumed that the credit limit for short-term loans will be increased to Rs 15,000. The IFFS results show that farmers have funds available to repay the loans of this magnitude which makes the assumption appear realistic.

Development of new industries in the study area is attracting a substantial number of agricultural laborers. Consequently, availability of labor for agricultural operations is declining over time. It is assumed that a considerable reduction in availability of agricultural labor will force the farmers to make decisions about readjusting their crop rotations. The impact of a decrease in labor availability to 60 mandays for each month is examined in the HLAB model. Effects of an increase in institutional credit with a decrease in availability of labor is also analyzed in the LABCRED model.

The government policy objectives with regard to privatization provide a rationale for the assumption that the prices of agricultural commodities will adjust to the world market prices gradually. The impact of a change in crop prices caused by paying farmers a price equivalent to world market prices is studied. It is also observed that almost every year in the recent past the government has increased wheat price. It is assumed therefore that the wheat price will be increased to Rs 115 per 40 kg per year.

## Effects of Increasing Institutional Credit - CRED Model

The CRED model shows the results of relaxing the constraint on institutional credit from Rs 10,000 to Rs 15,000. The results are shown in Table XXVI. It is interesting to note that the risk associated with each level of expected income is much lower than the corresponding levels of the basic MOTAD model. The maximum expected income also increased from Rs 96,736 to Rs 102,000 as shown in Table XXVI.

The pattern of crop rotations in farm plan 1 of the CRED model closely resembles that of the profit maximizing LP farm plan of the basic MOTAD model. An exception is the CRED plan 1 where acreage under wheat and rice is slightly lower than that of the MOTAD LP plan, and the number of buffalo is greater. When the expected income is parameterized to Rs 90,000, the area of both wheat and rice is reduced drastically from 13.2 acres and 17.26 acres to 9.35 acres and 8.36 acres, respectively. Sugarcane was brought into the solution at the level of 4.81 acres. Area under eggplants is also increased significantly from 0.43 acres to 5.49 acres. Area under wheat, rice, sugarcane and eggplants was 11.31, 13.21, 2.86, and 2.60 acres, respectively, in the corresponding MOTAD model with an expected income of Rs 90,000.

When expected income was further reduced to Rs 80,000, gourd was included in the solution at the level of 4.12 acres. Area under rice is reduced dramatically to 2.97 acres. In other farm plans with an expected income of Rs 70,000 or below, rice is completely replaced by gourd and eggplant. Area under wheat is reduced to 1.35 acres at an expected income of Rs 60,000. This

# TABLE XXVI

## SET OF RISK EFFICIENT FARM PLANS ASSUMING AN INCREASE IN INSTITUTIONAL CREDIT - CRED MODEL

| | Farm Plans | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 | Plan 7 | Plan 8 | Plan 9 | Plan 10 | Plan 11 |
| Exp. Income | 102,000 | 100,000 | 90,000 | 85,000 | 80,000 | 75,000 | 70,000 | 65,000 | 60,000 | 55,000 | 50,000 |
| TND | 98151.22 | 86131.70 | 57261.56 | 47112.79 | 38209.77 | 30501.45 | 26451.51 | 23496.33 | 20637.89 | 17882.78 | 15126.72 |
| MAD | 32717.07 | 28710.57 | 19087.19 | 15704.26 | 12736.59 | 10167.15 | 8817.17 | 7832.11 | 6879.30 | 5960.93 | 5042.24 |
| S.D. | 44927.51 | 39425.73 | 26210.78 | 21565.30 | 17490.05 | 13961.66 | 12107.85 | 10775.16 | 9446.74 | 8185.62 | 6924.07 |
| C.V. | 44.05 | 39.43 | 29.12 | 25.37 | 21.96 | 18.62 | 17.30 | 16.55 | 15.74 | 14.88 | 13.85 |
| <u>Crop Mix</u> | | | | | | | | | | | |
| Wheat | 13.20 | 13.67 | 9.35 | 6.29 | 8.25 | 8.41 | 6.55 | 3.10 | 1.35 | 1.35 | 1.35 |
| Rice | 17.26 | 15.64 | 8.36 | 4.84 | 2.97 | 0.66 | 0 | 0 | 0 | 0 | 0 |
| Sugarcane | 0 | 0 | 4.81 | 7.94 | 5.91 | 5.67 | 6.42 | 6.63 | 6.76 | 6.78 | 6.80 |
| Gourd | 0 | 0 | 0 | 0 | 4.12 | 7.03 | 7.43 | 7.55 | 7.69 | 7.86 | 8.03 |
| Sorghum | 2.80 | 2.33 | 1.83 | 1.83 | 1.83 | 1.92 | 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 | 3.00 | 3.00 |
| Besseem | 2.30 | 1.83 | 1.33 | 1.33 | 1.33 | 1.42 | 2.52 | 5.76 | 7.39 | 7.38 | 7.35 |
| Carrot | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | 0.43 | 2.52 | 5.49 | 5.95 | 5.66 | 5.21 | 4.81 | 4.48 | 4.21 | 4.03 | 3.84 |
| Buffalo | 5.18 | 3.33 | 1.33 | 1.33 | 1.33 | 1.69 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Total Area Sown | 40.99 | 40.99 | 36.17 | 33.08 | 35.07 | 35.32 | 34.56 | 34.35 | 34.23 | 34.23 | 34.20 |
| Cropping Intensity | 199.95 | 199.95 | 176.44 | 161.37 | 171.07 | 172.29 | 168.59 | 167.56 | 166.98 | 166.98 | 166.83 |

implies that given an expected income of Rs 60,000, wheat is produced only to meet the consumption requirements of the family. Resources used in farm plans in the CRED model are shown in Table XXVII.

Comparison of the basic MOTAD model and CRED model is depicted in Figure 20. The risk efficiency frontiers show that at each level of expected income the associated risk is lower for all CRED model farm plans than those of the corresponding basic MOTAD model. The CRED model efficiency frontier is dominant everywhere.

The stabilizing effect of increased availability of credit can be noticed from the C.V. and S.D associated with basic MOTAD plan and the corresponding CRED plan. With an expected income of Rs 90,000, the basic MOTAD model and CRED model shows CVs of 37.41 and 29.12, and SDs of 33,667.33 and 26,210.78, respectively. The coefficients of variation for all the farm plans in the CRED model are lower than the corresponding coefficients of variation in the basic MOTAD model farm plans. Increased availability of credit allows the decision maker to grow lower risk capital demanding crops, thus helping to reduce the risk associated with each plan.

### Effects of Changes in Labor Availability - HLAB Model

The impact of a potential decrease in hired agricultural labor is examined in the HLAB model. As shown in Table XXVIII, the expected income of the profit maximizing plan of the HLAB model declined to Rs 85,341 because of a decline in labor supply. The risk associated with farm plan 1 of the HLAB model is also higher than that of the corresponding farm plan in the basic MOTAD model.

# TABLE XXVII

## RESOURCES USED FOR CRED MODEL

| | | Farm Plans | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Units | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Expected Income | Rs | 102,000 | 100,000 | 90,000 | 85,000 | 80,000 | 75,000 | 70,000 | 65,000 | 60,000 | 55,000 | 50,000 |
| <u>Hired Labor</u> | | | | | | | | | | | | |
| Jan-Feb. | Mandays | 80.70 | 67.23 | 148.55 | 209.57 | 170.48 | 168.20 | 175.07 | 177.11 | 177.85 | 177.13 | 176.45 |
| Mar-Apr | Mandays | 92.70 | 79.27 | 64.30 | 63.97 | 64.18 | 66.84 | 58.63 | 56.93 | 54.73 | 53.55 | 52.38 |
| May-June | Mandays | 146.90 | 122.58 | 87.71 | 82.17 | 82.83 | 86.00 | 79.05 | 75.60 | 73.87 | 73.84 | 73.84 |
| Jul-Aug | Mandays | 121.61 | 97.96 | 48.44 | 33.10 | 51.17 | 62.86 | 55.25 | 54.43 | 54.13 | 54.33 | 54.54 |
| Sep-Oct | Mandays | 101.97 | 86.92 | 64.66 | 60.81 | 92.13 | 115.78 | 108.88 | 104.43 | 102.22 | 102.39 | 102.58 |
| Nov-Dec | Mandays | 235.92 | 214.13 | 214.73 | 230.06 | 195.51 | 181.08 | 174.61 | 165.25 | 161.11 | 157.28 | 158.47 |
| Instl. Credit | Rs | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 13343.69 | 12927.98 | 12532.45 | 12154.63 | 11777.87 |
| <u>Fertilizer Used</u> | | | | | | | | | | | | |
| Urea | Bags | 53.99 | 67.92 | 87.94 | 91.14 | 89.09 | 86.09 | 83.79 | 83.09 | 82.07 | 80.72 | 79.36 |
| DAP | Bags | 35.77 | 34.14 | 26.86 | 23.34 | 25.60 | 26.20 | 25.93 | 26.05 | 37.66 | 61.09 | 84.56 |

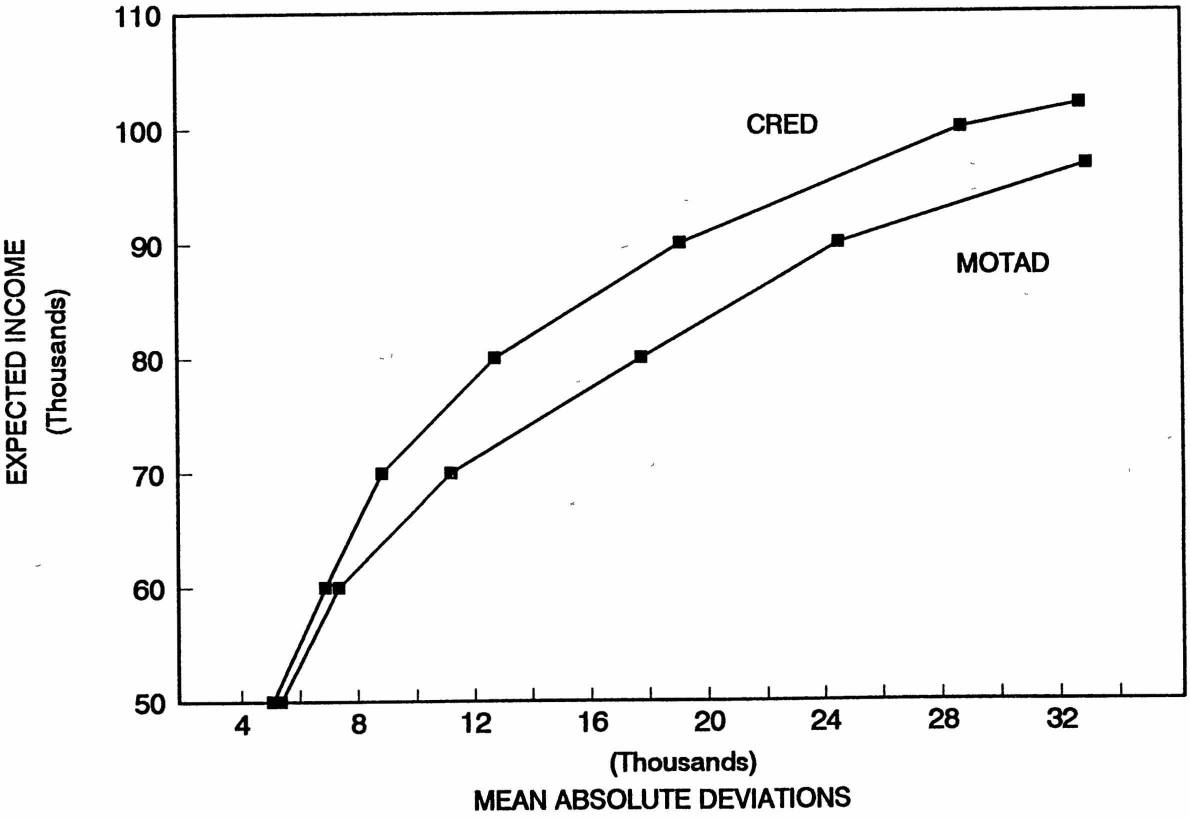


Figure 20. A Comparison of MOTAD and CRED Model Efficiency Frontiers

The results of the HLAB model show that reduced availability of hired agricultural labor will result in an increased risk in the farming business.

### TABLE XXVIII

### SET OF RISK EFFICIENT FARM PLANS OF HLAB MODEL

| | Farm Plans | | | | |
|---|---|---|---|---|---|
| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 |
| Expected Income | 85,341.43 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| TND | 69,083.81 | 57,423.72 | 37,833.48 | 23,426.95 | 16,499.21 |
| MAD | 23,027.94 | 19,141.24 | 12,611.19 | 7,808.98 | 5,499.67 |
| S.D. | 31,622.27 | 26,285.00 | 17,317.96 | 10,723.40 | 7,552.21 |
| C.V. | 37.05 | 32.86 | 24.74 | 17.87 | 15.10 |
| Crop Mix | | | | | |
| Wheat | 17.17 | 16.00 | 14.00 | 10.40 | 1.34 |
| Rice | 12.17 | 9.27 | 4.12 | 0.00 | 0.00 |
| Cotton | 0.00 | 0.00 | 0.00 | 0.84 | 2.36 |
| Sugarcane | 0.00 | 0.00 | 0.46 | 1.76 | 3.68 |
| Gourd | 3.78 | 6.89 | 9.36 | 5.18 | 8.95 |
| Sorghum | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 |
| Peas | 0.00 | 1.16 | 2.69 | 3.00 | 3.00 |
| Berseem | 1.33 | 1.33 | 1.33 | 1.33 | 4.90 |
| Carrot | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplants | 2.72 | 2.50 | 2.74 | 4.29 | 3.67 |
| Buffalo | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Total Area Sown | 41.00 | 40.98 | 38.53 | 30.63 | 31.73 |
| Cropping Intensity | 200.00 | 199.90 | 187.95 | 149.41 | 154.78 |

It is further observed that a labor shortage will bring about a dramatic change in crop rotations. The results of the HLAB model shows that in farm plan 2, 16 acres of wheat and 9.27 acres of rice are produced while in the corresponding basic MOTAD model with expected income of Rs 80,000 only 5.18 and 6.17 acres of wheat and rice were produced, respectively. Furthermore, in the basic MOTAD model, sugarcane was the dominant enterprise with 8.99 acres while in the corresponding HLAB model sugarcane was excluded from the solution. Gourd replaced sugarcane due to the reduction in availability of labor.

Other farm plans shown in Table XXVIII are also significantly different from those of corresponding basic MOTAD model plans. Wheat is the dominant crop in all the farm plans except in farm plan 5 with expected income Rs 50,000, because wheat is a less labor-intensive crop than other crops. Cotton and sugarcane appeared in the farm plans with an expected income of Rs 60,000 and Rs 50,000. Peas were brought into the solution at an expected income of Rs 80,000 and the area under peas was increased as expected income was decreased. Peas replaced wheat in the farm plans.

It is surprising to observe that cropping intensity in the HLAB model farm plans is higher than that of the corresponding basic MOTAD model. This implies that more farm area will be sown with the reduced availability of labor. One possible explanation is that farmers need to cultivate more area because in order to achieve the same level of expected income with less labor available. In the HLAB model, most of the labor is required in the second half of the year as shown in Table XXIX.

The set of efficient farm plans from the HLAB model is traced along the efficiency frontier and is compared with the MOTAD model efficiency frontier in

## TABLE XXIX

## RESOURCE ALLOCATION FOR RISK EFFICIENT FARM PLANS OF HLAB MODEL

| | | Farm Plans | | | | |
|---|---|---|---|---|---|---|
| | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 |
| Expected Income | RS | 85,341.43 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| Hired Labor | Mandays | | | | | |
| Jan.-Feb. | | 0.00 | 11.68 | 44.86 | 81.41 | 110.55 |
| Mar.-Apr. | | 0.00 | 16.35 | 46.25 | 58.14 | 48.92 |
| May-June | | 98.19 | 94.99 | 77.46 | 41.69 | 69.12 |
| Jul.-Aug. | | 80.05 | 86.28 | 76.94 | 32.85 | 67.27 |
| Sep.-Oct. | | 56.86 | 89.22 | 120.00 | 91.28 | 108.13 |
| Nov.-Dec. | | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 |
| Instl. Credit | RS | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 |
| Fertilizer Used | Bags | | | | | |
| Urea | | 62.52 | 63.36 | 66.04 | 70.94 | 71.38 |
| DAP | | 34.45 | 34.66 | 31.97 | 22.92 | 43.45 |

Figure 21. The shape of the efficiency frontier reflects the trade-off between expected income and risk.

### Effects of Simultaneous Change in Labor and Institutional Credit - LABCRED MODEL

Results of an increase in institutional credit and a decrease in labor availability are shown in Table XXX. The expected income for the profit maximizing farm plan (plan 1) was increased to Rs 88,770 from the

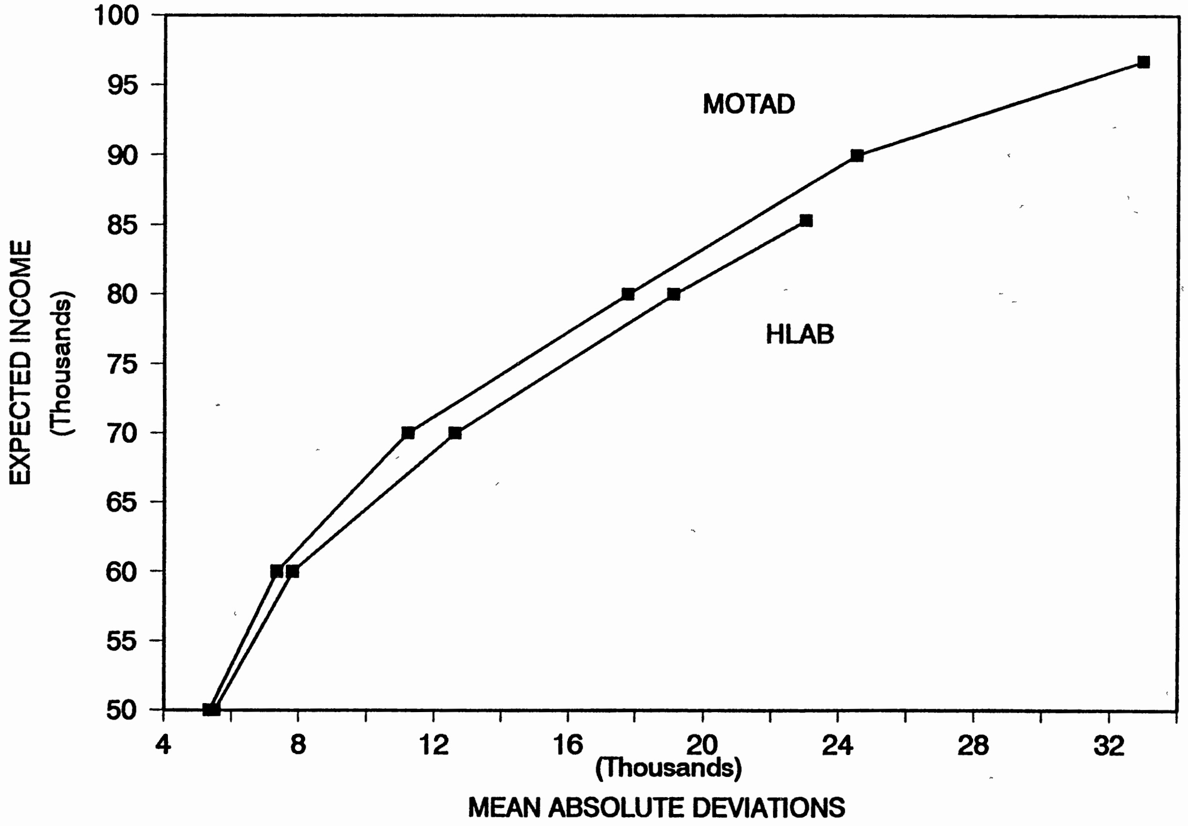


Figure 21. A Comparison of MOTAD and HLAB Model Efficiency Frontiers

corresponding farm plan in the HLAB model with an expected income of Rs 85,341. The risk associated with this plan was also lower than that of the corresponding HLAB model farm plan. However, the expected income of farm plan 1 of the LABCRED model is lower than that of the corresponding MOTAD model farm plan.

## TABLE XXX

## SET OF RISK EFFICIENT FARM PLANS FOR LABCRED MODEL

| | Farm Plans | | | | |
|---|---|---|---|---|---|
| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 |
| Expected Income | 88,770.28 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| TND | 59,323.28 | 43,560.40 | 29,572.13 | 20,961.53 | 15,212.24 |
| MAD | 19,774.43 | 14,520.13 | 9,857.38 | 6,987.18 | 5,070.75 |
| S.D. | 27,154.50 | 19,939.23 | 13,5366.28 | 9,594.88 | 6,963.22 |
| C.V. | 30.59 | 24.92 | 19.33 | 15.997 | 13.93 |
| Crop Mix | | | | | |
| Wheat | 17.16 | 15.71 | 14.80 | 5.05 | 1.34 |
| Rice | 9.57 | 5.26 | 0.00 | 0.00 | 0.00 |
| Cotton | 0.00 | 0.00 | 6.31 | 4.93 | 3.85 |
| Sugarcane | 0.00 | 0.00 | 0.00 | 1.42 | 2.79 |
| Gourd | 3.78 | 4.54 | 7.82 | 8.29 | 8.45 |
| Sorghum | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 |
| Peas | 0.00 | 1.45 | 1.98 | 3.00 | 3.00 |
| Berseem | 1.33 | 1.33 | 1.72 | 9.03 | 11.36 |
| Carrot | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplants | 5.32 | 5.75 | 4.54 | 4.03 | 3.57 |
| Buffalo | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Total Area Sown | 40.99 | 37.87 | 41.00 | 39.05 | 38.19 |
| Cropping Intensity | 199.95 | 184.73 | 200.00 | 190.49 | 186.29 |

The enterprise mix for the LABCRED model was significantly different from that of the HLAB model. Increasing the availability of institutional credit with reduced availability of labor helps the farmers in bringing more area under cotton. Cotton replaces rice at an expected income of Rs 70,000 and below. However, in this rice producing region these farm plans do not make much sense. Other crop mixes in the remaining farm plans closely resemble the HLAB model farm plans. Labor and other resources used in LABCRED model farm plans are shown in Table XXXI.

## TABLE XXXI

## RESOURCE ALLOCATION FOR RISK EFFICIENT FARM PLANS OF LABCRED MODEL

| | | Farm Plans | | | | |
|---|---|---|---|---|---|---|
| | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 |
| Expected Income | RS | 88,770.28 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| Hired Labor | Mandays | | | | | |
| Jan.-Feb. | | 11.09 | 35.44 | 36.13 | 75.27 | 98.70 |
| Mar.-Apr. | | 11.09 | 41.25 | 44.06 | 58.93 | 54.80 |
| May-June | | 96.36 | 73.20 | 74.69 | 67.71 | 66.15 |
| Jul.-Aug. | | 80.05 | 62.88 | 75.52 | 72.15 | 67.73 |
| Sep.-Oct. | | 69.88 | 88.74 | 120.00 | 119.43 | 112.09 |
| Nov.-Dec. | | 120.00 | 120.00 | 120.00 | 120.00 | 120.00 |
| Instl. Credit | RS | 15,000.00 | 15,000.00 | 14,861.90 | 14,331.57 | 13,148.92 |
| Fertilizer Used | Bags | | | | | |
| Urea | | 80.75 | 83.51 | 79.45 | 81.57 | 79.156 |
| DAP | | 31.85 | 28.30 | 32.62 | 31.71 | 60.35 |

The efficiency frontiers for the LABCRED model, HLAB model, and MOTAD model are depicted and compared in Figure 22.

### Effects of an Increase in Wheat Price - WPRICE Model

Changes in commodity prices, it is generally believed, will bring about changes not only in farm incomes but also in farm organization. Changing the price of one commodity will alter the intercrop parity and, thus, crop rotations. In this analysis, the MOTAD model was used to examine the effects of changes in wheat prices. It is assumed that the price of wheat will be increased to Rs 115 by the 1992 crop year. The results of the WPRICE model are given in Table XXXII. It is noticed that an increase in wheat price from Rs 106 to Rs 115 will result in an increase in the expected income from Rs 96,736 to Rs 97,550. The farm plan with expected income of Rs 97,550 suggests the same enterprise mix as that of profit maximizing LP farm plan. When expected income was parameterized to Rs 90,000, Rs 80,000 and so on, it was observed that changes in the enterprise mix were similar to those of the corresponding basic MOTAD model. The total area sown and cropping intensity were not significantly different from the corresponding MOTAD models. Resource allocation for the risk efficient plans is given in Table XXXIII. The risk efficiency frontiers for the WPRICE model and the MOTAD model are compared in Figure 23.

### Effects of Removing Price Distortions - INTPR Model

It is observed that government-controlled commodity prices in Pakistan are substantially lower than the corresponding world market prices (Choudary, Zia). The concept of export parity prices is introduced in this analysis for analyzing

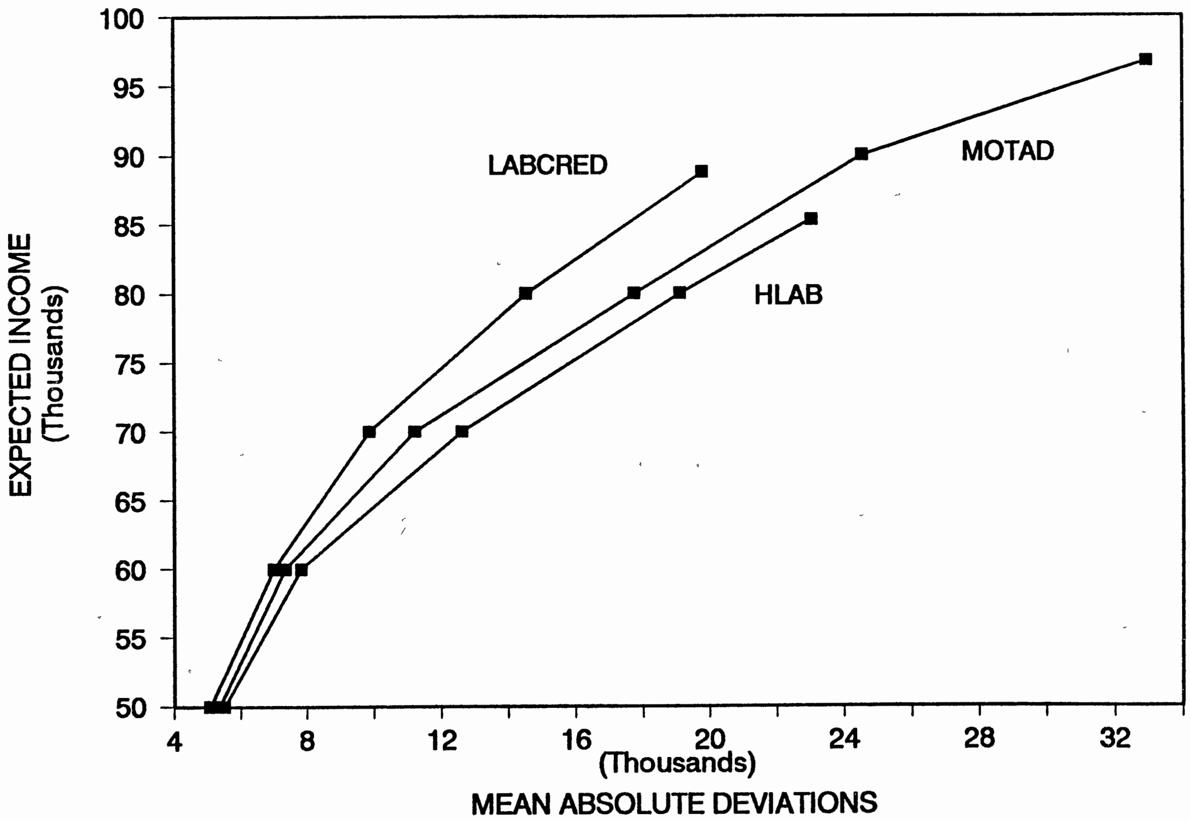


Figure 22. A Comparison of MOTAD, HLAB, and LABCRED Model Efficiency Frontiers

# TABLE XXXII

## EFFECTS OF INCREASING WHEAT PRICE ON RISK EFFICIENT FARM PLANS – WPRICE MODEL FARM PLANS

| | Farm Plans | | | | | |
|---|---|---|---|---|---|---|
| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 |
| Expected Income | 97,550.00 | 90,000.00 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| TND | 99,244.42 | 74,840.97 | 53,844.05 | 33,901.81 | 22,470.26 | 16,239.17 |
| MAD | 33,081.47 | 24,946.99 | 17,948.02 | 11,300.60 | 7,490.09 | 5,413.06 |
| S.D. | 45,427.91 | 34,257.53 | 24,646.45 | 15,518.14 | 10,285.49 | 7,433.28 |
| C.V. | 46.57 | 38.06 | 30.81 | 22.17 | 17.14 | 14.87 |
| Crop Mix | | | | | | |
| Wheat | 13.69 | 10.91 | 4.99 | 1.88 | 2.77 | 1.35 |
| Rice | 18.18 | 12.75 | 5.95 | 0.00 | 0.00 | 0.00 |
| Sugarcane | 0.00 | 3.26 | 9.18 | 12.28 | 5.92 | 6.30 |
| Gourd | 0.00 | 0.00 | 0.00 | 2.38 | 8.48 | 8.53 |
| Sorghum | 2.31 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 |
| Peas | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Berseem | 1.81 | 1.33 | 1.33 | 1.33 | 1.33 | 4.00 |
| Carrot | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | 0.00 | 2.66 | 3.54 | 4.00 | 4.27 | 3.84 |
| Buffalo | 3.25 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Total Area Sown | 40.99 | 37.74 | 31.82 | 28.70 | 29.60 | 30.85 |
| Cropping Intensity | 199.95 | 184.10 | 155.22 | 140.00 | 144.39 | 150.49 |

# TABLE XXXIII

# RESOURCE ALLOCATION FOR WPRICE MODEL FARM PLANS

| | | Farm Plans | | | | | |
|---|---|---|---|---|---|---|---|
| | Units | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 |
| Expected Income | Rs | 97,550.00 | 90,000.00 | 80,000.00 | 70,000.00 | 60,000.00 | 50,000.00 |
| Hired Labor | Mandays | | | | | | |
| Jan.-Feb. | | 51.08 | 102.02 | 219.72 | 281.45 | 156.70 | 162.99 |
| Mar.-Apr. | | 63.08 | 48.84 | 48.21 | 47.88 | 50.36 | 49.06 |
| May-June | | 123.38 | 92.33 | 81.66 | 74.39 | 75.26 | 73.85 |
| July-Aug | | 96.97 | 56.20 | 26.62 | 15.89 | 59.88 | 58.08 |
| Sep.-Oct. | | 73.26 | 53.59 | 46.17 | 59.00 | 104.75 | 102.76 |
| Nov.-Dec. | | 213.22 | 206.96 | 236.54 | 237.72 | 147.41 | 147.54 |
| Instl. Credit | Rs | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 |
| Fertilizer Used | Bags | | | | | | |
| Urea | | 50.27 | 68.09 | 74.26 | 77.49 | 73.87 | 73.86 |
| DAP | | 36.68 | 31.25 | 24.45 | 20.89 | 21.50 | 66.64 |

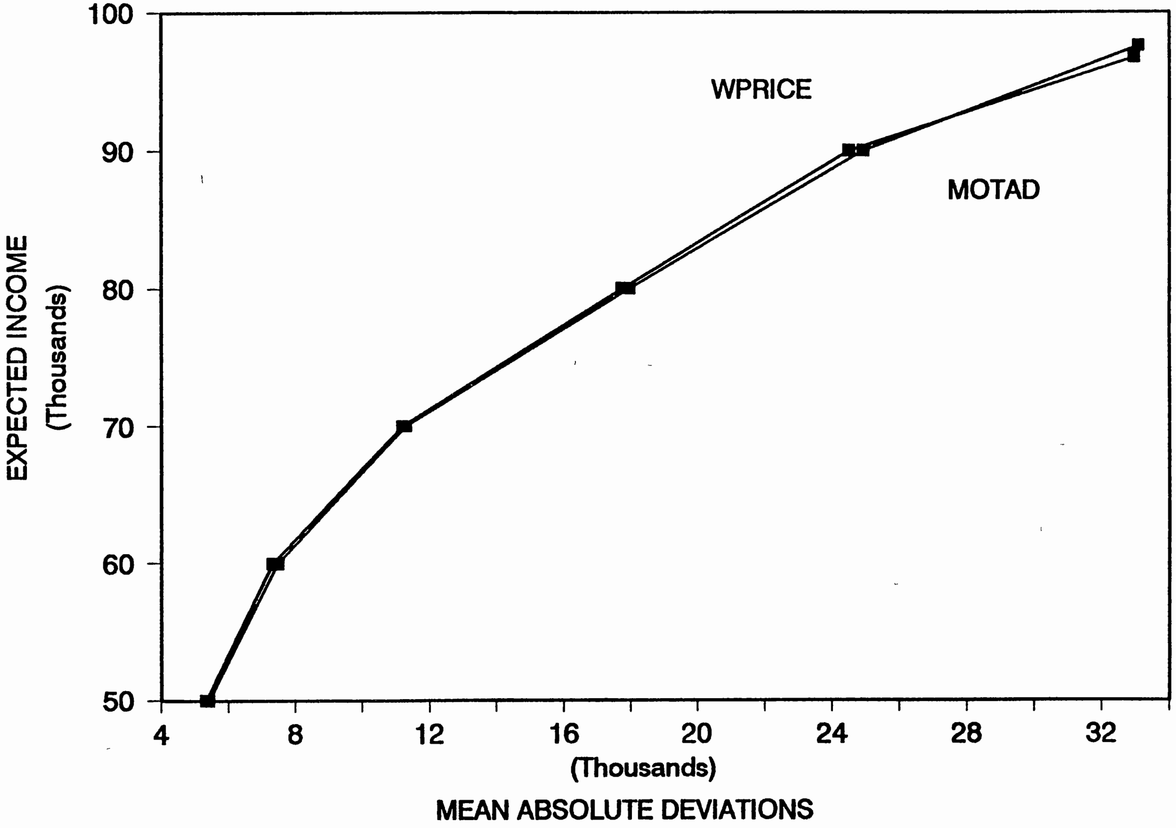


Figure 23. A Comparison of MOTAD and WPRICE Model Efficiency Frontiers

the impact of removing all price distortions on producers' income and resource allocation.

Domestic prices of agricultural commodities were adjusted to the international prices by using the domestic to international price ratios reported by Choudary as a conversion factors. It was assumed that this price ratio remained constant through the study period. Though it seems to be a weak assumption, the non-availability of data precludes the calculation of a series of prices with an adjustor for each of the past several years. However, the results of the INTPR model can be viewed as rough estimates of domestic prices given an open market. The reader must be cautious while using these results to recall the prices used are only rough estimates.

The results of the INTPR model shown in Table XXXIV show that if producers are paid a price equivalent to the export parity price rather than the domestic market price, the expected income of the farm can be increased to Rs 246,106. The risk efficiency frontier was traced by parameterizing expected income in Rs 20,000 increments and is compared with the basic MOTAD efficiency frontier in Figure 24. Wheat, rice and eggplants were found to be dominant enterprises in most of the farm plans. In the farm plans with expected income of Rs 80,000 or below, rice was replaced by gourd. Sugarcane was not included in the farm plans at any level of expected income. At lower levels of expected income, Rs 100,000 or below, peas were included in the solution, mostly at the cost of wheat.

In farm plan 1, farm plan 2, and farm plan 3, no hired labor was utilized in the months of January, February, March, and April. May, June, November, and December were found to be the months with demand for hired labor at its peak. In farm plan 1 and farm plan 10, the constraint on institutional credit was not binding as shown in Table XXXV.

# TABLE XXXIV

## EFFECTS OF REMOVING PRICE DISTORTIONS ON FARM INCOME AND ENTERPRISE MIX - INTPR MODEL

| | Farm Plans | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 | Plan 7 | Plan 8 | Plan 9 | Plan 10 |
| Expected Income | 246,106.00 | 220,000.00 | 200,000.00 | 180,000.00 | 160,000.00 | 140,000.00 | 120,000.00 | 100,000.00 | 80,000.00 | 60,000.00 |
| TND | 233,356.90 | 196,113.70 | 172,814.30 | 149,635.70 | 126,456.00 | 103,276.40 | 80,136.33 | 60,343.49 | 46,131.08 | 35,384.56 |
| MAD | 77,785.63 | 65,371.23 | 57,604.77 | 49,878.57 | 42,152.00 | 34,425.47 | 26,712.11 | 20,114.50 | 15,377.03 | 11,794.85 |
| S.D. | 106,816.25 | 89,768.64 | 79,104.08 | 68,493.90 | 57,883.68 | 47,273.50 | 36,681.42 | 27,621.49 | 21,115.94 | 16,196.85 |
| C.V. | 43.40 | 40.80 | 39.55 | 38.05 | 36.17 | 33.77 | 30.57 | 27.62 | 26.39 | 26.99 |
| Crop Mix | | | | | | | | | | |
| Wheat | 16.86 | 17.16 | 17.16 | 17.16 | 17.16 | 17.16 | 17.14 | 14.80 | 9.87 | 6.13 |
| Rice | 17.71 | 14.03 | 11.58 | 9.14 | 6.70 | 4.26 | 1.83 | 0.23 | 0.00 | 0.00 |
| Sugarcane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gourd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 1.51 |
| Sorghum | 2.14 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 | 1.83 |
| Peas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 2.36 | 3.00 | 3.00 |
| Berseem | 1.64 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Carrot | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | 0.66 | 3.06 | 3.51 | 3.95 | 4.39 | 4.84 | 5.27 | 5.21 | 5.94 | 4.90 |
| Buffalo | 2.54 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Total Area Sown | 41.00 | 39.41 | 37.41 | 35.41 | 33.41 | 31.43 | 29.43 | 27.76 | 23.97 | 20.70 |
| Cropping Intensity | 200.00 | 192.24 | 182.49 | 172.73 | 162.98 | 153.32 | 143.56 | 135.41 | 116.93 | 100.98 |

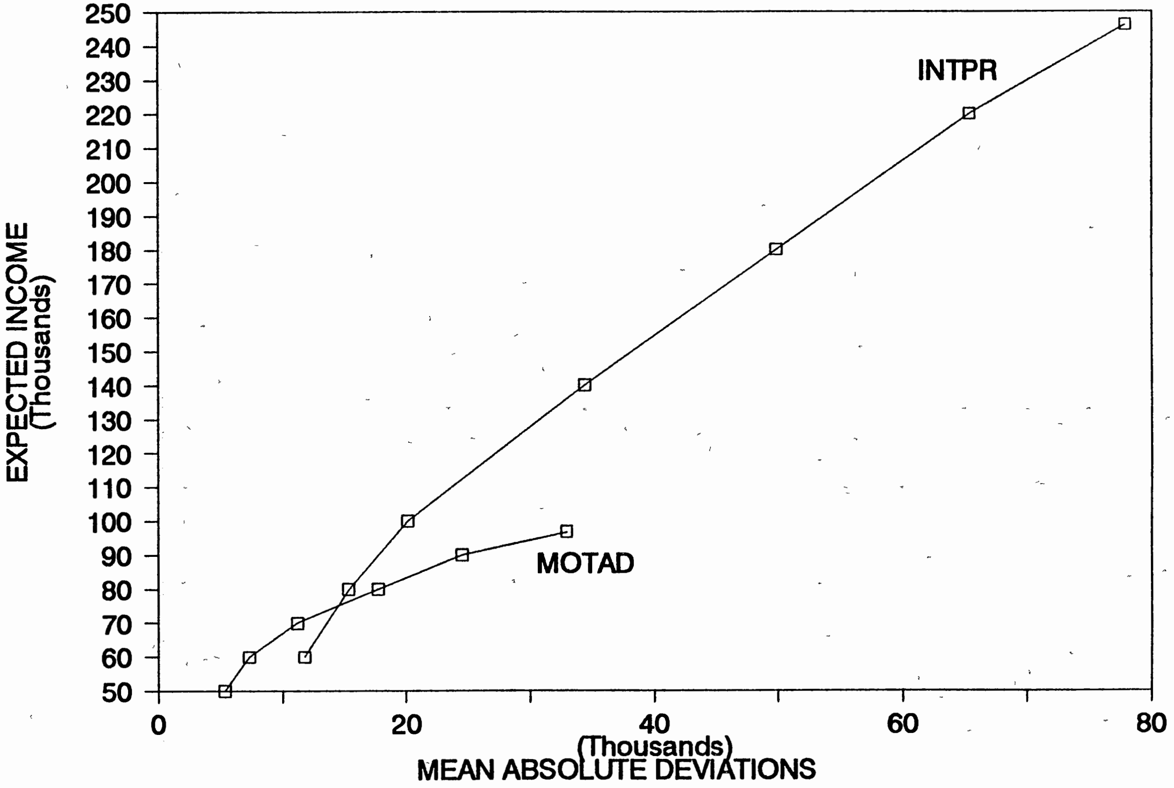


Figure 24. A Comparison of MOTAD and INTPR Model Efficiency Frontiers

# TABLE XXXV

## EFFECTS OF REMOVING PRICE DISTORTIONS ON FARM RESOURCE USE - INTPR-MODEL

| | | Farm Plans | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Plan 5 | Plan 6 | Plan 7 | Plan 8 | Plan 9 | Plan 10 |
| Expected Income | Rs | 246,106.00 | 220,000.00 | 200,000.00 | 180,000.00 | 160,000.00 | 140,000.00 | 120,000.00 | 100,000.00 | 80,000.00 | 60,000.00 |
| Hired Labor | Mandays | | | | | | | | | | |
| Jan.-Feb. | | 0.00 | 0.00 | 0.22 | 2.87 | 5.53 | 8.18 | 11.22 | 45.89 | 55.50 | 45.43 |
| Mar.-Apr. | | 0.00 | 0.00 | 0.22 | 2.87 | 5.53 | 8.18 | 11.33 | 55.34 | 67.50 | 57.43 |
| May-June | | 117.14 | 90.07 | 76.29 | 62.61 | 48.92 | 35.23 | 21.54 | 8.10 | 6.00 | 5.04 |
| Jul.-Aug. | | 87.88 | 63.08 | 51.02 | 39.04 | 27.06 | 15.08 | 3.12 | 0.00 | 0.00 | 1.90 |
| Sep.-Oct. | | 36.71 | 30.58 | 30.80 | 31.01 | 31.23 | 31.44 | 31.91 | 53.30 | 55.21 | 53.49 |
| Nov.-Dec. | | 156.85 | 133.25 | 121.19 | 109.21 | 97.23 | 85.25 | 73.75 | 101.10 | 97.13 | 75.82 |
| Inst. Credit | Rs | 8654.17 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 10,000.00 | 6,597.76 |
| Fertilizer Used | Bags | | | | | | | | | | |
| Urea | | 48.55 | 63.38 | 64.48 | 65.58 | 66.68 | 67.78 | 68.89 | 71.50 | 74.04 | 63.44 |
| DAP | | 36.21 | 32.53 | 30.08 | 27.64 | 25.20 | 22.76 | 20.33 | 18.73 | 14.21 | 11.97 |

# CHAPTER VI

# SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

## Summary

Few would disagree that agricultural production is a risky process. Farmers allocate their resources in the light of their life-long experiences. With the availability of new crop production technologies, new improved inputs, new developments in world trade, and ever-changing government policies, farmers are required to adjust their farm plans frequently, thus making their life-long experiences less applicable and their farming business more risky.

With each new development and/or change in government policy, Pakistani farmers must reevaluate the viability of their current crop rotations, enterprise mix, forage production, livestock balances, etc. Farm families who find a need to adopt new technology and/or adjust their farm plans to changes in government policies have an increased need for assistance in financial management and farm planning.

The primary objective of this study was to analyze the financial characteristics of selected Pakistani farming systems and to determine risk efficient optimal farming systems given existing economic and financial conditions. This was accomplished by conducting assessments of selected Pakistani farms using an IFFS model and employing risk programming and multiple objective goal programming procedures. A field survey of nine central

Punjab farmers was conducted in February - May 1991, to determine the socio-economic characteristics of the farmers and their resource base. The data collected was then utilized to develop an IFFS model and to determine the technical coefficients of the programming models.

Specific objectives of the study included: (1) to analyze the financial problems of selected farming systems at the farm level; (2) to estimate the short-term credit needs of selected existing farming systems; (3) to determine profit maximizing farming systems given current credit availability; (4) to determine the optimum farm resource allocation and enterprise combination in a risky environment; and (5) to analyze the sensitivity of optimal farm plans to changes in prices, institutional credit, and labor availability.

## Conceptual Framework

Agriculture in Pakistan is entering into a new era of commercialization. In commercial agriculture, farmers need to base their decisions on a combination of financial data, production data, and efficiency measures to analyze the strengths and weaknesses of their business. It is noticed that with the increasing complexities of farm business, coupled with higher use of capital, farmers are realizing the tremendous need for assistance in financial management. To assist farmers in evaluating their business, many computerized financial analysis programs have been developed. The IFFS model developed at Oklahoma State University was adapted for conducing assessments of selected Pakistani farming systems.

The theoretical framework adapted for risk analysis was the mean-variance (E-V) efficiency criteria. The E-V approach assumes the decision-maker is risk averse and has a quadratic utility function. Several linear approximations to the E-V model have evolved. In this analysis, linear approximations such as MOTAD and Target MOTAD were employed. This approach generally assumes that the decision-maker maximizes expected utility. Thus his preferences among alternative farm plans is expressed in terms of expected income and associated variance. Outcome distributions are assumed to be normally distributed.

The concept of a Target MOTAD model is based on the assumption that decision-makers often wish to maximize expected returns but are concerned only about net returns falling below a critical target level. In Target MOTAD, expected returns are maximized with a restriction on the level of negative deviations from the target.

MOTAD and Target MOTAD 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-makers utility function is required to find a definite unique solution. In practice, it is not easy to establish reliable and stable utility functions for a farmer. The Compromise MOTAD model was developed to help reduce the decision space on the efficiency frontier. Compromise MOTAD helps identify that area of the efficiency frontier where the tangency between the iso-utility curves and the E-A frontier occurs. 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).

Historical time series data for yields, prices, and costs of production provided the basis for developing series of net returns associated with each activity. In this analysis, the time series data extends over the period 1986-1991. Producers were assumed to base their farm plans on the long-term expected net returns and that any deviation from the mean is a random event.

## Farming Systems Financial Management

A financial analysis of selected Pakistani farming systems was conducted using an IFFS model. Budgets for all crop and livestock enterprises as well as additional income (AI) accounts were developed for all the farms included in the study. The quantity of crops reported as stored was generally used for family consumption. Thus, the stored commodities were not considered for computing net cash income per acre of enterprise. Computed net cash income is utilized in the cash flow statement for analyzing the cash flow situation of each farm.

Wheat and rice are the most important constituent of Pakistani diets. A substantial portion of wheat and rice produced was stored and was consumed on the farm. The average quantity of wheat and rice stored for household consumption was estimated to be 65.93 md and 8.5 md with a standard deviation of 34.79 md and 5.35 md, respectively. In addition to meeting the household consumption requirements, wheat and rice also produce hay for livestock.

Vegetable crops like peas, gourd, eggplants and carrot were found to be a significant part of the farming systems in the study area. The expected acreage under peas and gourds was estimated to be 1.75 and 1.17 with coefficients of variations of 11.66 and 19.73, respectively. Two out of seven farmers considered in the study were growing eggplants. Their average eggplant production area on the two farms was 0.75 acres.

Month-by-month cash flow conditions were computed for seven farms. The results indicated that most of the farmers do not face cash flow problems with their present crop rotations. In the months of April, September, and November, cash inflows declined on most of the farms except those where income increased due to increased livestock product sales. Declining cash inflows in

November indicate the problems farmers may face in purchasing inputs for the next *Rabi* crop. May, June, and December were found to be the months when most of the farmers realized farm income.

The income statements developed reflect profit for all farms surveyed over the accounting period from June to May. Profits on the farms which were growing non-traditional vegetable crops with traditional crop rotations were found to be significantly higher than the traditional farms. The non-traditional vegetable crops are labor intensive and require more capital.

Financial performance of the farms was measured in terms of change in equity, rate of return on equity, net cash flow as a percentage of cash operating expenses, net farm income, and net cash flow. The results show that changes in equity and the rate of return on equity were positive for all farms except farm number two and farm number six where the rate of return on equity was zero and negative, respectively. Farm number two did not own assets, and farm number six spends Rs 29,000 on family living, which is more than their net farm income of Rs 13,381. However, returns on actual cash operating expenses were found to be fairly high. That implies that small farms are viable and are capable of continuing in the farm business.

The impact of government policies, changes in prices, and changes in crop rotations on a typical Punjabi farm (farm #1) was examined using the IFFS model. It was found that a 2 percent increase in price of wheat will result in an increase of Rs 472 in total cash income. The analysis shows that increasing carrot acreage by two acres will increase the net cash income by Rs 608 and will improve the ratio of net cash flow to operating cash expenses by 10.45 points from 219.99 percent to 230.44 percent. A 2 percent tax on net farm income will cost Rs 1,804 to the farmer, given the present farm plan, and Rs 1,816 if the farm grows two more acres of carrots.

The IFFS-based analysis shows that small farm businesses are healthy and small farms are viable. In the months of March and April in the *Rabi* season and in October and November in *Kharif* season, cash inflows declined, forcing some farms to borrow in these months. However, most of the farms show a fairly good repaying capacity. The high income months were found to be May and December. In these months farmers will have cash available for debt payments. Lending institutions need to keep this fact in view while formulating their loan policies. The sensitivity analysis shows that a reorganization of present crop rotation can result in an increase in net farm income.

## The Optimal Farm Organization

A basic linear programming analysis was conducted to generate an optimal profit maximizing farm plan given the existing resource base. The optimal farm plan generated an expected income of Rs 96,736. This 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. Area under carrots was constrained at the margin by the availability of harvest labor. Sorghum and berseem are forced into the solution for meeting the fodder requirements of livestock raised on the farm. The farm plan requires having 3.25 head of buffaloes for meeting the milk consumption requirement of the family.

Risk-neutral decision-makers are assumed to select farm plan of the profit-maximizing model. However, the profit maximizing farm plan does not resemble actual present farm plans. Sugarcane and eggplants do not enter the optimal farm plan. However, both sugarcane and eggplants are common in the present crop rotations of the study area. This implies that the profit maximizing plan does not truly represent the farmers' behavior. The higher risk attached to the profit maximizing farm plan may be one of the reasons that farmers do not adopt it.

## Risk Minimizing Farm Organization

The MOTAD model is employed to generate risk efficient farm plans. The MOTAD model was applied in two steps. First, a basic linear programming model was formulated to determine the maximum attainable expected income given the existing resource base. Second, the element of risk was introduced for analyzing the impact of risk on optimal farm structures. The objective function of the MOTAD model minimizes the total negative deviations from a given expected income. An efficiency frontier is then traced by decreasing the maximum expected income parametrically in arbitrary increments. Risk associated with each farm plan was measured in terms of total negative deviation, mean absolute deviation, standard deviation, and the coefficient of variation. The decision-maker can select any farm plan according to his preferences for expected income and risk associated with it.

When expected income was reduced from Rs 96,736 to Rs 90,000, the C.V. declined from 45.82 to 37.41, eggplants and sugarcane were included in the solution, and the level of wheat and rice actively declined. A dramatic change in the levels of wheat, rice and sugarcane was noticed when the expected income was decreased from Rs 90,000 to Rs 80,000. Area under wheat and rice was reduced significantly, and sugarcane production was increased by 215 percent from 2.86 acres to 8.99 acres. This implies that high income variability is associated with rice. Rice was replaced by sugarcane, and because sugarcane is a year-round crop, area under wheat was also decreased. Rice was not included in the farm plan when expected income was further reduced to Rs 70,000.

Analysis shows that less risk-lower income farm plans included more area under sugarcane and gourd, while wheat and rice were the dominant crops in farm plans with higher expected income and thus higher risk. Production of carrots and peas was constrained by scarcity of labor. Levels of sorghum and berseem production were primarily dictated by the fodder requirements of the livestock enterprise. In turn, family consumption requirements dictated the level of livestock production.

### Low Risk Profit Maximizing Farm Organization

Sometimes it is argued that farmers do not intend to minimize risk; rather farmers maximize farm profit, but they are concerned about the risk of farm income falling below a specified target level. To generate farm plans consistent with this type of decision-making, a Target MOTAD model was applied. A target income was specified for the farm and risk was measured as the expected shortfall ($\lambda$) from the target. The parameter $\lambda$ was parameterized and the corresponding expected income and optimal levels of activities were recorded to trace the efficiency frontier for each target level of income.

When target income was specified at Rs 60,000, expected net returns ranged from Rs 96,736 when negative incomes were ignored to Rs 94,998 when negative income deviations were not permitted.

As parameter $\lambda$ was decreased, keeping the target income constant, the enterprise mix was not changed, however activity levels were altered. The area under wheat increased, while the area under rice, sorghum, and berseem declined. Eggplant production first declined and then showed an increasing trend. The area under sorghum and berseem declined because the fodder requirement was decreased due to a decline in the number of buffaloes. This implies that rice is the high risk crop. Similar results were found for target income of Rs 70,000, Rs 80,000, and Rs 90,000. However, higher values of λ were recorded with higher levels of target income.

A comparison of MOTAD and Target MOTAD solutions showed that Target MOTAD solutions always generated higher expected incomes with negative deviations less than those in the corresponding MOTAD solution. If risk is conceived as deviations below target income, Target MOTAD resulted in lower negative deviations and thus lower risk. The Target MOTAD efficiency frontiers are on the left of and higher than the MOTAD efficiency frontier. This implies that the Target MOTAD solutions are clearly superior to MOTAD solutions.

## Best Compromise Farm Organization

Decision-makers face multiple objectives, often conflicting, in agricultural planning problems. In situations where multiple objectives are involved, generally, the decision-maker is interested not in optimizing a single objective but finding a compromise among general objectives. In this analysis two conflicting objectives, namely profit maximization and risk minimization, were involved. A Compromise MOTAD model was applied to identify the compromise set of risk efficient farm plans.

Compromise MOTAD defines an ideal point and then minimizes the distance between the ideal point and the points on the efficiency frontier. The ideal point in this analysis was defined to be the maximum expected income of Rs 96,736 and a MAD of Rs 5,340. It can be seen that this solution is infeasible. The compromise set of farm plans was identified to be the plans with expected income between Rs 70,242 and Rs 77,930, given that the decision-maker attaches equal importance to both objectives.

The compromise set of farm plans is a subset of the risk efficient farm plans identified in MOTAD. This implies that application of Compromise MOTAD helps considerably in the reduction of the decision area and thus makes the decision-making process easier. Furthermore, Compromise MOTAD can usefully be applied to handle problems where multiple objectives are involved without introducing new computational difficulties, i.e. the model can be solved with a traditional LP algorithm.

## Potential Changes and Farm Organization

Risk programming models can usefully be utilized for analyzing the impacts of different structural and policy changes on farm organization. The MOTAD model was applied for estimating the effects of increasing the availability of institutional credit, decreasing the supply of labor, increasing institutional credit while decreasing the supply of labor, increasing the price of wheat, and removing all price distortions.

Effects of Changes in the Resource Base. Any change in the existing resource base will affect expected income and farm organization. When the constraint on available institutional credit was relaxed from Rs 10,000 to Rs 15,000, the maximum attainable expected income increased from Rs 96,736 to Rs 102,000. It was interesting to note that the risk associated with each level of expected income was considerably lower than the corresponding levels of the basic MOTAD model. This implies increased availability of institutional credit will have a stabilizing effect on farm income.

The impact of a potential decrease in agricultural labor supply was examined by assuming that only 60 mandays of labor will be available every month. The expected income of the profit maximizing farm plan was reduced to Rs 85,341. The risk associated with each labor restricted plan was also higher than for the MOTAD plans. A dramatic change in crop rotations was also noticed. Sugarcane was an important part of the MOTAD model crop rotations, while in the corresponding HLAB model plans, sugarcane was excluded from crop rotations, and the area under wheat and rice increased.

When more institutional credit was made available keeping labor supply at 60 mandays per month, the expected income for the profit maximizing farm plan increased from Rs 85,341 to Rs 88,770. Increased availability of institutional credit with a constraint on labor will result in an increase in the area under cotton at the cost of rice. However, in this predominantly rice-producing region, it does not seem to be a viable option.

Effects of Changes in Price Policy. Changes in commodity prices, it is generally believed, will bring about changes not only in farm income but also in farm organization. Change in the price of one commodity will affect the intercrop relationships and thus crop rotations. The MOTAD model was used to examine the effects of an increase in wheat price. When wheat price was increased to Rs 115 per 40 kg, the expected income was increased from Rs 96,736 o Rs 97,550. The results showed that a small increase in wheat price will not affect enterprise mixes significantly.

To examine the impact of removing all price distortions on income and resource allocation, domestic prices of agricultural commodities were adjusted to the international prices. It was found that if producers were paid a price equivalent to the export parity price rather than domestic market price, the expected income of the farm would be increased to Rs 246,106. Wheat, rice and eggplant were found to be dominant enterprises in most of the farm plans. At lower levels of expected income, rice was replaced by gourd, and peas were also included in the farm plans.

## Policy Implications

Farming systems financial analysis showed that in the study area small farm business are viable and healthy. However, producers faced cash inflow problems in the months of March and April and October and November. Farmers needed credit in these months to buy inputs for the next crop. The results of sensitivity analysis showed that an increased supply of credit would result in an increased and stabilized farm income. By making more funds available for agricultural credit through agricultural and commercial banks, risk in farming business can be reduced considerably, and farm income can be increased.

Most of the farmers showed a fairly good repayment capacity in the months of May and December. However, the cash inflow pattern varied from farm to farm, depending upon the crop rotations farmers adopt. The IFFS model generates useful cash inflow information that can be used to assess the repaying capacity of the farmer and to schedule repayments. The use of the IFFS model through credit officers can help financial institutions tailor better loan policies. An effective use of IFFS can increase the rate of loan repayments.

The sensitivity analysis showed that a reorganization of present crop rotations would generate more farm income. Farm reorganizations can only be done with close consultation of the decision-maker. The IFFS model can be used through the agricultural extension network to help producers reorganize their present farm plans. Given limited resources and computer facility, the IFFS model can be applied in some selected areas in the beginning and its use can be extended to other areas later.

The results of the deterministic linear programming model did not resemble actual current farm plans. This implies that a profit maximizing plan does not truly represent the farmers' current behavior. Research efforts need to be directed towards generating risk efficient farm plans for different regions of the country to help decision-makers allocate their resources in a risky environment.

The effects of some potential changes in farmers' resource base on farm organization and farm income were examined. It was noticed that availability of agricultural labor was declining in the study area because more off-farm jobs were available in newly developed factories in the area. The results of the analysis shows that the expected farm income will decline with a decrease in agricultural labor supply. It will also cause a dramatic change in crop rotations. To avoid undesirable structural changes in agriculture, labor saving crop production technologies must be evolved. It was also noticed that increased credit availability will mitigate the income reducing effects of reduced labor supply. This implies that introduction of labor saving technology, together with increased credit availability, can help the farmers maintain their farm income and save them from readjustment problems if labor availability declines.

It was found that removal of all price distortions (i.e. development of an open market) will have a positive effect on farm income. If the producers were paid a price equivalent to the export parity price, the expected farm income would be significantly increased. Moreover, the removal of price distortions will not cause a drastic change in crop rotations and, thus, will not create severe readjustment problems for the producers. But increased wheat prices can cause political instability. However, a gradual removal of subsidies and taxes will increase farm income and provide time for consumers to adjust to increasing food prices.

# REFERENCES

Akhtar, M.R., Z. Ahmad, and K.A. Tetlay. (1988). "Monitoring Wheat Varietal Diffusion in the Irrigated Punjab: Results from 1986-87," AERU Faisalabad Staff Paper No. 87-3.

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

Barry, P.J. and C.B. Baker. (1984). "Financial Responses to Risk in Agriculture." In P.J. Barry (Ed.), Risk Management in Agriculture. Ames: Iowa State University Press.

Berbel, J. (1988). "Target Returns with Risk Programming Models: A Multi-objective approach," Journal of Agricultural Economics. 39(2):263-70.

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.

Brink, L. and B. McCarl. (1978). "The Tradeoff Between Expected Return and Risk Among Cornbelt Farmers," AJAE. 60:259-263.

Carlos, P. and R.L. Simmons. (1983). "A Risk Programming Model for Mexican Vegetable Exports." In D.N. Rogers and L. Solis (Eds.), The Book of CHAC. Baltimore: The Johns Hopkins University Press.

Chaudhry, M.A. and R.A. Young. (1988). "Price Distortions and Efficiency Losses in Pakistan Agriculture: A Micro Level Analysis," Pakistan Journal of Agricultural Social Sciences. 2(2).

Cohon, J.L. (1978). Multiobjective Programming and Planning. New York: Academic Press.

Dillon, J.L. (1971). "An Expository Review of Bernoullian Decision Theory in Agriculture: Is Utility Futility?" Review of Marketing and Agricultural Economics. 39:3-80.

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.

Government of Pakistan. (1990). "Pakistan Economic Survey," Finance Division, Economic Advisor's Wing, Islamabad, Pakistan.

Hazel, P.B.R. (1971). "A Linear Alternative to Quadratic and Semivariance 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.

Helmers, G.A., H. El-Osta, M.R. Langemeier, and G.M. Morrill. (1986). "A Risk-Income Analysis of Crop Variety Selection." Paper presented at the Annual Meeting of American Agricultural Economics Association, Reno, Nevada, 1986.

Hourning, S.A. and N.L. Dalsted. (undated). "Agricultural Financial Management," Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, Colorado.

Johnson, S.R. (1987). "A Re-examination of the Farm Diversification Problem," J. Farm. Econ. 49:610-621.

Kaiser, E. and M. Boehlje. (1980). "A Multiperiod Risk Programming Model for Farm Planning," North Central Journal of Agricultural Economics. 2(1):47-54.

Love, R.O., H.P. Mapp, H.G. Haefner, and D.W. Richardson. (1988). Integrated Farm Financial Statements, Multi-year Version: User Manual. Stillwater: Oklahoma State University.

McCarl, B.A., and T. Tice. (1982). "Should Quadratic Programming Problems be Approximated?" American Journal of Agricultural Economics. 64:585-589.

Mahmood, A. and F. Walters. (1990). "Pakistan Agriculture: A Description of Pakistan's Agricultural Economy," Economic Analysis Network (EAN), Islamabad, Pakistan.

Mapp, H.P. Jr., M.L. Hardin, O.L. Walker, and T. Persaud. (1979). "An Analysis of Risk Management Strategies for Agricultural Producers," American Journal of Agricultural Economics. 61(5):1071-1077.

Misra, S.K. and S.R. Spurlock. (1991). "Incorporating the Impacts of Uncertain Fieldwork Time on Whole-Farm Risk-Return Levels: A Target MOTAD Approach," Southern Journal of Agricultural Economics. 23(2):9-17.

Novak, J.L., C.C. Mitchell, Jr., and J.R. Crews. (1990). "Risk and Sustainable Agriculture: A Target MOTAD Analysis of the 92-Year 'Old Rotation'." Southern Journal of Agricultural Economics. 22(1):145-153.

Okunev, J. and J.L. Dillon. (1988). "A Linear Programming Algorithm for Determining Mean-Gini Efficient Farm Plans," Agri-Economics. 2:273-285.

Paxton, K.W., L.R. Vandeveer and D.R. Lavergne. "Estimating the Potential Benefits of Irrigation Using Subjective Yield Expectations." Presented at the Southern Agricultural Economics Association meetings, Lexington, Kentucky, February 1992.

Pederson, G.D. and D. Bertelsen. (1986). "Financial Risk Management Alternatives in a Whole-Farm Setting," Western Journal of Agricultural Economics, 11(1):67-75.

Pinckney, T.C. (1989). "The Demand for Public Storage of Wheat in Pakistan," International Food Policy Research Institute, Washington, D.C.

Robison, L.J., P.J. Barry, J.B. Kliekenstein, and G.F. Patrick. (1984). "Risk Attitudes: Concepts and Measurement Approaches." In P.J. Barry (Ed.), Risk Management in Agriculture. Ames: Iowa State University Press.

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.

Schultz, T.W. (1983). Transforming Traditional Agriculture. Chicago: University of Chicago Press.

Schurle, B.W. and B.L. Ervin. (1979). "Sensitivity of Efficient Frontiers Developed for Farm Enterprise Choice Decision," American Journal of Agricultural Economics. 61:506-511.

Sheikh, A.D., D. Byerlee, and M. Azeem. (1988). "Factors Affecting Cropping Intensity in Barani Areas of Northern Punjab, Pakistan," Pakistan Journal of Agricultural Social Sciences, Vol. 2, No. 2.

Sonka, S.T. and G.F. Patrick. (1984). "Risk Management and Decision Making in Agricultural Firms." In P.J. Barry (Ed.), Risk Management in Agriculture. Ames: Iowa State University Press.

Spears, R.M. (1990). "A Microcomputer Based Approach for Integrating Risk Analysis into Whole-Farm Planning." An unpublished M.S. Thesis, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

Wallace, G.B. (1981). "An Evaluation of Possible Abatements to Finanacial Stress for a North Central Oklahoma Wheat and Livestock Farm." An unpublished M.S. Thesis, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

Watts, M.J., L.J. Held, and G.A. Helmers. (1984). "A Comparison of MOTAD to Target-MOTAD," Can J. Agr. Econ., 32:175-186.

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.

# VITA

Shahid Mahmood Zia

Candidate for the Degree of

Doctor of Philosophy

Thesis: ECONOMIC ANALYSIS OF RICE-WHEAT FARMING SYSTEMS OF PAKISTANI PUNJAB: A CASE STUDY

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Sheikhupura, Pakistan, June 24, 1956, the son of Mr. and Mrs. Ch. Muhammad Ali.

Education: Graduated from Government High School, Rasulpur Jattan, June 1972; received a Bachelor of Science (Hons) degree in Agriculture from University of Agriculture, Faisalabad in December 1982; received a Master of Science (Hons) in Agricultural Marketing from UA, Faisalabad in December 1984; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in May 1992.

Professional Experience: Scientific Officer, Pakistan Agricultural Research Council (PARC) 1985-1987; Technical Scientific Officer, Social Science Division, PARC, 1987-1988; Sub-Editor, Pakistan Journal of Agricultural Social Sciences, 1987-1988.

Professional Affiliations: Member of American Agricultural Economics Association, Southern Agricultural Economics Association, Pakistan Association of Agricultural Social Scientists.