SELECTION OF CROPPING SYSTEMS TECHNOLOGIES UNDER RISK: A STUDY OF SMALL UPLAND FARMS IN BATANGAS, PHILIPPINES

by

Constancia G. Maranan, B.Sc. Agri.

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DECLARATION

Except where otherwise indicated, this dissertation is my own work.

CGMaranan
Constancia G. Maranan

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ABSTRACT

Risk is considered to be one of the factors that affects farmers' use of new agricultural technology. This study uses a mathematical programming technique which takes into account both income and risk considerations in evaluating some new technologies developed for small upland farmers in the Philippines. The possible impact of introducing new rice and sorghum varieties is investigated through the model. The results show that those models with both income and risk considerations with an additional priority of meeting the subsistence requirements for rice simulate actual farm decision-making better than those not incorporating risk and such an objective. The results suggest that a new rice variety will replace the traditional variety, even where it gives only a 25% additional yield. Also, the new rice technology is likely to be adopted by farmers irrespective of the degree of their risk aversion. On the other hand sorghum is adopted widely only where its price or yield is twice the existing level, although risk is not again increased. Further, given additional land of any type (either owned or share tenanted) farmers are likely at existing price and yields to plant a larger area of both a new rice variety and sorghum. Moreover, the increase in available family labour per household has little effect on the adoption of both new rice and sorghum technologies.

While results are indicative of the potential of the new technologies, there are methodological and estimational problems in applying the MOTAD approach in assessing the impact of the introduction of new technologies. These would have to be considered in future studies of small farmers' decision-making.

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CHAPTER 1

INTRODUCTION

In the Philippines, agriculture plays a major part in the economy. It provides employment for two-thirds of the population and contributes about one-third of the national income. Because of this, its development is very vital. Development in agriculture can be achieved in many ways. The introduction of new agricultural technology is considered to be an important way of developing this sector.

In the last two decades, many agricultural institutions have been involved in developing and introducing new technologies to increase the productivity and income of many small farmers in less developed countries. Despite this, the problems of low productivity and consequently low income among farmers continues. This is because the farmers' use of new technologies has not been as widespread as expected. Recognizing this problem, many agricultural scientists believe that a new technology would gain wider acceptance if it were evaluated and modified at various stages of its generation. Evaluation can either be done at the design stage (ex-ante) or after field testing (ex-post). In the International Rice Research Institute (IRRI) cropping systems program, ex-post evaluation of new technologies is widely practiced. However, ex-ante evaluation might be appropriate with a cropping systems research. Barlow (1979) had noted the benefits of ex-ante evaluation to include: (a) the design of new technologies fitted to specific farming circumstances; (b) avoidance of introducing inappropriate technology for large-scale programs and consequently minimizing cost of failure if it should take place.

The most common method of evaluating the benefits of new technologies is through a costs and returns analysis. The advantage of using this method is that it can easily assess the likely benefits of new technology over traditional technology without the need for sophisticated calculations. The major disadvantage is that, being a partial analysis, it only gives the return above the variable cost of production and does not give an indication whether a new technology is feasible and fitted to the farmers' total available resources.

An alternative method is the whole farm approach via linear programming. Such an approach was used by Barlow et al. (1979) and Labadan et al. (1980) in the evaluation of cropping systems technologies developed for small farmers in the Philippines. Although their study gave results superior to those obtained with a costs and returns analysis, the risks associated with the introduced technologies were completely ignored. The high level of risk associated with new technology is considered to be one of the critical factors that limits its adoption, especially by small farmers whose production resources are low. In this regard, an evaluation approach which takes into account not only the resource constraints but also the risk associated with the new technology is desirable. Through this approach, the degree of acceptability of the new technology to the farmers in the specific localities for which they are designed, can be better evaluated.

1.1 OBJECTIVES OF THE STUDY

The aim of this study is to evaluate some new technologies developed for upland farms in the Batangas province in the Philippines where risk is considered important. Data are obtained from the IRRI's cropping systems program gathered from a group of farmers growing a multiplicity of crops. The economic benefits of new cropping systems technologies are evaluated by the use of the Minimization of Total Absolute Deviation (MOTAD) approach developed by Hazell (1971). In this approach both income and risk considerations are incorporated in the evaluation procedure.

Specifically, the objectives are:

(i) to analyze the choice of technologies by selected farms with different resource endowments, and to examine how their choice is affected by risk.

(ii) to evaluate the farm level impact of the introduction of a number of new technologies (some of which are already available, and others which are currently being developed) having different input requirements, returns and degree of risk.

(iii) to assess the implications of results obtained on the potential of the new technologies for large-scale farm level adoption and the consequence of such adoption on farm income.

1.2 OUTLINE OF THE THESIS

In Chapter 2, background information is given on the IRRI research site in Batangas, Philippines. The farming system operated by farmers is described in detail.

In Chapter 3, decision-making under risk is discussed. Discussion includes: source of risk in agriculture, criterion for risky decision-making and in the last section some approaches for accounting for risk in models of farm decision-making.

In Chapter 4, the methodology adopted is presented. The models used are discussed. Included also in the discussion are the review of studies where a similar model is used. The major assumptions of the model used are also given. In the later part, the data used in the study are presented. The crop and non-crop activities considered in the construction of the programming matrix are discussed. Lastly, the procedure used in the assessment of the potential of the new technologies are presented.

In Chapter 5, results from the model using the average farm model are presented. In the first part, the results from the model with only the existing technologies are presented. In the second part, the impact of the introduction of the new technologies are analyzed. In the first case, only the new rice variety was included in the existing model and in the second case, both the new rice variety and sorghum are included in the model. In all cases, the model results from the LP deterministic and MOTAD models with and without the consumption objective are discussed.

In Chapter 6, results are presented on how differences in the resource endowments of the sample farms would affect the acceptance of the new technology. This is done by parametrizing the level of resource (i.e. land and labour). Effects of change in prices and yield of new technology are also reported here.

In Chapter 7, implications and limitations are discussed.

CHAPTER 2

BACKGROUND TO THE STUDY

The IRRI cropping systems program was initiated in early 1973. Its objective was to develop new cropping technologies to increase crop productivity and cropping intensity in small scale rice based farming systems in Asia, by making more efficient use of available farm resources (Carangal, 1977).

It is recognized that such a research program needs to be location specific. Furthermore, to ensure that new technologies are properly tailored to farmers' actual environments, such research needs to include on-farm testing. Therefore, the program developed a methodology for on-farm cropping systems research as practiced in the Asian Cropping Systems Network (ACSN) sites (Zandstra et al., 1981).

2.1 DESCRIPTION OF THE BATANGAS RESEARCH SITE

In the Philippines, the first research site to test new cropping patterns in farmers' fields was established in Cale village in Batangas province. This was selected as being representative of many upland farming systems of the country. Batangas is one of the eight provinces that comprise the Southern Tagalog region. This region is the largest producer of upland rice in the country (Table 2.1).

The main research area was in village Cale, located in the north-eastern part of Batangas province. Cale is approximately 8 km from the medium-sized town of Tanauan, and about 80 km south of Manila

(Figure 2.1). The village has a third class road (feeder road with gravel and stones). Jeepneys (a modified jeep carrying up to 20 passengers and baggage) and tricycles are the common means of transport.

TABLE 2.1

AREA AND PRODUCTION OF UPLAND RICE IN THE PHILIPPINES, BY REGION, 1973

Region	Upland Rice Area (Has.)	Per Cent of Total Upland Rice Area	Production (Metric Tons)	Grain Yield (t/ha)
Southern Tagalog	131,370	30.2	104,984	0.80
Northern and Eastern Mindanao	110,440	25.4	93,588	0.85
Southern and Western Mindanao	76,550	17.7	57,640	0.75
Bicol	40,340	9.2	25,828	0.64
Cagayan	29,270	6.8	27,192	0.92
Western Visayas	22,240	5.1	13,068	0.59
Eastern Visayas	13,760	3.2	10,560	0.76
Central Luzon	7,040	1.6	5,456	0.78
Ilocos	3,410	0.8	3,300	0.96
Total	434,420	100	341,616	
Average				0.78

a) This is 14% of the total Philippines rice area (3.11 million ha., 1973).

b) This is 8% of the total rice production (4.41 million t/ha, 1973).

c) This is 55% of the national average rice yield (1.42 t/ha, 1973).

Source: Anden, T. (1974).

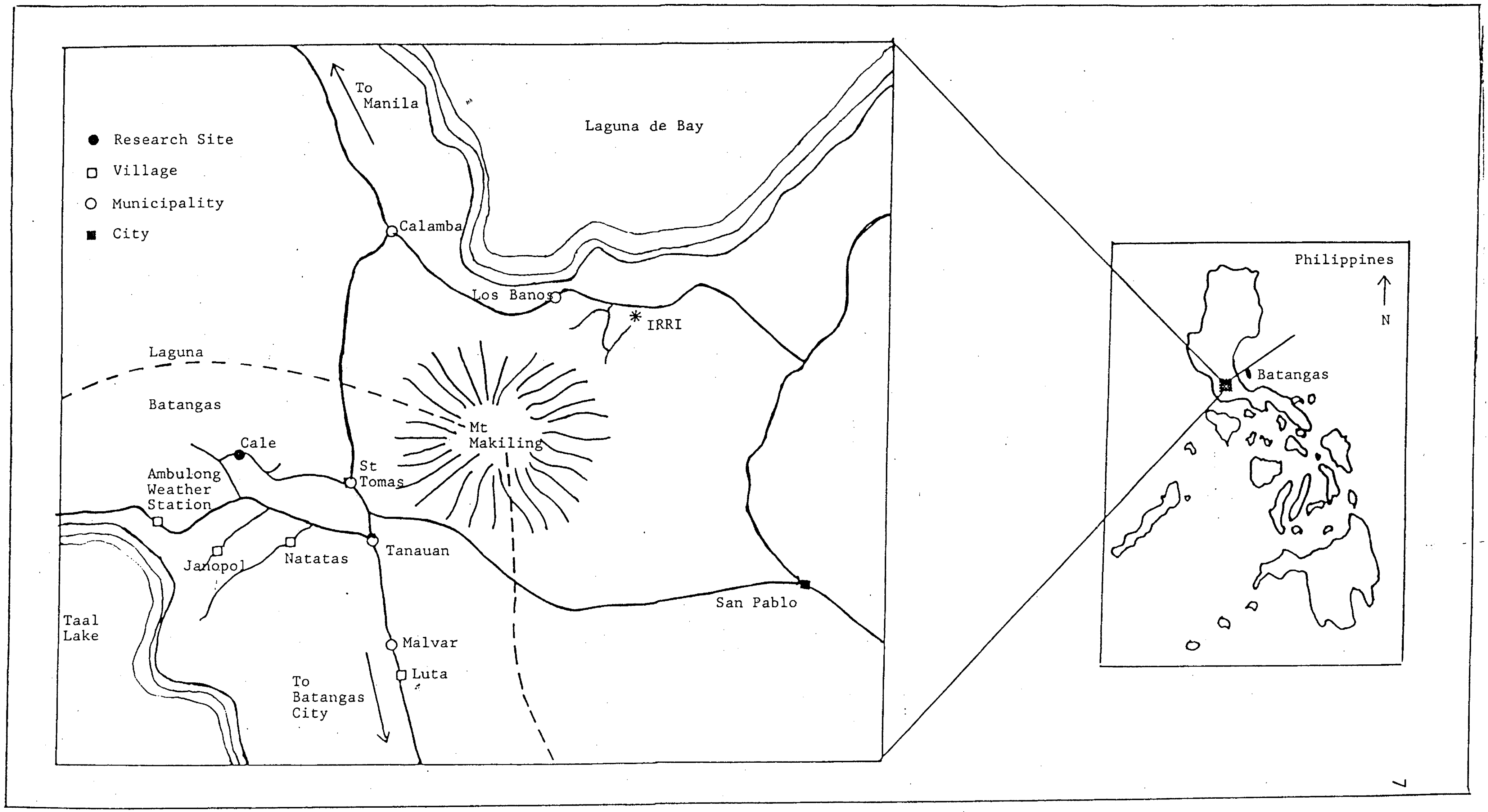

Fig. 2.1: Location of cropping systems site in Batangas Province, Philippines.

Cale has a population of about 400 households. Farming is the main source of livelihood for the villagers. Approximately half of the farm families in the village entirely depend on the income derived from their farms (O'Brien, 1978). The other half have other off-farm sources of income like buying and selling of vegetables or livestock (i.e. pigs, cows), and together with non-farm employment by other members of their families in Manila and other suburbs.

The land area is characterized by a gently rolling topography with slight terracing of fields through natural erosion controlled by fence-rows of trees, shrubs, and grass. The topography is typical of that portion of the upland rice area in the Philippines with a potential for an animal or tractor tillage and hence, intensive cropping. The soil is well-drained mollisol of geologically recent volcanic deposit classified as Taal Series with a texture ranging from 4.9 to 6.2 with an average of 6.0. The soil was tentatively classified as an Andeptic Hapludoll; loamy, mixed, isohyperthermic family (Samson et al., 1976, p.2).

The rainfall pattern is quite similar to most of the upland rice growing areas of the country. Typically, there are 5 to 7 months of wet season starting in May with at least 200 mm of rain per month while it is relatively dry during the ret of the year. Figure 2.2 shows the rainfall pattern (26-year average) in Ambulong (approximately 4 km from Cale), and the 4-year rainfall pattern in Cale for the period 1974-77.

Crop seasons are defined as early, mid and late wet season. The weekly mean rainfall fluctuates because of typhoon occurrence in July to November. The probabilities of obtaining at least as much as the mean for any given weeks are approximately 20% from January to April,

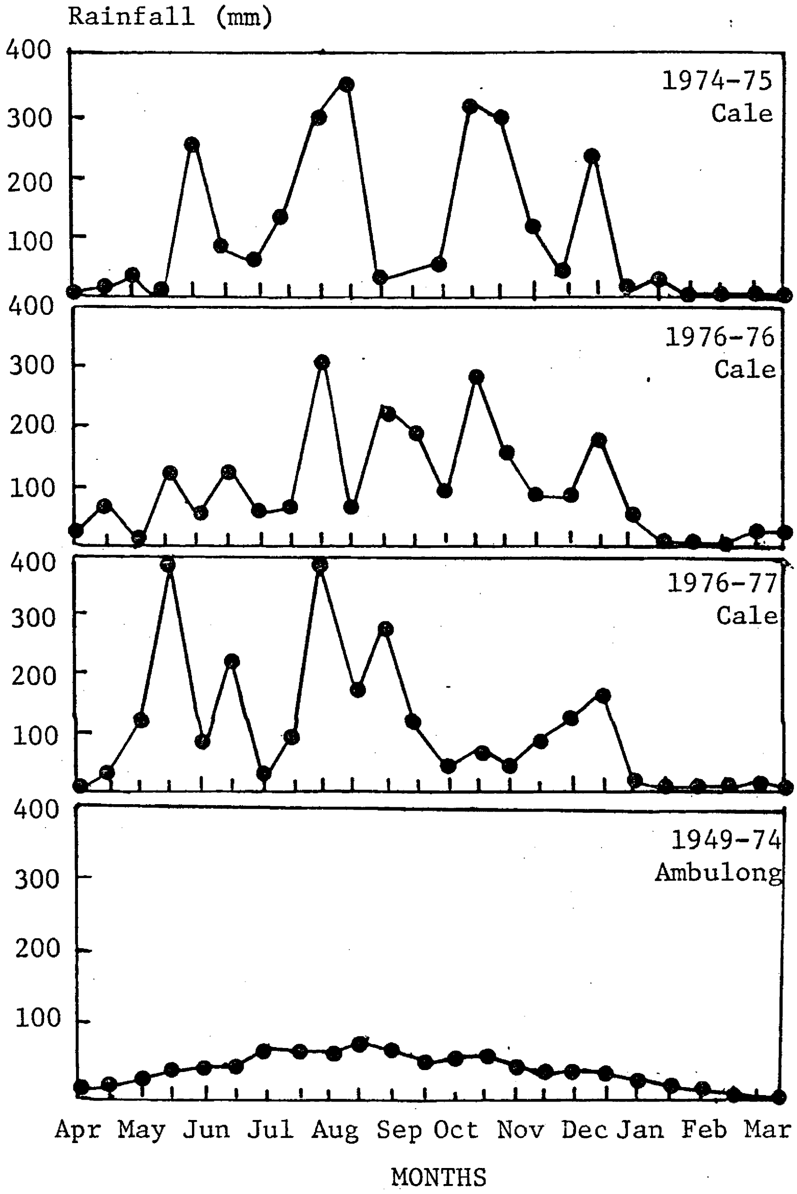

Fig. 2.2: Rainfall for Ambulong (26-year average) and Cale (1974-77), Tanauan, Batangas.

Source: Samson et al. (1976), Frio and Price (1979).

30% for May, June, November and December and 40% for July-September, indicating relative variability during different months (Samson et al., 1976, p.3).

2.2 FARM CHARACTERISTICS AND CROPPING PATTERNS

The IRRI's work in the village started with a baseline survey of 100 randomly selected farms. Data were gathered on crop production and other aspects of the farming system. Ninety of these farmers had agreed to participate in the farm record-keeping project, to be managed by the Economics component of the project. These farmers were stratified based on the cropping patterns, general standard of living and other characteristics, and a total of 50 farmers were selected to participate in the farm record-keeping project. Fifty farmers participated for two years (1973-75); but only thirty-five farmers were retained in the project in the last two years (1975-77).

Table 2.2 shows the 1973 baseline information on the 35 farmer co-operators of the village. The average education level of the farmers was 3.5 years in school. The average farm size was 1.25 farmers, and many farmers had at least one working animal used in the farm.

Fourteen per cent of the farmers owned all the land they cultivated and 51% of the farmers were share tenants, the others having a mix of fully-owned and tenanted land. The tenancy arrangement varied between farms. In all arrangements, the farmers paid the pre-harvest expenses, i.e. fertilizers, chemicals, and pre-harvest labour. The harvest and post harvest expenses (which also includes marketing costs) were paid by the farmer from the crop harvested. The landlord was either paid in kind (share of the crop harvested) which is the common practice for rice or in cash (value of the crop share) in the case of corn and vegetables.

TABLE 2.2

BASELINE INFORMATION OF 35 CO-OPERATING FARMERS, CALE, TANAUAN, BATANGAS, 1973

Item	Mean
Age of Operators (Years)	48
Number of Years in School	3.5
Size of Family	6.4
Farming Experience (Years)	22
Number of Working Animals	0.8
Farm Size (Hectares)	1.25

Tenure	Number	Per Cent
Owner	5	14
Share	18	51
Owner cum Share	11	32
Owner-Share-Leasee	1	3

Source: Frio and Price (1979).

Table 2.3 shows the percentage of land planted to various cropping patterns for 1973-77. In all years more than 70% of the total cropland was planted to a rice-based pattern. The relative importance of rice in the diet of the villagers may explain their preference for this pattern. Of these, the rice-corn pattern occupied more than 50% of the total area.

TABLE 2.3

PERCENTAGE OF LAND PLANTED TO VARIOUS CROPPING PATTERNS, 35 FARMS, CALE, TANAUAN, BATANGAS, 1973-77

Cropping Pattern	1973-74	1974-75	1975-76	1976-77
Rice-Corn	57	52	53	63
Rice-Vegetables	23	33	21	14
Trellis Crop	5	5	5	4
Corn-Corn	3	1	3	3
Corn-Vegetables	3	1	3	4
Vegetable Intercrop	3	3	3	4
Single Crop	3	3	3	2
Vegetables-Vegetables	2		4	1
Rice/Corn with Relay Crop		1	5	5
Total	100	100	100	100

a) Less than 1%.

b) Vegetables include cowpea, mung, bitter gourd, tomato, sponge gourd, garlic, bottle gourd, etc.

c) Vine crops are grown simultaneously or in sequence throughout the year.

d) Vegetables intercropped with other vegetables or vines.

e) Crops grown in monoculture and are cultivated the year round, i.e. eggplant, sweet pepper, cassava.

f) Relay crops include sponge gourd, hyacinth bean, bottle gourd planted shortly before harvesting the first crop.

Source: Frio and Price (1979).

The rice-vegetables pattern ranked second in terms of area planted. Vegetables were the main source of cash income for the farmer followed by corn, while rice was mainly grown for home consumption.

The trellis crop patterns were third in terms of planted area. Here the crops are grown simultaneously or in sequence throughout the year. Permanent posts and wiring trellis are constructed to support the growth of climbing vegetables. However, while this system is highly profitable, many farmers do not practice this system presumably because of high initial costs of constructing the trellis.

2.3 LEVEL OF RESOURCES USED

In rainfed agriculture the intensity of land use is entirely dependent on the amount and timing of rainfall. Table 2.4 shows that the total cropped area and multiple cropping index varied throughout the period mainly due to a variation in rainfall.

TABLE 2.4

TOTAL CROPPED AREA, FARM SIZE AND MULTIPLE CROPPING INDEX
35 FARMERS, CALE, TANAUAN, BATANGAS, 1973-77

Year	Total Cropped Area (Has.)	Total Farm Size (Has.)	Multiple Cropping Index
1973-74	71.73	46.73	153
1974-75	64.87	47.79	150
1975-76	56.55	46.14	123
1976-77	58.87	42.68	138

Source: Frio and Price (1979).

The rainfall pattern for 1974-77 (Figure 2.2) shows a high degree of variability within a month and between months. In 1975-76, after the first crops were harvested, there was a short period of rain which declined very rapidly in late October to early November. The lack of sufficient soil moisture decreased the area double-cropped in that year. The same pattern was also observed in 1977.

Changes in the allocation of inputs to different crops and crop groups are shown in Table 2.5. Fertilizers used for crops increased over the period. Most fertilizers was applied to high valued vegetable crops.

Farmers use both family and hired labour. Hired labour contributed more than 50% of the total labour used in rice in most years. Most of this labour was spent on hand weeding, harvesting and threshing. Hired labour for hand weeding came from landless labourers in the village. Harvesters and threshers came also from nearby villages. In other crops, hired labour use was very low.

The distribution of farm labour by task for major crop groups is shown in Figure 2.3. Harvesting required from 34% to 65% of the total labour used in each crop. Except for corn, where yields increased over the period, the level of harvesting labour in other crops varied from year to year, depending on yield levels. Vegetables required frequent harvesting.

In vegetable cultivation, crop maintenance tasks, such as weeding, fertilizing and spraying utilized most labour. Generally, weeding labour varied for all crops from year to year.

2.4 YIELD AND OUTPUT PRICES

Table 2.6 shows the changes in yield of different crop/crop groups for the period 1973-77. Yields of all crops fluctuated from year to year. The yield variations are very much related to changes in rainfall patterns.

TABLE 2.5

CHANGES IN THE ALLOCATION OF INPUTS BY CROP/CROP GROUP, 35 FARMERS, CALE, TANAUAN, BATANGAS, 1973-77

Input	Crop/Crop Group										
	1	2	3	4	5	6	7	8	9	10	Mean
					Per Hectare						
Fertilizer (Kilogram Nitrogen)											
1973-74	47	13	76	2	66	32	81	44	108	64	53
1974-75	42	15	71	16	134	73	97	32	144	124	75
1975-76	53	66	103	55	95	76	143	120	111	76	89
1976-77	66	63	109	29	87	133	134	95	131	124	97
					Percentage						
Labour (Manhours) A. Hired Labour											
1973-74	52	1	27	0	11	2	1	52	9	2	16
1974-75	34	0	36	0	10	23	1	12	17	2	14
1975-76	52	5	21	9	2	0	2	20	7	10	13
1976-77	53	3	26	0	1	0	1	24	34	2	16
B. Family Labour											
1973-74	48	99	73	100	89	98	99	48	91	98	84
1974-75	66	100	64	100	90	77	99	88	83	98	86
1975-76	48	95	79	91	98	100	98	80	93	90	87
1976-77	47	97	74	100	99	100	99	76	55	98	84

a) Crop/Crop Group

1. Rice
2. Corn (wet)
3. Corn (dry)
4. Field crops
5. Leaf-vine stem vegetables
6. Bulb-root-tuber vegetables
7. Fruit vegetables
8. Rice/corn with intercrops
9. Vegetable combinations
10. Trellis

Source: Frio and Price (1979).

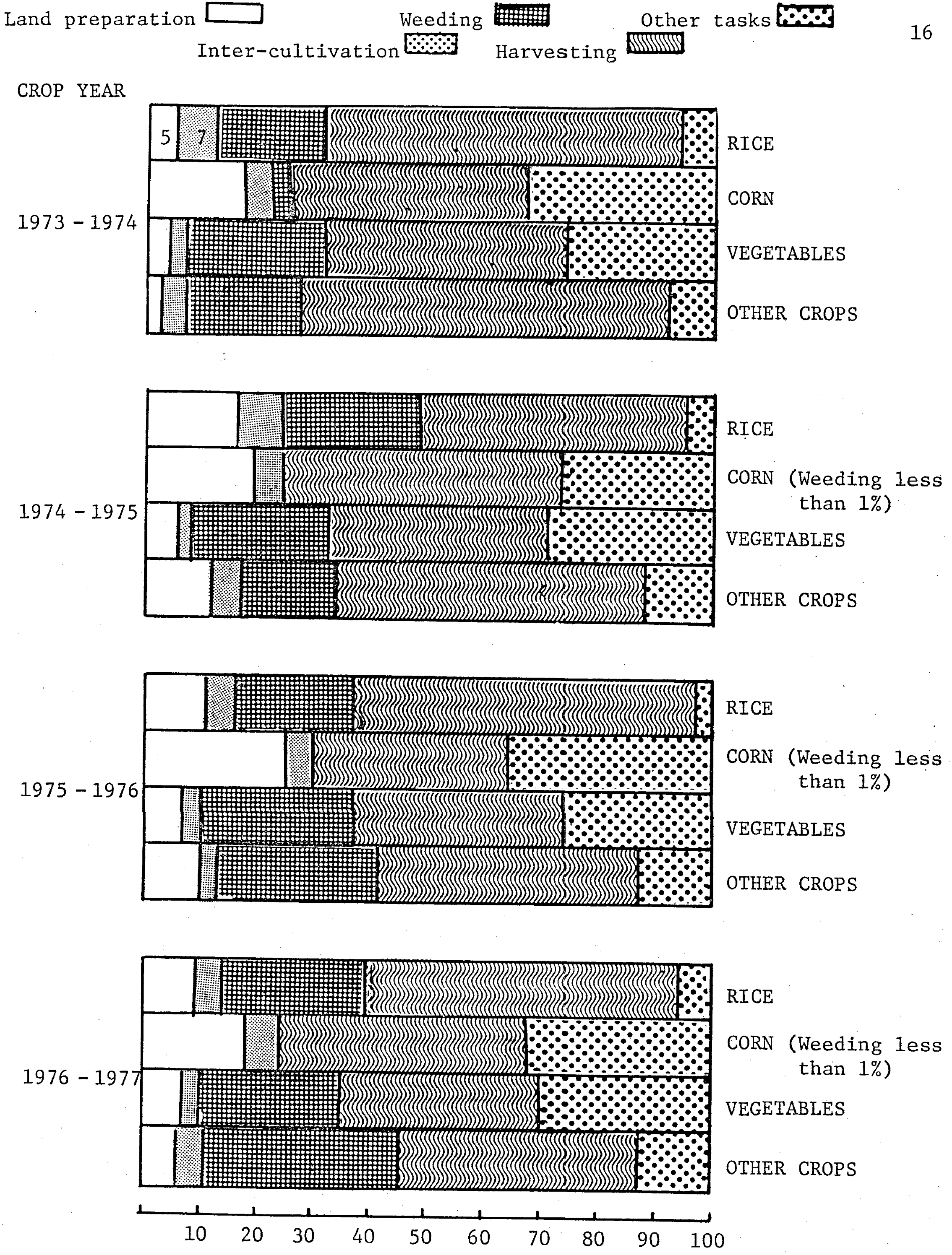

Fig. 2.3: Percentage of total labour manhours for various crop operations spent on each crop, Cale, Tanauan, Batangas, 1973 - 1977.

Source: Frio and Price (1979).

TABLE 2.6

CHANGES IN YIELD OF DIFFERENT CROP/CROP GROUPS, 35 FARMS, CALE, TANAUAN, BATANGAS, 1973-77

Crop/Crop Group	Year			
	1973-74	1974-75	1975-76	1976-77
	Tons Per Hectare			
1. Rice	1.96	1.05	1.80	1.95
2. Corn (wet)	1.08	1.67	1.75	2.20
3. Corn (dry)	1.81	2.46	4.16	3.27
4. Field Crops	0.32	0.76	1.33	0.86
5. Leaf-Vine Stem Vegetables	2.94	7.32	7.49	7.16
6. Bulb-Root-Tuber Vegetables	3.18	5.50	1.59	1.73
7. Fruit Vegetables	8.77	6.95	14.08	7.78
8. Rice/Corn with Intercrops	2.82	2.90	5.77	3.16
9. Vegetable Combinations	9.37	11.62	10.88	6.15
10. Trellis	9.66	10.93	9.38	6.71

Source: Frio and Price (1979).

Wet season corn was the only crop that showed a steady increase in yield. Vegetable yields fluctuated widely while rice yields were relatively stable. Wet season corn yields were generally lower than dry season yields, but were less variable.

The farmers have two markets for their produce, the Tanauan public market and Divisoria market in Manila. A big truck usually comes to the village every day to take farm produce to Manila. A farmer can either sell directly or through a middleman who is paid for his services. Farmers who sell their produce in Tanauan use jeepneys to get there. Usually prices in Manila are higher than the price received by farmers in Tanauan. However, the price paid by Manila dealers in the village is lower than Tanauan market prices. Even when transport costs to Tanauan are taken into account, most farmers feel it is more profitable to take their produce to Tanauan and sell it there. Prices of selected crops in Manila are shown in Figure 2.4. Prices of vegetables in particular showed higher fluctuations (i.e. eggplant, tomato, sponge gourd, bitter gourd and lima beans), while prices of non-perishable crops showed least fluctuations (i.e. mungbeans and taro).

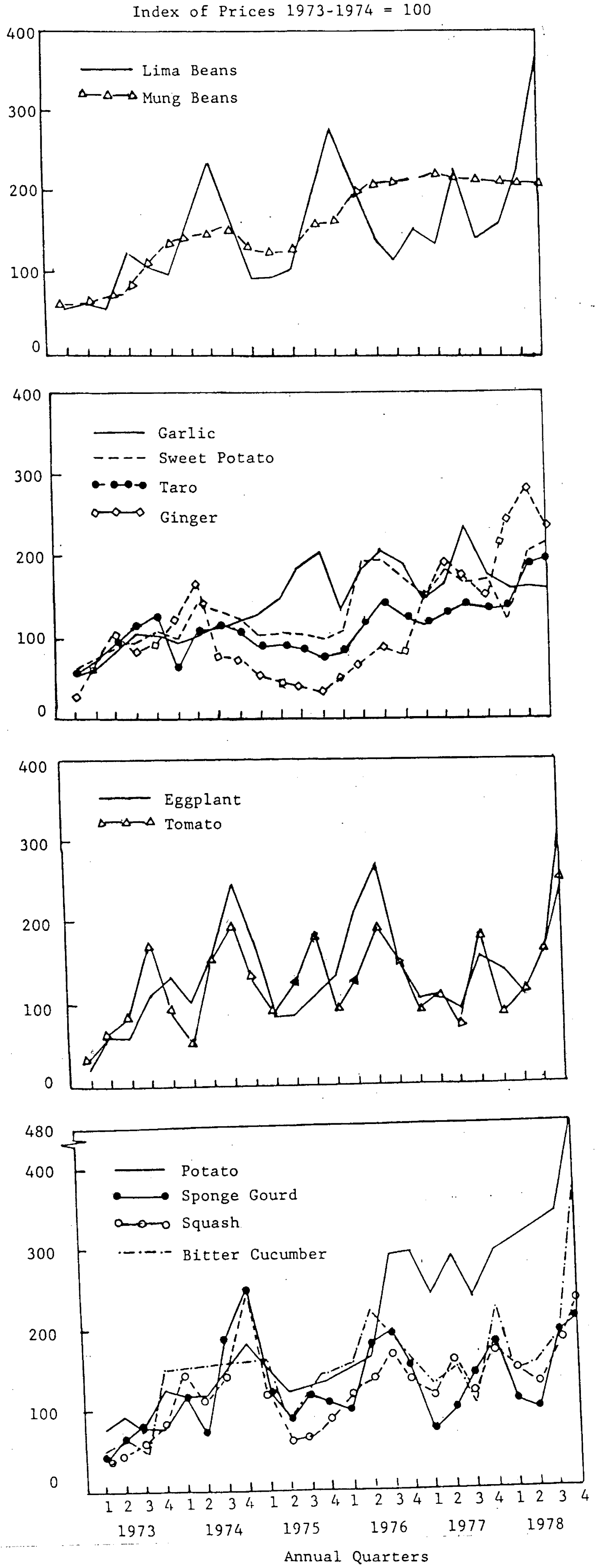

Fig. 2.4: Quarterly prices of selected crops, Divisoria market, Manila.

CHAPTER 3

DECISION-MAKING UNDER RISK

In this chapter various aspects of decision-making under risk are discussed. In Section 3.1, the concept of risk and unceraintty is given. The main sources of risk in agriculture and the criteria or rules often used for risky decision-making are considered in Sections 3.2 and 3.3 respectively. Some of the widely used approaches for accounting for risk in farm decision-making and some of its applications to agricultural problems are considered in detail in Section 3.4.

3.1 CONCEPT OF RISK AND UNCERTAINTY

F. Knight (1921) distinguished between 'risk' and 'uncertainty'. Risk refers to the situations in which alternative outcomes exist with known probabilities, and uncertainty to situations where probabilities for the outcomes are unknown.

In modern decision theory, the above distinction is no longer used. Uncertainty refers to all situations where a single action may lead to alternate consequences, and risk refers to a characteristic of the subjective probabilities over the consequences associated with an action (Roumasset, 1976). Common measures of risk are: (a) variance; (b) standard deviation; and (c) coefficient of variation.

3.2 SOURCES OF RISK IN AGRICULTURAL PRODUCTION

3.2.1 Yield Risk

Yield risk arises from many sources including: (a) variability in the weather and climatic factors; (b) plant pests and diseases. The incidence of pests and diseases can be controlled by protective measures such as spraying pesticide. However, variability in the weather lies outside the farmers' control. Among these factors, rainfall is the most important in our study area, as it has a completely rainfed agricultural system.

Both the timing and the amount of rain are crucial factors that contribute to risk associated with rainfall. The Philippines is frequently visited by tropical cyclones, locally termed typhoons. Typhoons often result in serious flooding, and also destroy the crops due to the strong winds associated with them. Floods can cause delays in the establishment of the crop, and postpone the performance of crop maintenance operations such as weeding, fertilizing and spraying.

Besides the damaging effects cited above, the amount and timing of rain can significantly affect the planting calendar of the farmers. A late onset of rain will delay the planting of the first crop which in turn also delays the second crop. The delayed planting of the first crop can decrease the yield by increasing the probability of the crop being exposed to drought stress during the late months of the season, thus affecting the plants during the reproductive and fruiting stages of the crop. The yield reducing effect on the second crop would be through shortening the time in which water can be available for the plant, and consequently exposing the crop to drought stress.

3.2.2 Price Risk

The price risk includes both the input and output price risk. Roumasset (1976) in his study of risk in decision-making of low rice farmers in the Philippines excluded the output price as a source of farm risk. He argued that price risk is generally small in comparison to yield risk and that in the case of rice and corn, prices were highly predictable. This is because these crops are government controlled, and hence will not fluctuate very much. In this study area, however, output prices is an important source of farm risk. This is because apart from rice and corn, prices of other crops, such as vegetables, produced in the farm are subject to considerable variations other than normal seasonal fluctuations. Despite this, most of the farmers grow vegetables, due probably to the following reasons: (a) they are profitable; (b) they can give regular incomes.

Input price risk is generally low in the study area. According to O'Brien (1978), (a) prices of inputs such as fertilizers and chemicals are known with certainty because most farmers buy these inputs at the start of the planting season; (b) all other factor payments such as landlord shares and land rents are fixed; and if altered, are arranged before the planting season; and (c) although the price of labour (wage rate) is increasing each year, it does not change within one cropping season.

3.3 CRITERIA FOR RISKY DECISION-MAKING

A decision problem arises when the decision-maker is uncertain about the consequences of his alternative courses of action. In decision theory, the decision-maker is usually supposed to act in accordance with a set of rules or criteria. It is through this choice of criteria that the decision-maker makes his choice among alternative decisions. The most common choice criteria considered in theories of risky decision-making are disussed below.

3.3.1 Expected Profit Maximization

In one criterion, that of expected profit maximization, the course of action with the greatest expected return (profit) is adopted irrespective of risk or variability associated with that return. This criterion is appropriate for decision problems where risk is not a factor, or when the decision-makers are risk neutral.

3.3.2 Expected Utility Maximization

The criterion of expected utility maximization has been strongly proposed as an alternative to maximization of expected profit in risky decision problems (Anderson, Dillon and Hardaker, 1977). The criterion is based on the expected utility theorem, or Bernoullis' principle, which states that: given a decision-maker whose preferences do not violate a set of axioms (discussed below), there exists a function U, called a utility function which associates a real number or utility index with any risky prospect faced by the decision-maker. The theory thus provides a mechanism for ranking risky prospects in order of preference, the most preferred prospect being the one with the highest utility. It brings together in an explicit way the decision-maker's degree of belief and his degree of preference.

The postulates or axioms (also known as von Neumann and Morgenstern axioms) for deducing the expected utility theory for the case of single dimensional consequences are:

(a) Ordering and transitivity

A person either prefers one of the two risky prospects a_1 and a_2, or is indifferent between them. The extension of ordering is transitivity or orderings of more than two prospects, i.e. a_1, a_2, a_3. This implies that if a person prefers a_1 to a_2 (or is indifferent between them) and prefers a_2 to a_3 (or is indifferent between them), he will prefer a_1 to a_3 (or be indifferent between them).

(b) Continuity

If a person prefers a_1 to a_2 to a_3, a subjective probability $P(a_1)$ exists other than zero, or one such that he is indifferent between a_2 and a lottery yielding a_1 with probability $P(a_1)$ and a_3 with probability $1-P(a_1)$.

(c) Independence

If a_1 is preferred to a_2, and a_3 is any other risky prospect a lottery with a_1 and a_3 as its outcomes will be preferred to a lottery with a_2 and a_3 as outcomes when $P(a_1) = P(a_2)$. In other words, preference between a_1 and a_2 is independent of a_3.

The acceptance of the above axioms implies the existence of the utility function. One important property of this function is that the scale on which the utility is defined is arbitrary. In particular the property of this function that is relevant to a choice or decision analysis is that it is not changed under a linear transformation. Because of this characteristic, the general shape of the utility function is not dependent on the origin, and the scale chosen.

The risk attitudes of the decision-maker determines the shape of the utility function. Given the utility function $U = f(M)$, where M is the monetary gains, the function can have any of the three types of shape as shown in Figure 3.1 (Halter and Dean, 1977). All three

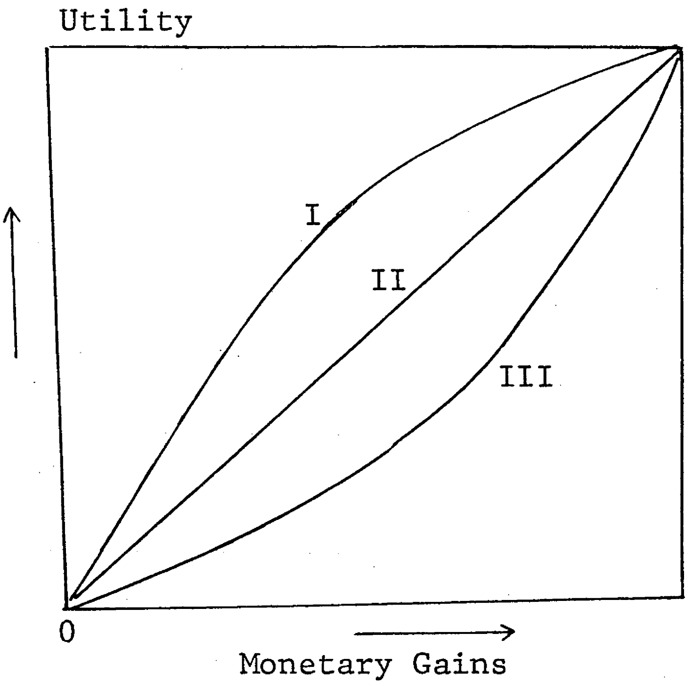

Fig. 3.1: Three possible shapes of utility functions for three individuals:

- I. risk averse
- II. risk neutral
- III. risk taker

functions are increasing monotonically throughout, i.e. $dU/dM > 0$ which means that the marginal utility of income is always positive. The figure shows that the marginal utility of an additional dollar varies among the three individuals.

Individual I has a decreasing marginal utility, i.e. $d^2U/d^2M > 0$, which indicates that as dollar gains increase, they become subjectively less valuable. This individual falls into the category of risk averse or risk evader in the sense that in a risky situation he prefers the action with lower variability for a given level of expected return.

Individual II, however, has a constant marginal utility of money, i.e. $d^2U/d^2M = 0$, which indicates that this individual values an additional dollar just as highly, regardless of whether it is the first dollar or the 100th dollar. This individual then is considered to be risk neutral because in the face of a risky situation he ignores variability.

On the other hand, individual III has an increasing marginal utility of money $d^2U/d^2M > 0$. This individual will gamble or take a bet even if the expected value of the outcome is negative. This individual falls into the category of risk taker or risk preferrer, in the sense that he will tend to pick an action with greater variability at the same expected monetary gain.

3.3.3 Security/Safety First Rules of Thumb

These rules of thumb are not derived from Bernoullian utility functions, although in some cases, it is possible to relate the optimal allocation decisions to equivalent decisions based on such functions. Many methods have been proposed (to be discussed in

Section 3.4.3) that highlight the security desires of decision-makers by focusing attention at crucial (but generally arbitrary) levels in the lower tails of probability distributions (Anderson, 1979, p.47).

3.4 THREE WIDELY USED APPROACHES FOR ACCOUNTING FOR RISK IN FARM DECISION-MAKING[1]

3.4.1 Mean Variance (E-V) Approach

The use of the mean variance (E-V) approach assumes that the decision-makers maximize expected utility and that either the utility function is quadratic with respect to expected income and variance of income or the distributions are normal (Borch, 1969; Feldstein, 1969). Markowitz (1952) introduced the approach in the context of the choice of the optimal stock market portfolio. He suggested the use of quadratic programming (QP) to find the most efficient portfolio. He defined a portfolio as efficient if: (a) no other portfolio with the same return has a lower variance (or standard deviation); and (b) no other portfolio with the same variance has a higher rate of return. Based on this definition, given two portfolios with the same mean return (E) an investor will prefer the portfolio with the lower standard deviation, and of the two portfolios with the same standard deviation, he will prefer the portfolios with the higher E.

Given a set of efficient portfolios, the choice of these portfolios to any investor will, however, depend on his preference between various expected returns and associated variance, as described by the E-V utility function. An investor who is indifferent or prefers risk will put all his wealth into one security. If he is

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[1] For detailed reviews of incorporating risk into programming models see Anderson, Dillon and Handaker (1977), Hubbard (1977), and Boussard (1979).

indifferent it will be the one with the highest rate of return regardless of risk.

Since many of the decisions facing the farmers will also involve a choice of an enterprise mix to a farm, the use of this approach was extended to agriculture. The first programming model explicitly incorporating risk in agriculture was done by Freund (1956). He used the QP to find the optimum combinations of crops for a representative Eastern North Carolina farm. In this study he found that the expected net revenue and standard deviation of net revenue from crop combinations obtained from the QP program were much lower than that obtained from non-risk programs (ordinary linear programming). Furthermore, he found that the combination of high risk crops will be reduced in the QP results. Since their studies of risk in agriculture has been numerous (for a review see Anderson, Dillon and Hardaker, 1977). A recent study by Rajagoapalan and Varadarajan (1978) in Tamil Nadu, India, used the QP to measure the impact of technology on farm risk and evaluated the economic benefits of formal and informal methods of risk management. One difficulty, however, of using the QP is the need for a non-linear programming algorithm with desired features and capacity. Because of this problem a number of linear approximations to quadratic functions has been proposed.

An alternative approach to QP was proposed by Hazell (1971), the Minimization of Total Absolute Deviation (MOTAD). In this approach the mean absolute income deviation was used as a measure of risk. This approach can be solved on ordinary linear programming (LP) algorithms with parametric option. A more detailed discussion of this approach is presented in Chapter 4.

Another approach suggested by Thomas et al. (1972) is the use of separable programming. In this approach the non-linear variance constraint is replaced by a piece-wise linear approximation which can be solved by a linear programming code. As with QP, it selects farm activities which are efficient in terms of expected income and income variance.

Chen and Baker (1974) on the other hand have proposed the use of the marginal risk costraints (MRC) approach which can be fitted into a linear model with dichotomous MRC, along with the usual resource constraints. The MRC uses a multistage LP algorithm to approximate the E-V boundary. In this approach it is assumed that the investor/ decision-maker maximizes the expected return provided that the marginal contribution of each activity to the total variance of return does not exceed its expected unit of income, divided by a risk aversion parameter.

Driver and Stackhouse (1976) also suggested an approach called linear programming-risk simulation (LP-RS). In their approach the LP-RS model evaluates the relative riskiness of individual activities by discounting the expected gross margin in correspondence to its variation given by the standard deviation. Risk discounting forces alternate planning solutions with unique resource utilizations, activity combinations and levels, expected net farm incomes, net cash position and standard deviation of expected net farm income. The model derived the E-$\sqrt{V}$ over the range of expected net farm income (E) - standard deviation ($\sqrt{V}$) combinations.

A rather useful approach is Monte Carlo Programming (MCP) which was developed by Donaldson and Webster (1968). In the MCP the portfolio of activity levels are selected at random using a computer. The portfolios generated are first tested for feasibility and are then evaluated in terms of some specific objective function. A large number of such portfolios can be inspected and the optimal one can be chosen by the decision-maker. The advantages of this approach are: (a) that it is very easy to take into account integer constraints on activities; and (b) that almost any form of objective function can be applied. In particular, the utility function defined in terms of the mean and variance of total revenue is readily computable and in principle higher order moments of the distribution can be accommodated (Anderson et al., 1977). As in QP, the efficient set of portfolios can be represented by an E-V utility function. The actual applications of the approach are still quite limited. Anderson (1975) has used the MCP to generate many near optimal plans and used the stochastic dominance rules to select the most risk-efficient plan.

3.4.2 Stochastic Dominance Rule[2]

Hadar (1971) has defined the general idea of stochastic dominance (SD) to consist of rules of identifying unamimous preference by a group of agents or utility maximizers among completely specified risky prospects (cited in Anderson, 1979, p.51). The application of SD to portfolio choice was proposed over the E-V approach because the constraints placed on the utility function by the various dominance criteria (FSD, SSD, TSD) are more theoretically appealing than the assumptions of a quadratic utility function, i.e. increasing risk aversion with increasing wealth or normal distribution of returns.[3]

The SD rules are based on the following dominance conditions. Firstly, define the following variables:

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[2] Discussion draws heavily on Anderson, Dillon and Hardaker (1977) and Anderson (1979).

U is the ith derivative of utility function U;

x is the unscaled measure of consequence such as profit or income;

F and G are a pair of continuous cumulative density functions (CDF) defined within the range a,b with probability density functions f(x) and g(x).

The first degree stochastic dominance (FSD) rule requires only that the decision-maker utility function be monotonically increasing, where the first derivative be strictly positive $U_1(x) > 0$, i.e. that decision-makers always prefer more to less of x. In terms of CDFs, F is said to dominate G in the sense of FSD if $F_1(x) < G_1(x)$. In graphical terms this rule means a first-degree stochastically dominant CDF curve lies nowhere to the left of a dominant curve.

The second degree stochastic dominance (SSD) not only requires the function to be monotonically increasing, $U_1(x) > 0$ but further assumes risk aversion by the assumption that the second derivative be negative, $U_2(x) < 0$. In terms of CDFs, F dominates G in the sense of SSD if $F_2(x) < G_2(x)$. In graphical terms, a distribution function F dominates another G if it lies more to the right in terms of differences in area between the CDF curves cumulated from the lower values of uncertain quantity.

The third degree stochastic dominance (TSD) incorporates the assumption of FSD [$U_1(x) > 0$] and SSD [$U_2(x) < 0$], adding the further restriction that the third derivative be positive, $U_3(x) > 0$. This restriction is implied by the requirement that as people become

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3. However, it has also been argued that the E-V rules are quite acceptable in practice and that they yield results very similar to those given by the SD rules (Tsiang, 1972 and 1974; Levy and Markowitz, 1979).

wealthier, they become averse to risk. That is, the distributions F dominate G in the sense of TSD if $F_3(R) < G_3(R)$ for all possible R and if $F_2(b) < G_2(b)$ where b is the upper range. Furthermore, the three dominance rules require as necessary conditions: (a) that for one distribution to dominate another is that its mean not be less, and (b) that the smallest value of a dominant distribution cannot be less than the smallest value of a dominated distribution.

Markowitz (1959) has also suggested an approach very similar to the E-V approach called the mean-semivariance (E-S) approach. This approach uses the semivariance (S) as a measure of risk where S is defined as a variance below a specified level. The E-S approach can be applied in two ways. The first is to measure the semi-variance as the expected value of deviation below the mean. The second is to measure the semivariance as the expeced value of deviation below a critical (target) value. Porter (1974) has shown that the E-S efficient set with semivariance around the mean shows that much consistency with the SSD rules and hence is more consistent with expected utility maximization. This has been discussed by Fishburn (1977) and further extensions have been suggested by Menezes, Geiss and Tressler (1980). However, the computational procedure involved in this approach can be rather tedious.

3.4.3 Safety First Rules[4]

Some of the safety first rules are:

(1) Safety Principle

The safety principle was first suggested by A.D. Roy (1952) and

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[4] Discussion has drawn heavily on Anderson (1979).

involved minimizing the probability that some attribute, usually profit (π) falls below a specified 'disaster level' d*, i.e. minimize $P(\pi < d)$ or minimize $F_i(d^*)$ where F_i denotes the cumulative distribution functions of the ith prospect. Operationally, the rule is often expressed in terms of mean (E) and standard deviation (S) as minimize $(d^* - E)/S$, either by appeal to the Tchebychev inequality (Roy, 1952) or by restriction to two parameter distributions in general (Pyle and Turnovsky, 1970) as the normal distribution in particular. The rule has a direct interpretation in expected utility terms if the utility function is unity above d* and zero below, which is a very restrictive assumption.

(2) Safety First Principle

The strict safety first rule (Telser, 1955) is equivalent to chance constrained programming (Charnes and Cooper, 1959) and consists of maximizing the objective function (usually the expected profits) subject to (possibly amongst others) a constraint on disaster expressed in terms of an exogenously specified crucial probability P*, i.e. maximize E subject to $P(\pi < d^*) \leqslant P^*$.

This rule was incorporated into a focus loss constrained program (FLCP) by Boussard and Petit (1967) into a mathematical programming model which can be solved by an ordinary linear programming algorithm. Studies using this model includes one by Kennedy and Francisco (1975) on selected wheat and sheep farms in New South Wales, Australia. Their model assumed that the decision-maker maximize expected income (E) subject to some specified probability (α) of obtaining a given minimum level of income (F). In their analysis, they hypothesize that farmers are prepared to trade E for F while maintaining a given level of utility. Further, they derived the E-F indifference curves through an interview procedure where an estimate of c, the marginal rate of substitution of E for F, is obtained. In their model the farmers seek to maximize E - cF.

(3) Lexicographic Safety First (LSF) Rules

Roumasset (1976) discusses extensively LSF rules. He identifies two variations LSF_1 (maximize E whenever the safety first constraint is met, and minimize the probability of disaster when it is not) and LSF_2 (maximize E whenever the safety first constraint is met, and follow the safety first rule when it is not) and explored their implications and descriptive powers. He used these rules to model the choice of technology (traditional or high yielding rice variety) by low income rice farmers in the Philippines.

Kunreuther and Wright (1979) have used a similar model based on lexicographic preference in order to explain allocative behaviour on the part of the income farmers. They used data from Bangladesh on small farmers with the problem of allocating land to rice (subsistence crop) or jute (cash crop). The same lexicographic model was applied by them to the choice between cotton (cash crop) or corn (subsistence crop) in the nineteeth century U.S. South data.

CHAPTER 4

METHODOLOGY

The methodology used in this study is discussed in this chapter. A detailed discussion of the model used and application of similar models to other studies are considered in Section 4.1. In Sections 4.2 and 4.3, the data used and procedure for evaluation of technologies are discussed.

4.1 RATIONALE FOR THE CHOICE OF THE MODEL

From the different models which account for risk in the whole farm setting, the MOTAD model suggested by Hazell (1971) was used in this study. It is a linear approximation to QP. It uses the mean absolute income deviation as a measure of risk and can be solved by parametric linear programming. Since the results obtained from the model are remarkably similar to those from QP, this model was selected for use in this study.[1] Also, the use of a more sophisticated model was not justified by the quality of available data (discussed in detail in Chapter 7).

Hazell (1971) has presented two conditions which when met will make the MOTAD model a good substitute for a QP model. The first of these conditions is that the total income variance and mean absolute

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1. Johnson and Boehlje (1981 and 1982) have also showed that MOTAD and QP give simlar results in solving expected utility maximization problems.

income deviations are estimated from the sample data. The second is that the population of possible income outcomes from farm plans are normally distributed. Based on these conditions, any differences in the reliability of results from the two models for the same sample data will depend upon the differences in the properties of these estimators (i.e. variance and mean absolute income deviation). Since both estimators are unbiased, any differences arise from the relative efficiency of the two estimators. For large sample sizes the estimated mean absolute deviation is slightly lower than the estimated standard deviation (Fisher, cited in Hazell, 1971, p.55). However, Hazell further argued that the superiority of the sample standard deviation is sufficiently marginal for sample sizes greater than four or five and justifies the use of the sample mean absolute deviation.

4.2 THE MODEL

There were four models used in this study: (a) a deterministic LP model where the farmers' objective was specified as maximization of net cash income; (b) an ordinary LP model where the farmers' objective included as a priority goal the meeting of subsistence rice needs; (c) a MOTAD model where the farmers' objective incorporated both income and risk considerations; and (d) a MOTAD model where the farmers' objectives included in addition the priority goal of meeting the subsistence rice needs. The formulation of the models used are given below.

4.2.1 Deterministic LP (Non-Risk) Model

Maximize

$$\sum_{j=1}^{n} \bar{c}_j x_j \tag{4.1}$$

subject to:

$$\sum_{j=1}^{n} a_{ij}x_j \leqslant b_i \qquad \text{(for all i, i = 1, ..., m)} \tag{4.2}$$

$$x_j \geqslant 0 \qquad \text{(for all j) ,} \tag{4.3}$$

where:

j = 1, ..., n activities;

x_j = level of the jth activity;

a_{ij} = technical requirements of the jth activity for the ith constraint;

b_i = ith constraint level;

$\bar{c}_j$ = expected income for the jth activity;

m = number of constraints.

The priority goal of meeting subsistence rice requirements was included in the constraint set.

4.2.2 MOTAD Model[2]

In this model, risk is measured by mean absolute income deviation (A). A is an unbiased estimator of the population mean absolute income deviation defined as follows:

$$A = \frac{1}{s} \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (c_{hj} - \bar{c}_j)\, x_j \right| \tag{4.4}$$

or

$$A.s = \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (c_{hj} - \bar{c}_j)\, x_j \right| , \tag{4.5}$$

where:

c_j = hth observation on net income for the jth activity;

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[2] For a detailed discussion see Hazell (1971).

$h = 1, \ldots, s$ observation in a sample of net incomes.

All other variables are as defined for equations (4.1), (4.2) and (4.3).

To generate E-A farm plans, define another variable y_h, given in the following formulae:

$$y_h = \sum_{j=1}^{n} c_{hj}x_j = \sum_{j=1}^{n} \bar{c}_j x_j \qquad \text{(for all } h,\ h=1, \ldots, s\text{)} \qquad (4.6)$$

such that

$$y_h = y_h^{+} - y_h^{-} \qquad (4.7)$$

and

$$y_h,\ y_h^{-} \geqslant 0 \qquad (4.8)$$

that is, such that y_h $(h = 1, \ldots, s)$, are unconstrained in sign. Then, if y_h^{+} and y_h^{-} are selected in some minimal way so that one or the other is zero, $|y_h| = y_h^{+} + y_h^{-}$ $(h = 1, \ldots, s)$.

From equation (4.5)

$$\begin{aligned} A.s &= \sum_{h=1}^{s} \left| \sum_{j=1}^{n} (c_{hj} - \bar{c}_j)\ x_j \right| \\ &= \sum_{h=1}^{s} \left| \sum_{j=1}^{n} c_{hj}x_j - \bar{c}_j x_j \right| . \end{aligned}$$

Then

$$A.s = y_h \quad \text{(see equation 4.6)}$$

since

$$y_h = \sum_{h=1}^{s} (y_h^{+} + y_h^{-}) \qquad \text{(from equation 4.7)} .$$

Now for a given farm plan,

$$y_h^{+} = \left| \sum_{i=1}^{n} (c_{hj} - \bar{c}_j)\ x_j \right|$$

when

$$\sum_{j=1}^{n} (c_{hj} - \bar{c}_j) x_j$$

is positive or zero otherwise. Thus,

$$\sum_{h=1}^{s} y_h^+$$

is the positive total income deviations around the expected net income deviations based on sample mean net income. Similarly,

$$y_h^- = \left| \sum_{j=1}^{n} (c_{hj} - \bar{c}_j) x_j \right|$$

when

$$\sum_{j=1}^{n} (c_{hj} - \bar{c}_j) x_j$$

is negative and zero otherwise, so that,

$$\sum_{h=1}^{s} y_h^-$$

is the sum of the absolute values of the negative total income deviations around the expected net income deviations based on sample mean net income. It follows then that

$$\sum_{h=1}^{s} y_h^+ = \sum_{h=1}^{s} y_h^-$$

if $\bar{c}_j$ $(j = 1, \ldots, n)$, are sample mean net income.

The model based on minimizing only the sum of the absolute values of the negative total net income deviations

$$\sum_{h=1}^{s} y_h^-$$

are given on the following formulae:

Minimize

$$\sum_{h=1}^{s} y_h^-$$

subject to:

$$\sum_{j=1}^{n} (c_{hj} - c_j)\, x_j + y_h^- \geqslant 0 \qquad \text{(for all h, h = 1, ..., s)} \qquad (4.9)$$

$$\sum_{j=1}^{n} \bar{c}_j x_j = \lambda \qquad (\lambda = \text{ 0 to unbounded}) \qquad (4.10)$$

$$\sum_{j=1}^{n} a_{ij} x_j = b_i \qquad \text{(for all i, i = 1, ..., m)} \qquad (4.11)$$

$$x_j, y_h^- \geqslant 0 \qquad \text{(for all h,j)} , \qquad (4.12)$$

where

λ = scalar which is parameterized from zero to the maximum attainable level.

All other variables are as defined for equations (4.1) to (4.8).

The structure of the matrix used in this study is given in Tables 4.1 (LP deterministic model) and 4.2 (MOTAD model). A detailed discussion of the components of the matrix is given in Section 4.2.

4.3 APPLICATION OF SIMILAR MODELS IN OTHER STUDIES

The MOTAD model is preferred over other alternatives to approximate QP because it can easily be run with most available computer packages.

Schluter and Mount (1976) studied farms in the Surat District, India, using a MOTAD model. The aims of their study were to determine

TABLE 4.1

OUTLINE OF THE LINEAR PROGRAMMING (NON-RISK) MATRIX

Resources		Crop Production Activities $X_1, \ldots, X_n$	Palay Consumption Activity	Labour Hiring		Power Hiring		Constraint
				1	2	1	2	
Fully Owned Land	1							
	2							
Share Tenanted Land (3:1)	1							
	2							
Share Tenanted Land (2:1)	1							
	2							
Labour (Manhours)	1							
	2							
Cash Cost (₱/ha)	1							
	2							
Palay Balance (t/ha)								
Palay Consumption Minimum (t/ha)								
Expected Income (₱/ha)								

Note: Palay balance, minimum and consumption activity were deleted in situations where the farmer has no subsistence objective.

TABLE 4.2

OUTLINE OF THE LINEAR RISK PROGRAMMING MATRIX

Resources		Crop Production Activities	Palay Consumption Activity	Labour Hiring		Power Hiring		Annual Deviation			Constraints
		$X_1, \ldots, X_n$		1	2	1	2	Y_1	Y_2	Y_n	
Fully Owned Land	1										
	2										
Share Tenanted Land (3:1)	1										
	2										
Share Tenanted Land (2:1)	1										
	2										
Labour (Manhours)	1										
	2										
Cash Cost (₱/ha)	1										
	2										
Palay Balance (t/ha)											
Palay Consumption Minimum (t/ha)											
Expected Income (₱/ha)											
Income Deviation for 1974-75											
1975-76											
1976-77											

Note: Palay balance, minimum and consumption activity were deleted in situations where the farmer has no subsistence objective.

the cropping patterns chosen by the group study farmers, and to examine the contrasting importance of risk and credit between irrigated and unirrigated farms. In their model risk was measured as the mean absolute deviation of net cash income around its mean. The main finding of their study was that farmers in the Surat District made decisions which appeared to be based on the dual and competing objectives of increasing income and reducing risk; the farmers appeared willing to substantially reduce their incomes from the maximum obtainable level to lower the risk.

Brink and McCarl (1978) also used the MOTAD approach in their study of the trade-off between expected return and risk among corn-belt farmers in the U.S.A. They used the model to determine if incorporating risk in the model helps to predict actual farmer behaviour in terms of crop acreages and to explain the diversity between farmers' farming practice in terms of their trade-off between return expectation and risk. The decision criterion used measured risk as a total negative deviation from an expected level. Some of the results of their study were that: (a) risk aversion was not an important factor in the choice of crop acreages; (b) there was a large variation in individual risk aversion coefficients. Recognizing the limitations of their study, they concluded that risk aversion probably plays a smaller role in corn-belt crop farming decisions than in other types of farming.

A method for incorporating risk in stochastic input-output coefficients in a programming model was proposed by Wicks and Guise (1978). Their method extends the MOTAD approach of Hazell to incorporate this other important source of risk in farm planning. The solutions they obtained represented estimated partial equilibria for given expected gross margins, resource availabilities, and attitudes to risk, and can be readily updated when any of these components change significantly. They illustrated the use of their proposed approach by using data on three sheep-grain farms in the Northern Tableland of New South Wales, Australia.

Another application of the MOTAD approach was undertaken by Gebremeskel and Shumway (1979) in their study of cow-calf producers in the Texas Gulf Coast. Their model accounted for forage quality and was used to determine forage species, fertilization rates, herd size, and degree of on-farm integration in the framework of the E-A efficient set. The effect of calving season on the risk-constrained solutions was evaluated and annual calf-marketing strategies were derived based on observable information relevant for predicting subsequent calf prices and forage yelds.

Mapp et al. (1979) used the MOTAD approach to analyze risk management strategies for agricultural producers in Southern Oklahoma. They used the MOTAD model to analyze risk management scenarios. In one of the models incorporating risk, the producer was assumed to minimize negative deviations from the gross margin expectations, subject to receiving a specified level of income. In the other, they assumed that storable commodities, such as wheat, may be marketed at harvest or sequentially during the crop year. In addition, this model permitted consideration of forward contracting for a portion of the wheat crop. The results of the model showed that there was the possibility of reducing the relative variability through diversification, sequential marketing and forward contracting of wheat.

In a different context, Plain et al. (1981) have used the approach to assess the role and potential of new crops, i.e. oilseed and grain legume crops within the existing wheat-sheep regime in New South Wales, Australia. Their analysis proceeded by setting up a land-use decision model into which known profitability characteristics of both traditional and new enterprises were explored. The proportion of total arable land allocated to new crops was then used as a basis for assessing their potential. They found out that the new crops could be adapted to the farmers' traditional system and had the potential to increase farm incomes and reduce income variability. Although the new crops were adapted, there were no substantial changes in traditional land-use patterns and the size of the apparent gains were relatively small. This was because wheat remained more profitable and saleable than the new crops, oilseed and grain-legumes.

4.4 THE ASSUMPTIONS OF THE MODEL USED IN THE STUDY

Assumptions commonly made in MOTAD models were summarized by Hubbard (1977, pp.55-56) and classified into three classes:

(a) Assumptions about stochastic elements in the farm business:

- (i) stochastic nature of activity net returns are represented by the historical variation in activity gross margin absolute deviations from their means;
- (ii) covariances are implicitly considered through the historical pattern of activity gross margin deviations;
- (iii) there is no explicit distributional assumption on gross margins.

(b) Assumptions about decision-makers' objectives:

- (i) decision-makers wish to minimize income dispersion (measured by mean absolute income at various levels of expected income). From this set of plans the decision-maker can choose the one most suited to his preferences;

(ii) dispersion, which includes both upward and downward fluctuations, is minimized. Thus both upward and downward fluctuations are of interest to the decision-maker.

(c) Assumptions about decision-makers' view of the future and risk:

(i) the future is represented by the decision-makers' expectations;

(ii) risk is measured by historical patterns of activity gross margin variability.

Generally, another implicit assumption made is that input-output coefficients are not stochastic.

4.5 DATA USED IN THIS STUDY

Most of the data used in this study were obtained from the IRRI's farm record-keeping project in Cale, Tanauan, Batangas, in the Philippines during the crop year 1974-75 to 1976-77. Other relevant data were derived from the Institute's Annual Reports in various years and research publications of the IRRI cropping systems program research team.

4.5.1 Description of the Sample Farmers

In this study, data from five selected farmers for whom fairly complete information was available was used. Some of the characteristics of these selected farmers are shown in Table 4.3.

The percentage of land planted to various cropping patterns for the five farmers during the period 1974-77 is shown in Table 4.4. The rice-corn pattern occupied at least 60% of the total area planted in all years. Over this period there was a substantial increase in area planted to rice/corn with relay crops.

TABLE 4.3

GENERAL INFORMATION ON 5 SELECTED FARMS,
CALE, TANAUAN, BATANGAS, 1977

Item	Mean	Per Cent
1. Characteristic of Farmers		
Age (in years)	49	
Educational Attainment (in years)	4	
Size of Household (number)	6	
2. Tenure Status (number of farmers)		
Owner cum Share	3	60
Share Tenants	2	40
Total	5	100
3. Farm Size (hectares)	1.50	

4.5.2 The Average Farm Model

Based on the records of these five farmers an 'average' farm model was developed. Data limitations were the main reason for choosing this approach. The limitations of such an approach are discussed in Chapter 7.

For purposes of this study, crop production technologies of the sample farmers were classified into three major groupings:

(a) Existing technologies (ET) refers to technologies traditionally practiced by farmers. Data for this technoloies were based on farm records.

(b) Available new technology (ANT) refers to technology introduced to farmers during the research project. Data for this technology was

TABLE 4.4

PERCENTAGE OF LAND PLANTED TO VARIOUS CROPPING PATTERNS, FIVE SELECTED FARMS, CALE, TANAUAN, BATANGAS, 1975-77

Cropping Pattern	1974-75	1975-76	1976-77
1. Rice-Corn	61	59	67
2. Rice-Vegetables[b)]	21	13	5
3. Rice-Corn with Relay Crops[c)]	0	3	6
4. Corn-Corn	a)	1	2
5. Corn-Vegetables	5	1	2
6. Vegetables-Vegetables	1	13	9
7. Vegetable Intercrop[d)]	4	2	4
8. Trellis Crop[e)]	5	5	3
9. Single Crop[f)]	2	2	1
Total	100	100	100

(a) Less than 1%.

(b) Vegetables include cowpea, mung, bitter gourd, tomato, sponge gourd, garlic, bottle gourd, etc.

(c) Relay crop includes sponge gourd, hyacinth bean, bottle gourd planted shortly before harvesting the first crop.

(d) Vegetables intercropped with other vegetables or vines.

(e) Vine crops are grown simultaneously or in sequence throughout the year.

(f) Crops grown in monoculture and are cultivated the year round, e.g. eggplant, sweet pepper, cassava.

obtained from results of research trials conducted by agronomists on farmers' fields. Some adjustments to this data were made judgementally in developing the activity vectors to reflect farmers' management ability. Thus, the base yields in the model for new rice technology were only 25% higher than the farmers' yields.

(c) Potential new technologies (PNT) refers to technologies which is currently being developed or tested but which has not been made widely available to farmers. Basic information for this kind of technoloies were also derived from research trials conducted by agronomists on farmers' fields. Some adjustments on these data were also made when the activity vectors were developed.

The number of crop production activities under each grouping is shown in Appendix Table A.1. There were fifteen crop activities under ET, 1 under ANT and 2 under PNT. The available new technology was a new upland rice variety and the two potential 'new technologies': (a) cultivation of a single crop of sorghum and (b) sorghum followed by a ratoon crop.

Among the crops considered, rice was mainly used for home consumption, while others were mainly for sale.

The crop year was divided into the first (wet) and second (dry) seasons; crop activities were also specified by seasons.

Three land types were distinguished in the model based on type of ownership. These were fully-owned (FO) land and share tenanted land (ST) with different types of tenancy arrangements. The two sharing arrangements observed in tenanted land were the sharing of output in the ratio of 3:1 and 2:1 between farmer and landlord.

In the case of share tenanted lands, the yields and income used in the model were net of landlord's share and harvester's and thresher's shares.

The land is relatively homogeneous upland and all crops cited earlier can be planted in any of the farmers' fields. Hence, land was not stratified by physical characteristics.

Aside from crop production activities, other activities were included the model. A 'palay' (unmilled rice) consumption activity was included to account for subsistence on the farm. This was specified to be equal to the amount of rice needed by the farmers' household in one year, where a subsistence rice constraint was incorporated in the model. This subsistence requirement for rice was estimated at 2 tons of palay per farm.

Labour and 'carabao' (water buffalo) hiring activities were also included in the model. Hired labour is widely used for many operations including hand weeding, harvesting and post-harvesting operations. Animals are hired mainly for land preparation. Farmers are assumed to face no cash constraints in relation to hiring activities. In this area payments to labourers can be made after the harvesting season (i.e. from crop sales) and cash flow bottlenecks are not very stringent in the case of these farmers who usually obtain crop incomes throughout the year.

The levels of resources assumed for the average farm are shown in Table 4.5. The levels of these resources were parametrically varied to examine the implications of differences in the resource endowments.

The input and output price data were based on 1976-77 crop year average prices (Appendix Tables B.1 and B.2). More recent price data were not available; however, they are known to be somewhat higher than the 1976-77 prices. Prices were also varied parametrically and sensitivity analysis was conducted (see Chapter 6).

TABLE 4.5

RESOURCE CONSTRAINTS FOR THE AVERAGE FARM ASSUMED IN THE MODEL

Resources		Level
Fully-Owned Land (ha.)	1	0.50
	2	0.50
Share Tenanted Land (3:1) (ha.)	1	0.50
	2	0.50
Share Tenanted Land (2:1) (ha.)	1	0.50
	2	0.50
Labour (manhours)	1	2,500
	2	2,500
Power (ahours)	1	1,100
	2	1,100
Palay consumption minimum (t/ha)		2

4.6 EVALUATION OF TECHNOLOGIES

The procedure followed in the evaluation of technologies were similar to the approach of Plain et al. (1981). The different types of technologies defined in Section 4.2.2 were evaluated by progressively including activity vectors based on: (a) existing technology only; (b) existing + available new technology; and (c) existing + available + potential new technology in the models. The potential of the new technology was assessed by the degree of adoption indicated by model results and consequent ability to increase income over that obtained from the existing technology for a given set of resources and similar risk. From each run an 'efficient frontier' (E-A frontier) was constructed which represented the minimum income

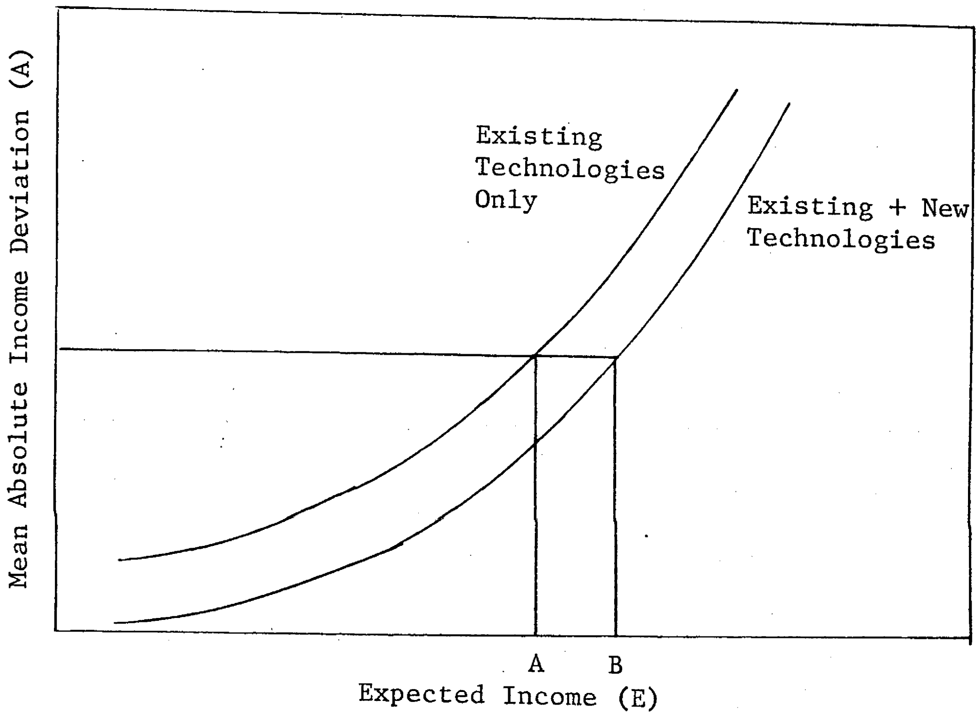

Fig. 4.1: Hypothetical effect of introduction of the new technology on expected income and mean absolute income deviation.

deviation obtained for a range of expected incomes. If addition of the new technology shifts the E-A frontier always to the right of the existing E-A frontier as shown in Figure 4.1, the farm plans with the new technology will always be preferred over those plans with only existing technology, since they enable a higher expected income at a given level of income variability. The magnitude of the potential income increase from the use of the new technology was obtained by comparing the differences between the expected income for the farm plan (distance A to B) at each level of income variability (line C). The greater the distance between A and B, the more the farm plans with new technology will be preferred over those plans with only traditional technology.

CHAPTER 5

EMPIRICAL RESULTS

The results obtained from the model using the average farm data in the last chapter are presented in this chapter. In Section 5.1, the selection of optimum crop combinations in the farmers' existing system are presented and discussed. The results of the introduction of the new technology are presented in Section 5.2. The farm level impact of the introduction of the new rice variety and the two sorghum activities are considered. The level of adoption and its effects on income and risk are discussed. To get some estimate of the cost to the farmers of producing the subsistence crop rather than procuring it in the market, two basic situations are considered with and without the subsistence objective. Further, in each situation two solutions are obtained based on maximum profit with no account taken of risk as well as a series with both income and risk considerations.

5.1 FARMERS' EXISTING TECHNOLOGIES

The profit maximizing plans for the farmers' existing technologies with and without the subsistence constraints are shown in Table 5.1. With the subsistence constraints, 85% of the total area planted in the first season is allocated to rice and only 15% to upland crops. Other crops planted during the second season are garlic intercropped with bitter gourd and a small proportion of a two season crop, eggplant intercropped with hyacinth bean. Both these crops are

TABLE 5.1

OPTIMAL FARM PLAN ESTIMATED FROM THE DETERMINISTIC LP MODEL, EXISTING TECHNOLOGIES

Land Type	Crop Production Activity	With Subsistence Objective	Without Subsistence Objective
		Hectare	
Fully-Owned Land	T. Rice, 1st Crop	0.50	
	Eggplant, 1st crop		0.50
	Garlic + Bitter gourd, 2nd Crop[1]	0.50	0.50
Share Tenanted 1 (3:1)	T. Rice, 1st Crop	0.50	
	Eggplant, 1st Crop		0.50
	Garlic + Bitter Gourd, 2nd Crop	0.50	0.50
Share Tenanted 2 (2:1)	T. Rice, 1st Crop	0.28	
	Eggplant + H. Bean[2]	0.22	0.50
	Garlic + Bitter Gourd, 2nd crop	0.28	
Total Labour Use (manhours)		6,561	6,531
Total Income[3] (₱)		14,883	23,189

(1) Garlic intercropped with bitter gourd.

(2) Eggplant intercropped with hyacinth bean, cultivated during the whole year.

(3) Above cost of hired labour and purchased material inputs.

highly profitable to grow but their material costs and labour requirements are high. The total net income (above cost of hired labour and purchased material inputs) is ₱14,883. When this result is compared with the annual farm plans of one of the farmers who has similar resources, the cropping patterns in the model solution is found to be similar but less diversified. The total net income are also found to be substantially higher than the actual farm income.

In the model which had no consumption constraints, no rice was produced. Instead upland crops are planted in all land in both seasons. The total income is ₱23,189 which is 55% higher than the income obtained in the constrained situation (after valuing the rice used for consumption). This result suggests that upland crops are more profitable to growth than rice and that without the subsistence objective, farmers will not grow rice if their concern is for maximum income, since the additional income would be much higher than the cost of subsistence requirements.

However, these results tend to overestimate the benefits of not planting rice for subsistence as it ignored the fact that often the purchase price of rice is higher than the sale price and that farmers have to incur transport and other costs to purchase rice in the market.

The optimal solution given by the model with the subsistence constraint indicates a slightly higher labour use level than the unconstrained model. In the constrained model, family labour contributed 61% of the total labour used and hired labour 39%. In the unconstrained model, family labour provided 70% and hired labour 30%.

Table 5.2 shows the results of the MOTAD model with and without the subsistence constraint. With the subsistence constraint, all farm

TABLE 5.2

OPTIMAL FARM PLANS ESTIMATED FROM THE MOTAD MODEL, EXISTING TECHNOLOGIES

Farm Plan	Crop Production Activity (Has.)									Total Labour Use (mhrs)	Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice 1st Crop Trad.	Eggplant 1st Crop	Y. Corn HYV 1st Crop	Tomato 2nd Crop	G. Corn 2nd Crop	Y. Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean			
					With Subsistence Objective							
1	1.28			0.43	0.38	0.50			0.18	1,558	3,200	0
2	1.32			0.43	0.39	0.50			0.18	1,597	5,200	43
3	1.36			1.02		0.22	0.12		0.14	3,044	7,200	216
4	1.45			1.13			0.32	0.05		3,905	9,200	716
5	1.36			1.05			0.31	0.14		3,965	11,200	1,434
6	1.31	0.05		0.64			0.70	0.14		5,049	13,200	2,517
7	1.28						1.28	0.22		6,561	14,883	4,196
					Without Subsistence Objective							
1	0.15	0.06	0.96	1.10					0.34	1,793	5,010	0
2	0.54			1.27			0.23			3,202	7,510	194
3	1.38			1.07			0.31	0.12		3,952	10,010	992
4	1.15	0.01		0.89			0.27			4,097	12,510	1,852
5	0.89	0.08		0.73			0.24			4,254	15,010	2,774
6	0.52	0.15		0.50			0.17			4,475	17,510	3,714
7	0.19	0.22		0.28			0.13			4,676	20,010	4,697
8		0.30					0.30			5,274	22,510	6,087
9		1.50					1.50			6,531	23,189	7,155

plans (naturally) included rice. In all farm plans more than 80% of the total area planted during the first season (or 40% of the total area planted during the two seasons) are allocated to rice. In general, the cropping systems are more diversified at the lower income plans than at the higher income plans. This result indicates that farmers who are strongly risk averse tend to diversify their cropping systems. Comparing these farm plans with the actual farm plan operated by a farmer with similar resources, it is found that the farmers' plans are quite similar to those in the model with the subsistence constraints. These results indicate that the optimal solutions given by an LP model which does not incorporate risk generates farm plans which are considerably different to farmers' actual plans and which give higher incomes but also higher risk.

In the models without the consumption constraint, most of the farm plans include rice, except those with high expected incomes. Those farm plans which include rice have lower incomes and lower risk. This suggests that if farmers are risk averse, they will tend to allocate some portion of the area to rice even if they have no subsistence orientation as such and choose a mix of crops such that a lower than maximum feasible mean income will result. Comparing the cropping systems with those obtained in the constrained situation, corn which is a traditional second crop is not included in any solution. Intercropping of vegetables is indicated only at intermediate income-risk plans. There is a shift to monoculture cropping at the higher income-high risk plans in the unconstrained situation.

Figure 5.1 shows the estimated E-A frontier of farm plans generated in the MOTAD model with and without the subsistence

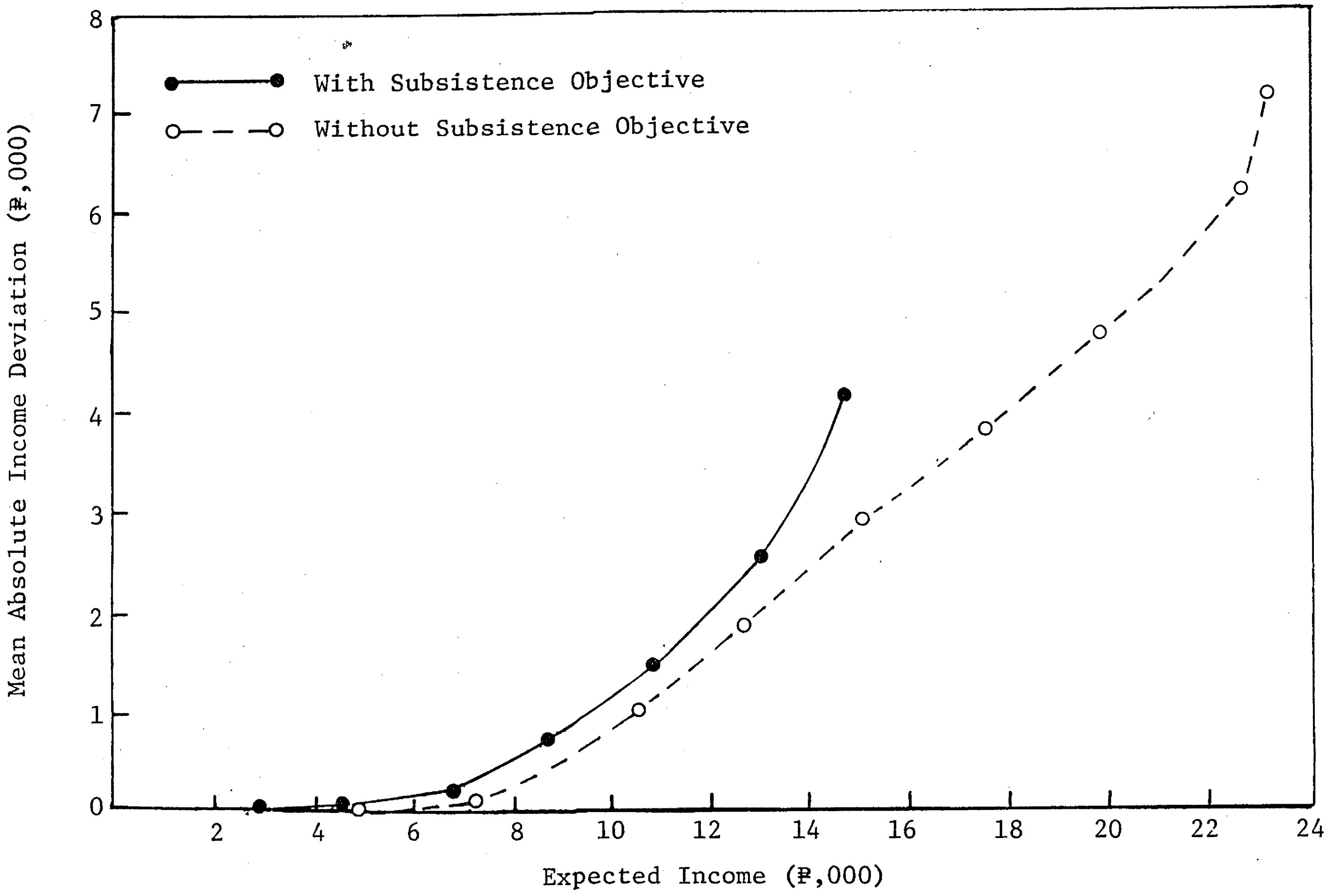

Fig. 5.1: Estimated E-A frontier with only existing technologies.

constraint. With the subsistence constraint, the additional expected income tends to be very low after farm plan 4 and thus only farmers with very low risk aversion will tend to operate beyond this. The figure also shows that relaxing the consumption constraint will not have a significant impact on expected income in lower crop combinations. This is due to the reason cited earlier; even without the consumption constraint substantial rice are grown at lower income-deviation plans. After farm plan 7, the expected income tends to be very small from a more risky crop combination and hence only very moderately risk averse to risk neutral farmers will operate beyond this point on the frontier. In both situations, the final farm plan corresponds to the linear programming (deterministic) solution, where a risk neutral farmer will operate.

The amount of labour used in the constrained situation is much higher than the amount used in the unconstrained situation at the same level of income.

5.2 IMPACT OF THE INTRODUCTION OF NEW TECHNOLOGIES

As discussed earlier, two basic new technoloies were developed and evaluated using the programming models.

5.2.1 Existing + Available New Technology

One new technology already available and tested in the village is an upland rice variety C171-136. This variety has many features similar to that of the traditional rice variety (Dagge), but average yields are somewhat higher. In the basic model, the yield of the new variety is assumed to be only 25% higher than the traditional variety to allow for lower yields under farmers' management. In the researcher managed trials conducted on the farmers' yields, it actually yielded an average of 1.5 t/ha more than the traditional variety (i.e. nearly 80% higher yields) when planted as a sole crop (Liboon et al., 1978). To determine the effect of progressively higher yields, yield is parametrized in the model.

The profit maximizing plans from the LP deterministic model with and without the subsistence constraint are shown in Table 5.3. With the subsistence constraint, rice naturally appeared in all farm plans. With a 25% higher yield assumed for the new variety, the area planted to rice is actually smaller than with the traditional variety, only 65% of the total area planted during the first season. The area allocated to upland crops increased, which resulted in an increase in income by 16% over that with the existing technologies. The level of other crops planted is very similar to that obtained with the existing technologies, the only change being in share tenanted land 2 where the whole area is planted to eggplant with hyacinth bean. Further, when the new rice variety is planted labour use declined by 10%. This is due to lower labour requirements for hand weeding, harvest and post-harvest operations. The new rice variety produces more tillers, reducing weed growth and thus lower weeding labour requirements. Harvesting operations also required less labour as it does not lodge, matures evenly, and hence permits harvesting with a sickle. Dagge harvesting is done by removing individual panicles and cutting the entire plant; because it matures unevenly, the fields need to be harvested two or three times resulting in higher labour use (Liboon et al., 1978).

However, without the subsistence constraint, rice did not appear in the plan. Thus, the new rice variety still remained less

TABLE 5.3

OPTIMAL FARM PLAN ESTIMATED FROM THE DETERMINISTIC LP MODEL, EXISTING + AVAILABLE NEW TECHNOLOGIES

Land Type		Crop Production Activity	With Subsistence Objective	Without Subsistence Objective
			Hectare	
Fully-Owned Land		N.T. Rice, 1st Crop	0.48	
		Eggplant, 1st Crop	0.02	0.50
		Garlic + Bitter Gourd, 2nd Crop[1]	0.50	0.50
Share Tenanted (3:1)	1	N.T. Rice, 1st Crop	0.50	
		Eggplant, 1st crop		0.50
		Garlic + Bitter Gourd, 2nd crop	0.50	0.50
Share Tenanted (2:1)	2	Eggplant + Hyacinth Bean[2]	0.50	0.50
Total Labour Use (manhours)			5,919	6,531
Total Income[3] (₱)			17,280	23,189

(1) Garlic intercropped with bitter gourd.

(2) Eggplant intercropped with hyacinth bean, cultivated the whole year round.

(3) Above cost of purchased labour and material inputs.

profitable than any other upland crops at the assumed yield of 25% over the traditional variety (2.35 t/ha) and price of ₱1.05 per kg. The farm plan was identical to the profit maximizing plan with only existing technologies (Table 5.1).

Table 5.4 shows the series of farm plans estimated from the risk model with and without the subsistence constraint. With the subsistence constraints, the new rice variety always replaced the traditional variety as the dominant crop in the first season. The rice area in most farm plans was lower than that with the traditional variety, as subsistence requirements could be met with a lower rice area. Because of this, the area planted to upland crops increased.

Without the subsistence constraint, the new rice variety appeared in lower income plans. Comparing the area planted with the new rice variety to that planted with the traditional variety (at the same level of income) a larger area is planted to the new variety. This resulted in a much lower income deviation at all levels of income.

On the other hand, the farm plans at the low income levels were similar in models with and without the subsistence constraint. Thus, the introduction of a new rice technology would have a similar effect on farmers irrespective of whether they are subsistence oriented or not as long as they are strongly risk averse (Figure 5.2). But as the degree of risk aversion decreases, the farmers with no subsistence objective will decrease rice cultivation and increase upland crop cultivation. Although upland crops are risky to produce, the additional expected income would also be higher.

In all cases, farmers who are less subsistence oriented will obtain higher cash incomes. However, the added benefits of the introduction of the new rice variety would tend to be higher for

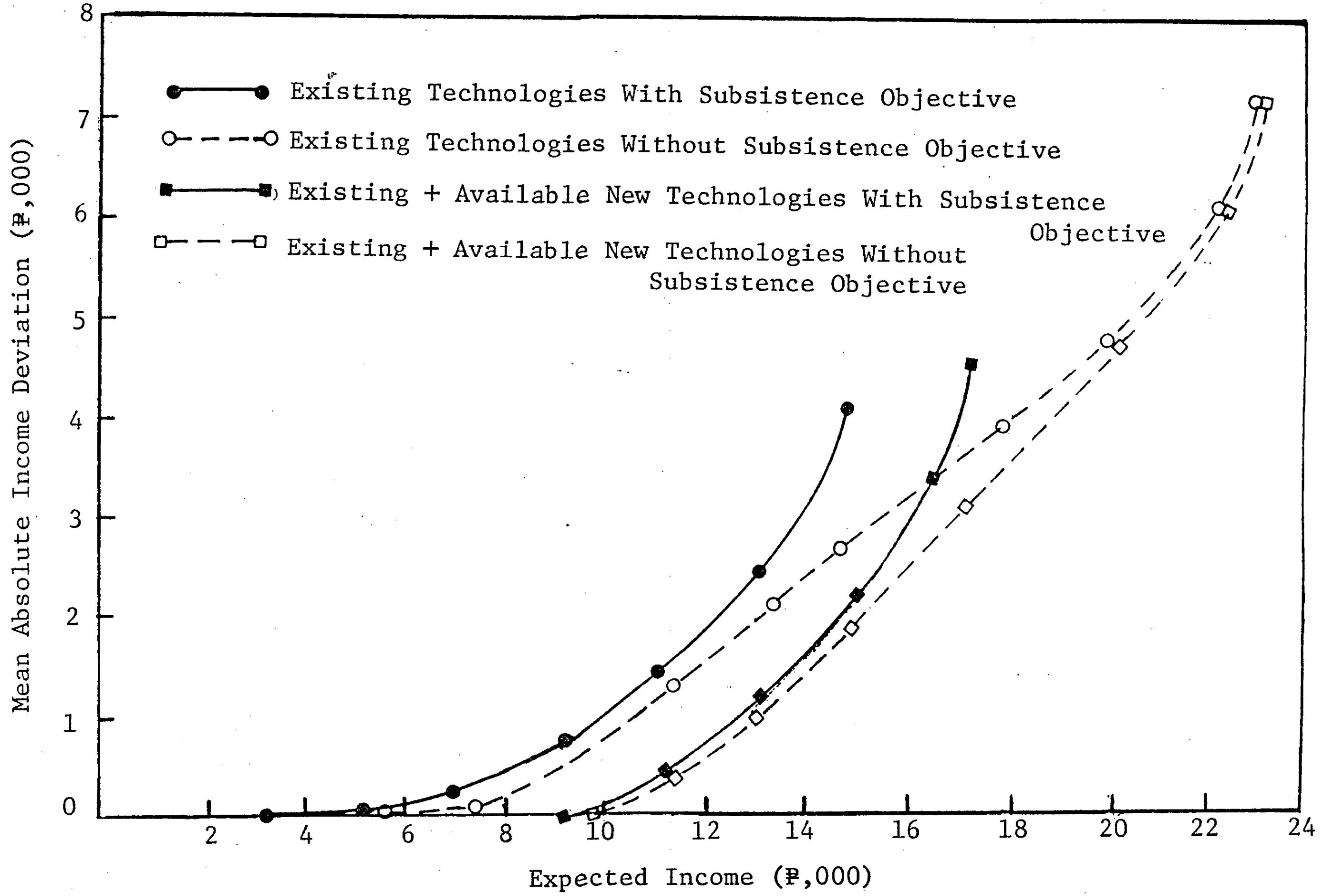

Fig. 5.2: Estimated E-A frontier with introduction of new technology, existing + available new technologies.

farmers who are subsistence oriented. While others will also benefit, the magnitude of the change in income will be lower and is very small at farm plans with higher levels of income.

Again, in both situations, at the same levels of income labour use was lower when the new rice variety was planted. This relative reduction in labour use is greater with the subsistence constraint, as a larger area was allocated to the new variety in this situation.

5.2.2 Existing + Available + Potential New Technology

Sorghum is the potential new technology evaluated in this study. Agronomists in the research team felt that it may have considerable potential in the village, hence agronomic evaluation of its potential is important. Two technology vectors were specified; sorghum as a single crop and sorghum followed by a ratoon crop. Both can be an alternative crop to dry season corn. It fetches a similar price but gives higher yields and is more resistant to drought. It should be noted, however, that adequate market channels between farmers and feed millers/buyers are assumed, as well as a relatively favourable price.

As in previous models, situations with and without the subsistence constraint were studied. The result of the LP deterministic model were identical to the one obtained with only existing + available new technology (Table 5.4). This means that the introduction of sorghum either as a single crop or sorghum followed by a ratoon, will not have any effect on income, because farmers who are only profit maximizers will not adopt it at the basic yield of 2.5 t/ha and 3.75 t/ha respectively and price of ₱1.05 per kg. However, yield and price are varied parametrically, and the results are presented in Chapter 6.

TABLE 5.4

OPTIMAL FARM PLANS ESTIMATED FROM THE MOTAD MODEL, EXISTING + AVAILABLE NEW TECHNOLOGIES

Farm Plan	Crop Production Activity (Has.)							Total Labour Use (mhrs)	Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice 1st Crop N.T.	Eggplant 1st Crop	Y. Corn HYV 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Corn + H. Bean	Eggplant + H. Bean			
				With Subsistence Objective						
1	1.00	0.09		1.06		0.25	0.15	2,701	9,200	0
2	1.41	0.09		1.17	0.33			3,549	11,200	272
3	1.24	0.12		1.05	0.31		0.14	3,967	13,200	1,192
4	1.05	0.16		0.71	0.50		0.29	4,434	15,200	2,240
5	1.08	0.23		0.03	1.30		0.18	5,373	17,200	3,535
6	0.98	0.02			1.00		0.50	5,919	17,280	4,668
				Without Subsistence Objective						
1	1.15	0.06	0.26	1.14	0.33		0.03	3,509	10,010	0
2	1.31	0.11		1.10	0.32		0.08	3,632	12,510	868
3	1.01	0.14		0.88	0.27		0.35	3,900	15,010	2,058
4	0.62	0.16		0.58	0.20		0.72	4,252	17,510	3,271
5	0.20	0.24		0.30	0.14		1.06	4,614	20,010	4,528
6		0.30			0.30		1.20	5,274	22,510	5,087
7		1.50					1.50	6,531	23,189	7,155

Table 5.5 shows the farm plans generated in the MOTAD model with and without the subsistence constraint. As above, in the constrained situation the new rice variety appeared in all farm plans, but at a smaller area than when the traditional variety was planted. It should be noted, however, that there was an income increase from farm plan 1 to farm plan 2 with very little increase in income deviation. Farm plan 1 underutilizes some of the farmers' resources, and generates a low income with 0 level deviation. In farm plan 2 which has a minimal increased deviation however, the whole area is planted in both seasons, and a larger area is planted to the new crops.

Table 5.5 shows that the addition of sorghum, then followed by a ratoon enables farmers to reduce income deviations, especially in the lower income plans. This means that risk averse farmers will tend to plant sorghum to minimize risk. In the case of the moderately risk averse to risk neutral farmers, the introduction of sorghum will not have any impact on income and risk, as observed on farm plans 5 and 6. These plans are the same as those obtained when only new rice technology is introduced (see Table 5.4).

However, at the above assumed yield of 3.75 t/ha (sorghum followed by a ratoon crop), the traditional second crops such as tomato, green corn and yellow corn were all replaced by sorghum in the low income plans. Again, the results indicate that sorghum, like the new rice variety, is most likely to be adopted by risk averse farmers.

When no subsistence objective is specified in the model, the results are quite similar. The new rice variety and sorghum are only planted in the lower income-lower deviation plans, suggesting that as the degree of risk aversion decreases, adoption of these crops will decrease. The removal of the subsistence constraint does not

TABLE 5.5

OPTIMAL FARM PLANS ESTIMATED FROM THE MOTAD MODEL, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES

Farm Plan	Crop Production Activity (Has.)									Total Labour Use (mhrs)	Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Y. Corn HYV 1st Crop	Garlic + B. Gourd 2nd crop	Tomato 2nd Crop	Sorghum + ratoon 2nd Crop	Eggplant + H. Bean	Corn + H. Bean			
					With Consumption Objective							
1	0.18	0.68	0.06		0.17		0.58	0.09	0.22	2,332	9,200	0
2		1.07	0.05	0.32	0.48		0.96	0.06		3,546	11,200	1
3		1.37	0.11		0.49		0.99	0.02		3,573	13,200	511
4		1.07	0.13		0.44		0.76	0.30		3,963	15,200	1,648
5		1.09	0.23		1.30		0.02	0.18		6,352	17,200	3,516
6		0.98	0.02		1.00			0.50		5,919	17,280	4,668
					Without Consumption Objective							
1		1.15	0.06		0.33	0.14	1.01	0.03		3,509	10,010	0
2		1.40	0.10		0.49		0.80			3,549	12,510	170
3		1.08	0.13		0.41		0.53	0.29		3,839	15,010	1,512
4		0.67	0.15		0.29		0.28	0.68		4,207	17,510	2,895
5		0.23	0.23		0.18			1.04		4,584	20,010	4,313
6			0.30		0.30			1.20		5,274	22,510	6,087
7			1.50		1.50					6,531	23,189	7,155

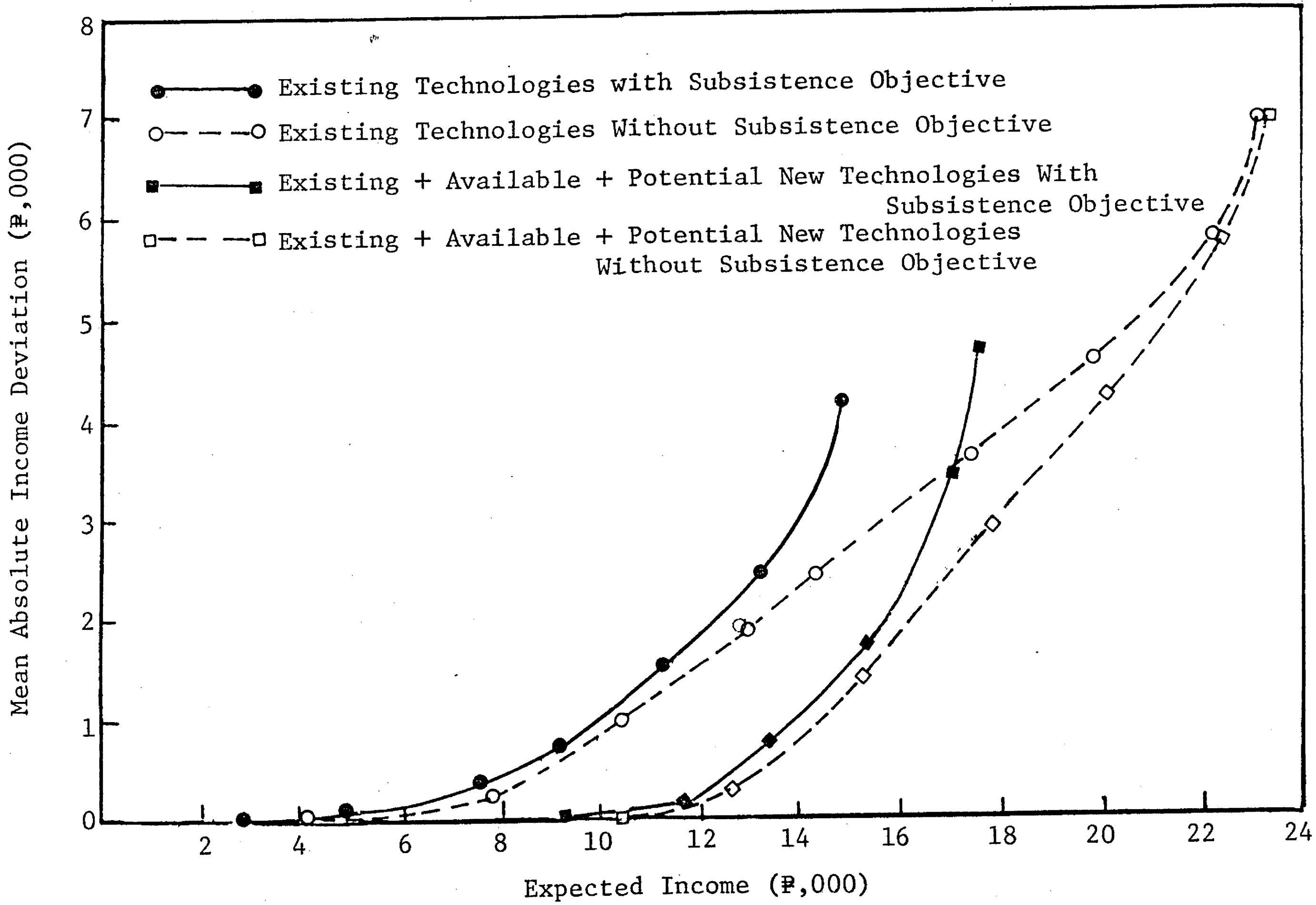

Fig. 5.3: Estimated E-A frontier with introduction of new technology, existing + available + potential new technologies.

significantly increase expected incomes in the low risk plans. Figure 5.3 shows the overall impact of both crops graphically. The introduction of new crops significantly increases the expected income at the same level of risk obtained in the farmers' existing system when a subsistence constraint is specified. Also, the maximum attainable income is higher with new crops.

With no subsistence constraint, the additional income obtainable at a given level of risk tends to decrease, as the expected income of the farm plans goes up.

In all cases, farmers with no subsistence constraint can obtain higher cash incomes. However, the additional benefits from new technologies are generally greater for the more subsistence oriented farmers, though their total income at a specified level of risk is lower.

Actual observations of farmers in the village shows that most farmers grow substantial areas of rice, and hence can be thought of as more subsistence oriented (and/or strongly risk averse). As many recent studies of farmers' risk attitudes appear to show that farmers are generally only moderately risk averse (Binswanger, 1980; Sillers, 1980), those models with a subsistence constraint appears to simulate actual farm decisions better. Hence, the introduction of new technologies is likely to have a significant impact on income and is likely to be adopted at the price, yield and variability levels specified in the model.

CHAPTER 6

EFFECTS OF CHANGES IN RESOURCE ENDOWMENTS, PRICE AND YIELD LEVELS ON THE CHOICE OF TECHNOLOGIES, FARM INCOME, AND RISK

This chapter comprises three main sections. In the first two sections (6.1 and 6.2) the results obtained by parametric variation of the basic farm resources of land and labour are discussed. The level of these resources are varied to examine the implication of differences in resource endowments. The prices and yields of the new rice variety and sorghum are parameterized in Section 6.3. This is done to determine how adoption patterns are influenced by performance of new technology and by output price changes. Since the previous analysis suggests that the models with a subsistence constraint simulated actual farmers' decisons better, only those models are discussed here.

6.1 LABOUR SUPPLY

The effects of an increase in the amount of household labour supply on choice of technology and land allocation are analyzed by increasing the current level of available labour by 50% and 100%.

In the model with only existing technologies there is not much change in area planted to traditional rice with increases in labour at lower income plans. Appendix Table C.1 shows the area planted to various crops in each farm plan generated in the model. As indicated in the E-A frontier (Figure 6.1) in the low income plans the income

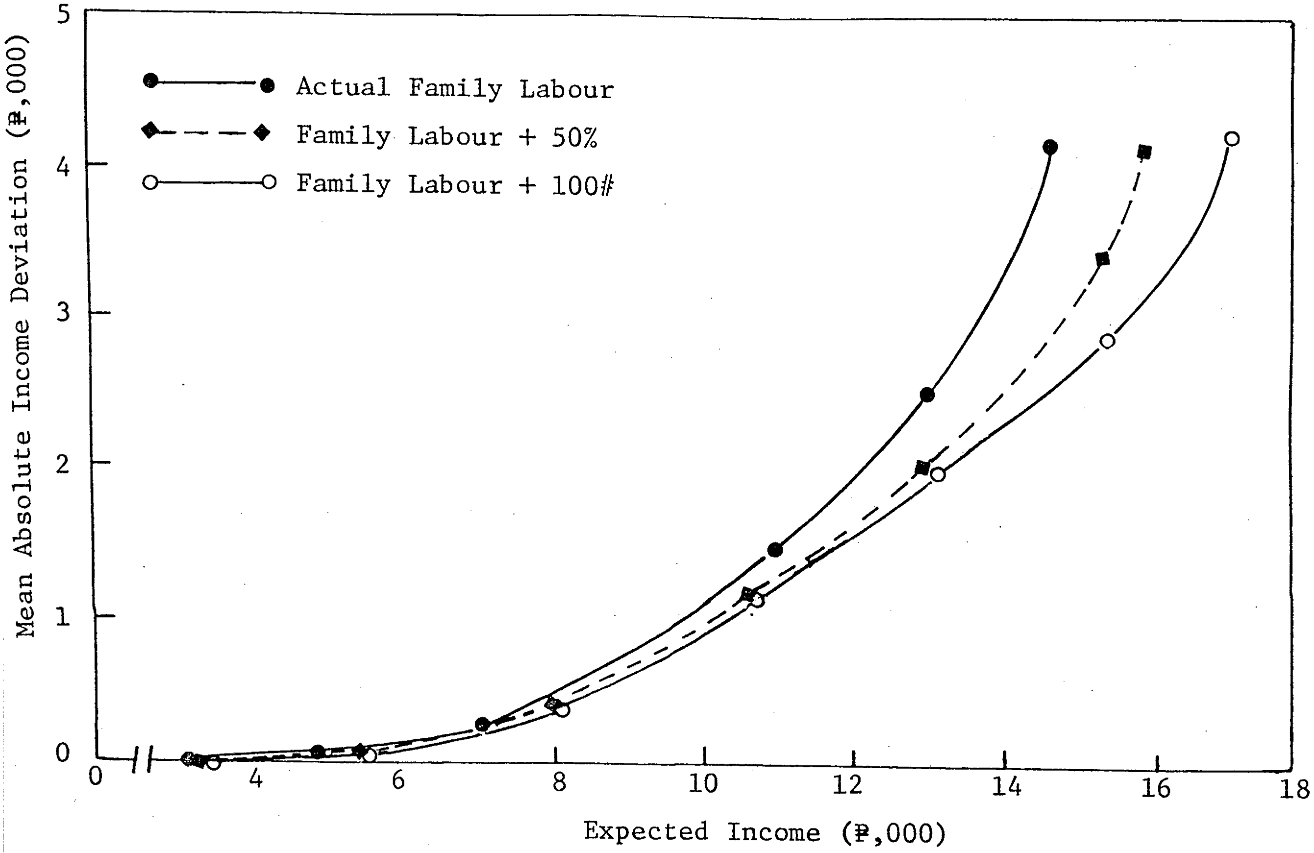

Fig. 6.1: Effects of increases in family labour on expected income and mean absolute income deviation, existing technologies, with subsistence objective

gains are marginal; somewhat larger increases are observed at higher income-deviation plans where the moderately risk averse to risk neutral farmers are likely to operate.

The effects of increased household labour supply in adoption patterns of the new technology (NT) are shown in Figures 6.2 and 6.3. Increase in farm incomes and changes in resource allocative decisions was marginal in both models at the lower income plans. At the higher income plans, the area planted to non-upland crops (i.e. rice and rice + sorghum) tends to decrease, suggesting that farmers shifted to the more labour intensive upland crops. The area allocated to various crops in each plan are given in Appendix Tables C.2 and C.3. Furthermore, the additions to farm incomes are higher in the higher income plans, where the less risk averse farmers are likely to operate. As expected, additional increases in labour availability results in progressively lower additions to total farm income.

6.2 LAND SUPPLY

In this section, the results of increasing the amount of land available by 50% and 100% are presented.

In the first instance, only the fully-owned land is increased by 50% and 100%. Figure 6.4 shows the results from the model with only existing technology. The area allocated to traditional rice fluctuates in the low income plan but decreases steadily in the high income plans. Also, the attainable income substantially increases and the E-A frontier shifts to the right significantly, with larger increases in the upper region. In addition, as the E-A frontier shifts to the right, the same farm tends to choose a high income-high risk plan and the less risk averse farmers operate at a high

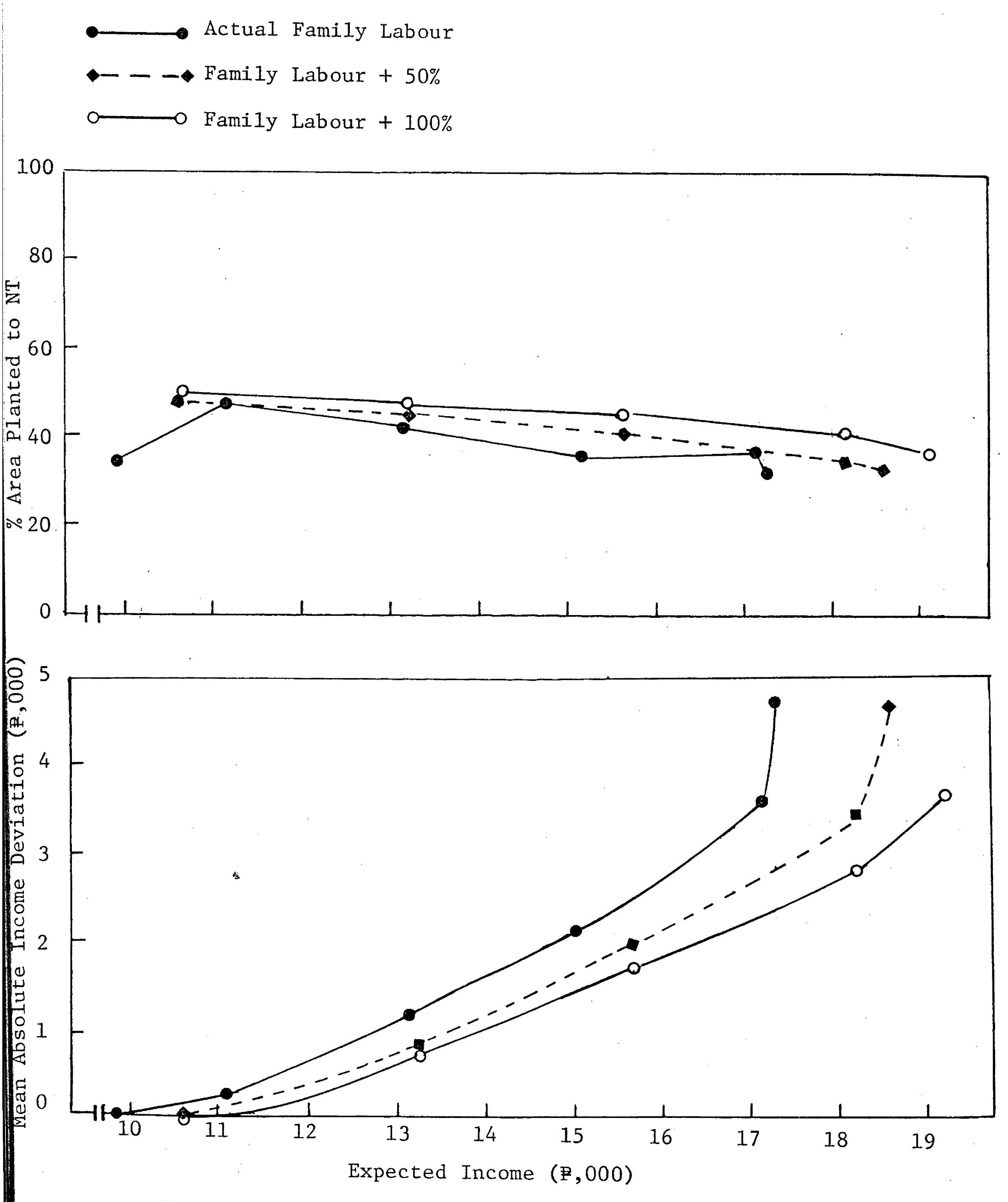

Fig. 6.2: Effects of increases in family labour on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available new technologies, with subsistence objective.

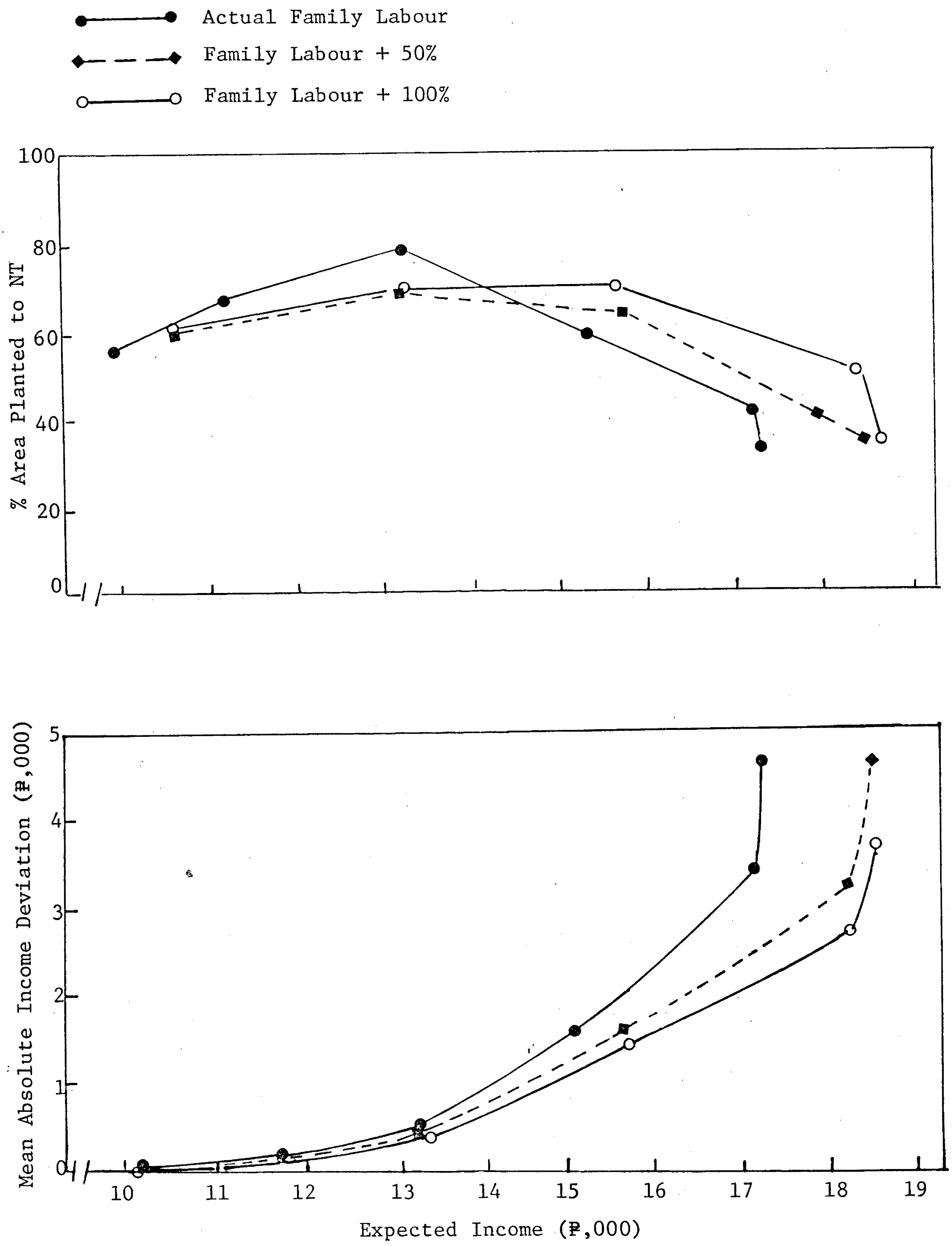

Fig. 6.3: Effects of increases in family labour on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

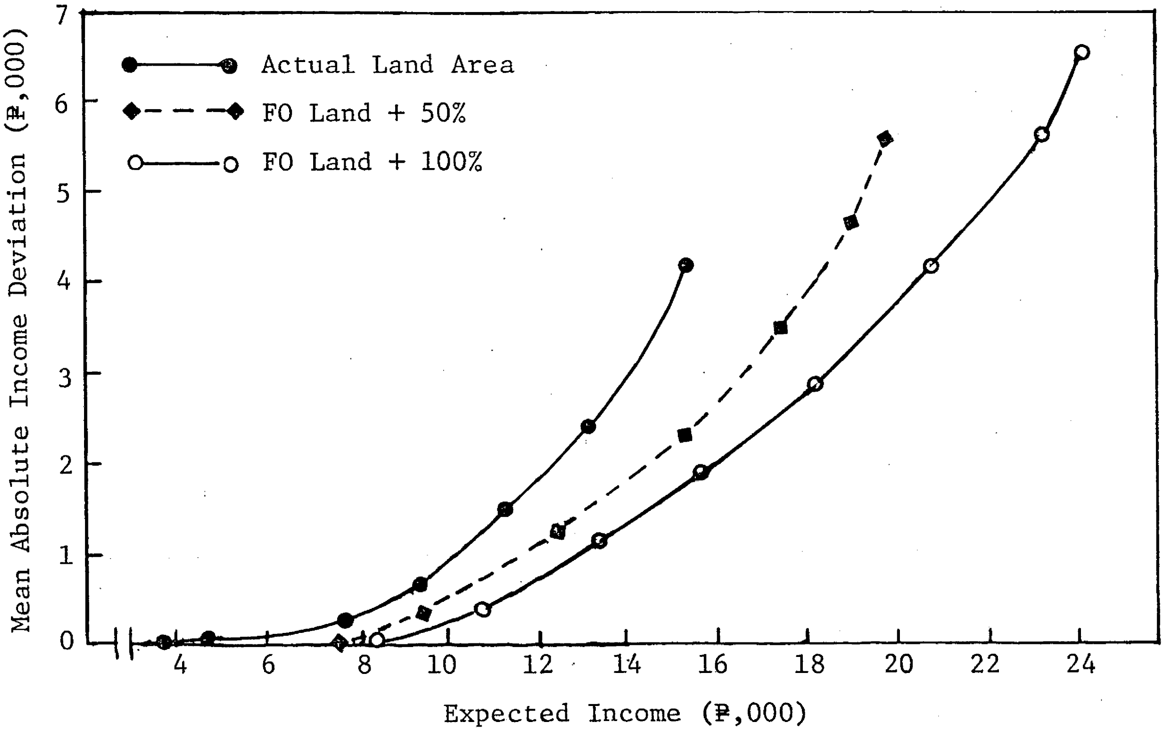

Fig. 6.4: Effects of increases in area of fully owned land on expected income and mean absolute income deviation, existing technologies, with subsistence objective.

income-high risk plan.

The results of increasing the fully-owned land in the models with only the new rice variety and new rice variety + sorghum are shown in Figures 6.5 and 6.6. With only the new rice variety available, in most plans the percentage planted area increases slightly when the area is increased by 50%. However, when the area is further increased by 100%, the percentage area planted declines, suggesting that farmers shifted to cultivation of high valued non-rice crops.

On the other hand, in the models incorporating both the new rice variety and sorghum, the area planted to these crops increases initially, followed by a gradual decline as income goes up. Thus, we may expect that while the more risk averse larger farmers may increase area under these crops, the less risk averse are likely not to increase the area under those crops.

Compared to increases in labour supply the income effects of larger fully-owned land are considerable.

The results from increasing only the share tenanted land (3:1) are presented at Figures 6.7, 6.8 and 6.9. In the case of the existing technology only, the area allocated to rice shows a similar pattern in all cases, increases followed by decreases.

In the models with new technology, increases in share tenanted land have a smaller effect on incomes at the same risk level compared to increases in fully-owned land. There is not much difference in the levels of the adoption of the new technologies in the two cases.

Essentially, the same conclusion can be derived from examination of the results of simultaneously increasing all land (see Appendix A.1, B.1 and C.1 for relevant figures).

Details of crop combinations in each farm plan generated in the

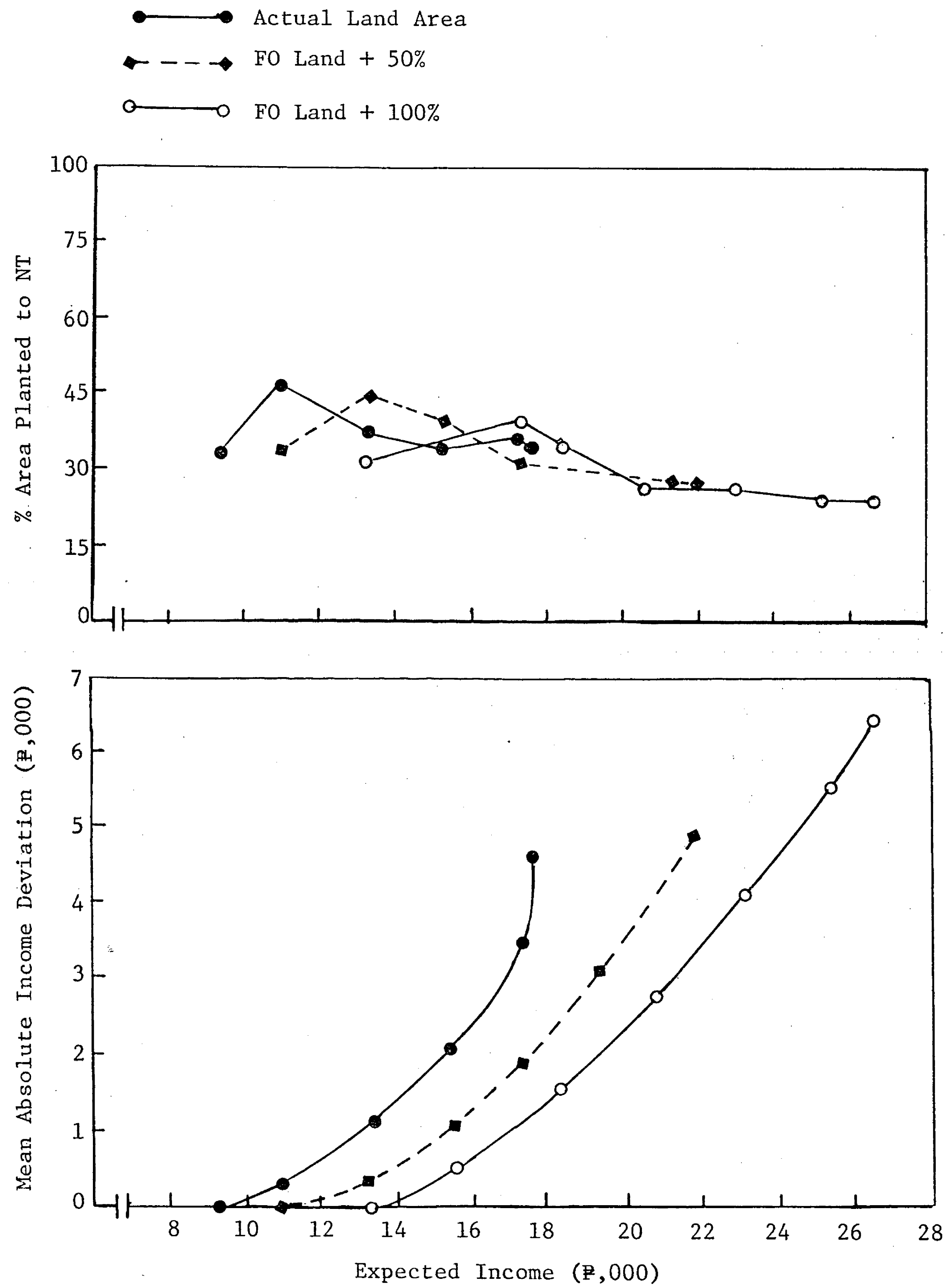

Fig. 6.5: Effects of increases in area of fully owned land on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available new technologies, with subsistence objective.

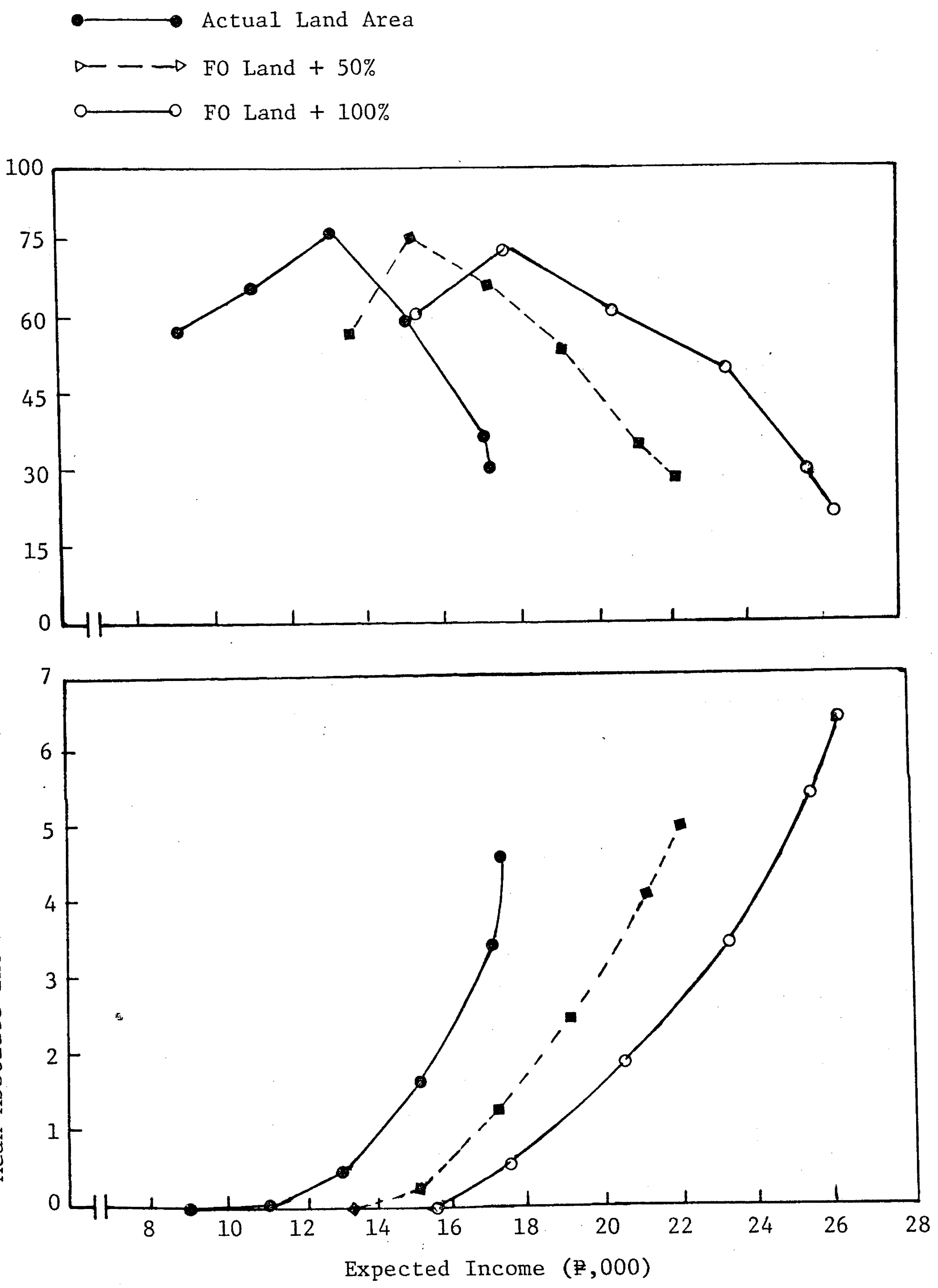

Fig. 6.6: Effects of increases in area of fully owned land on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

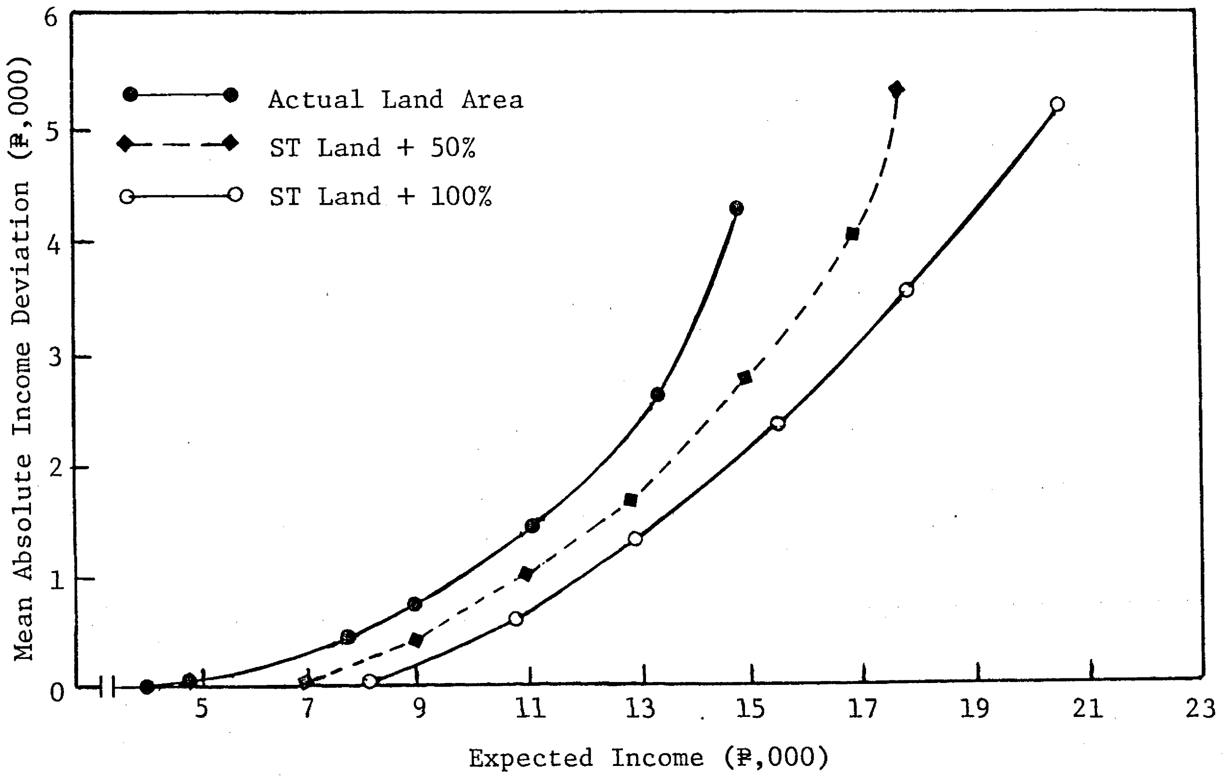

Fig. 6.7: Effects of increases in area of share tenanted land (3:1) on expected income and mean absolute income deviation, existing technologies, with subsistence objective.

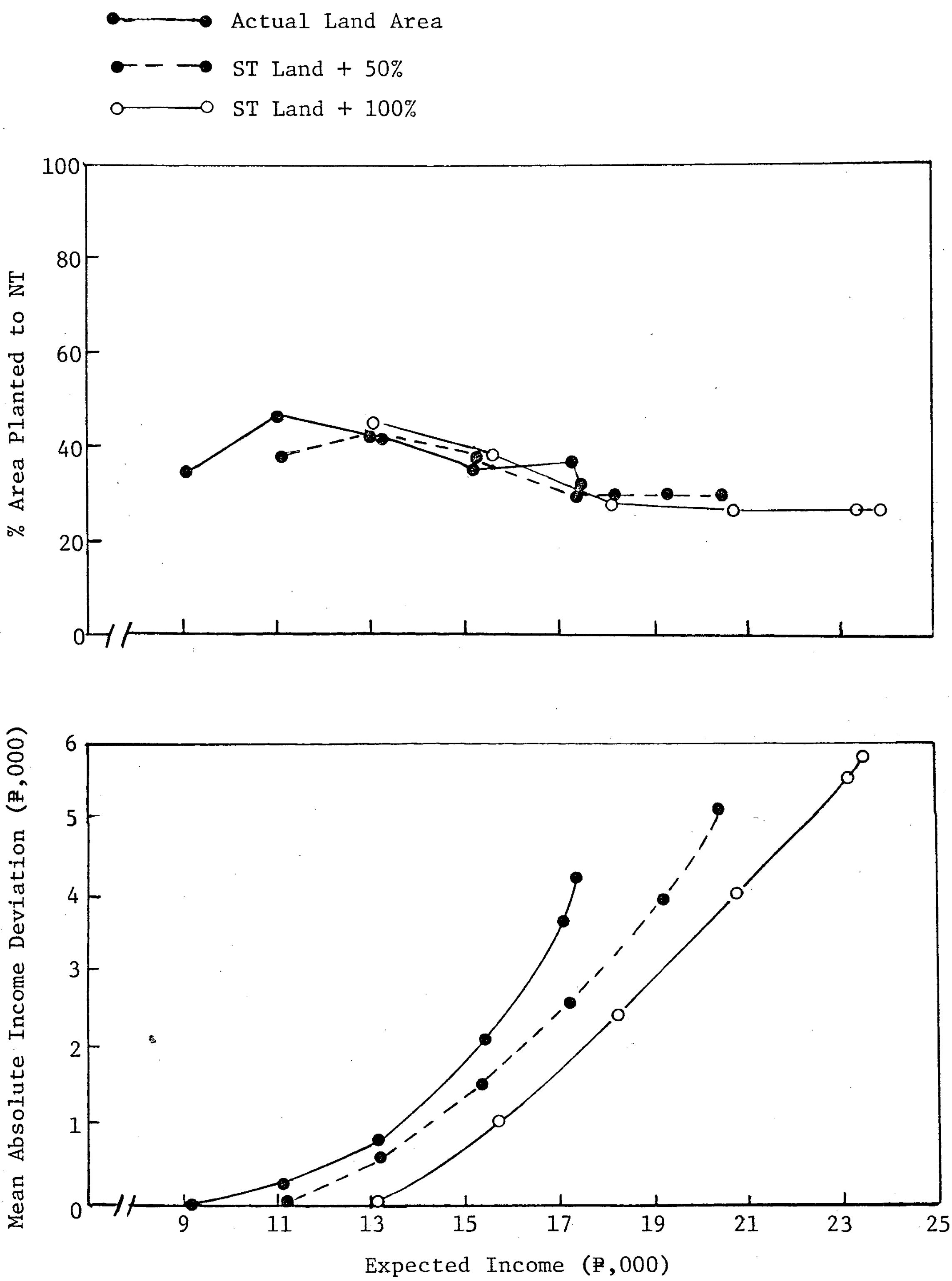

Fig. 6.8: Effects of increases in area of share tenanted land (3:1) on percentage of total area planted to NT, expected income, and mean absolute income deviation, existing + available new technologies, with subsistence objective.

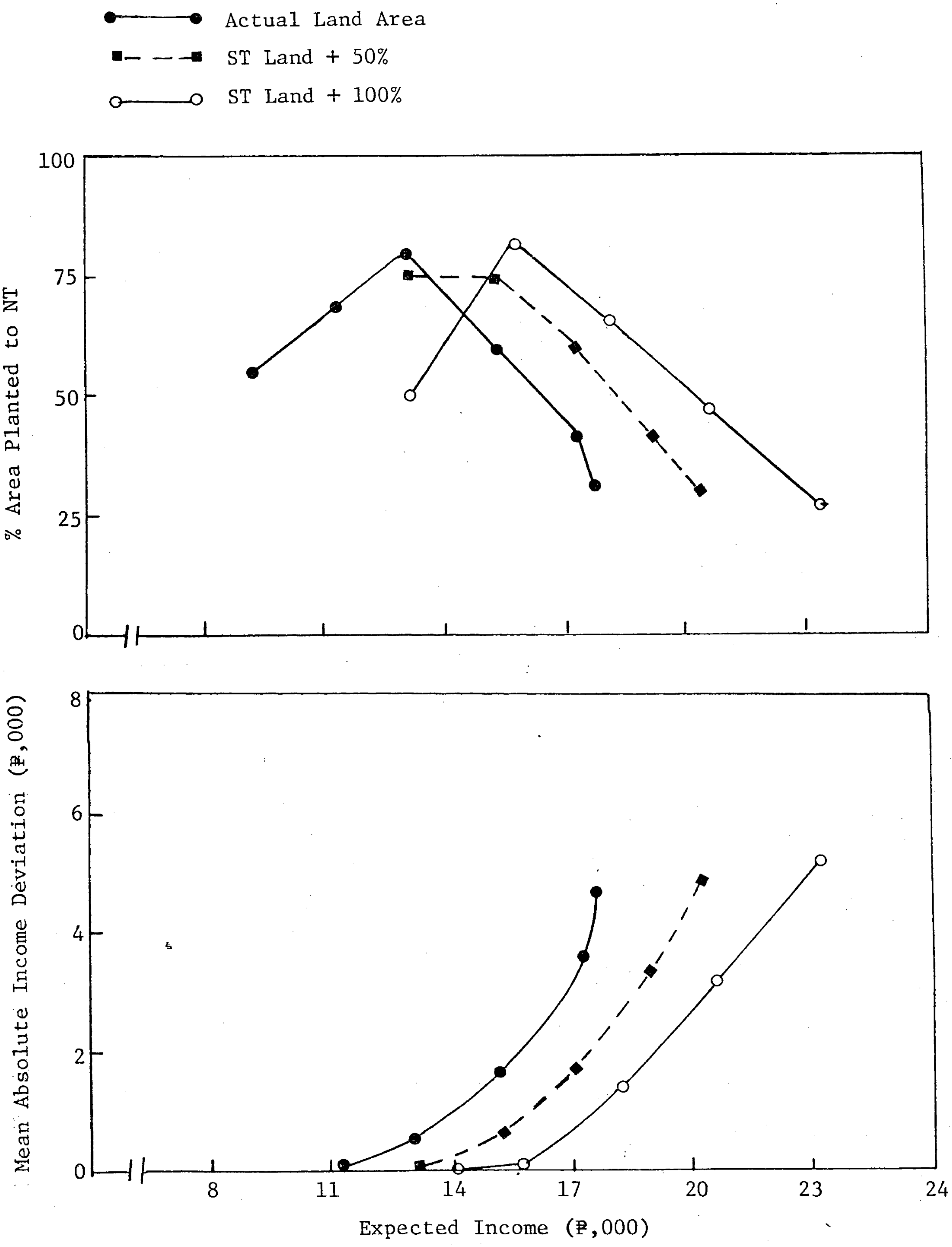

Fig. 6.9: Effects of increases in share tenanted land (3:1) on percentage of total land area, expected income and mean absolute income deviation, existing + available + potential new technology, with subsistence objective

model with increases in land supply are presented in Appendix Tables D.1, D.2, D.3, E.1, E.2, E.3, F.1, F.2 and F.3.

6.3 CHANGES IN PRICE AND YIELDS OF NEW RICE VARIETY AND SORGHUM

A number of studies with similar models have assumed that price and yield increases have identical effects (Schluter and Mount, 1974; Plain et al., 1981). However, changes in price do not necessarily have an identical effect to a similar change in yield since the latter also changes the harvesting and post-harvest labour requirements. Hence, yield variations are explored separately in the model. The prices and yields of rice and sorghum are reduced by 50% and increased by 50% and 100% from their base levels in the models.

6.3.1 Changes in Price

The price of the new rice variety are changed in the two models (existing + available new technologies, and existing + available + potential new technologies). The results from both models are similar (Figures 6.10 and 6.11). With a decrease in price, the E-A frontier shifts to the left of the original price frontier, and increases in price shifts the frontier to the right. The area planted to rice increases with increase in price in most of the low to intermediate income plans. In the high income plans, however, the area planted to rice does not change with changes in the price in this range. Although the area allocated to rice does not change, a substantial increase in income is observed.

On the other hand, when price is reduced by 50%, the area allocated to rice is decreased in the lower income plans. As a minimum area has to be planted to meet subsistence rice requirements,

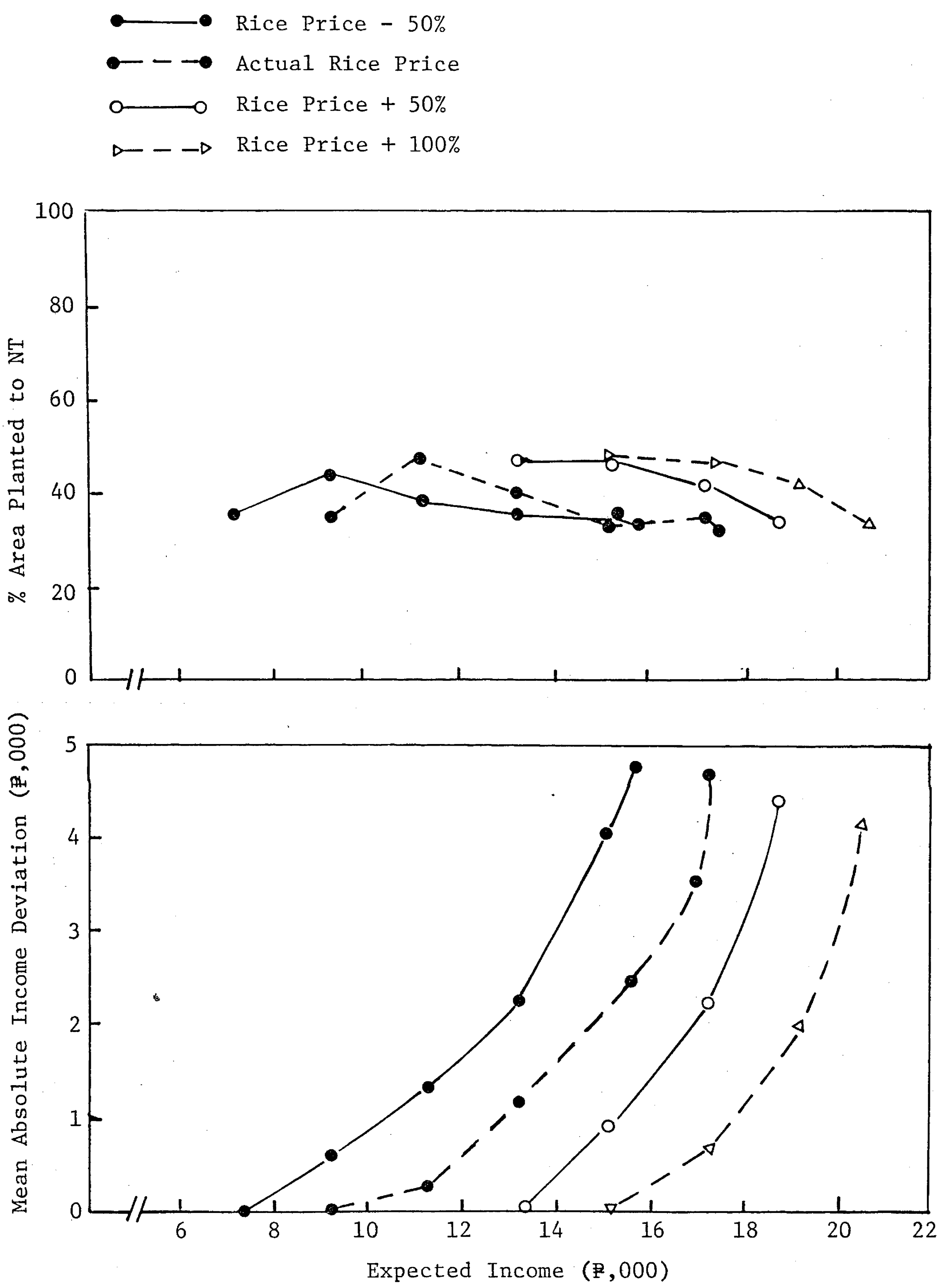

Fig. 6.10: Effects of changes in price of rice on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + avilable new technologies, with subsistence objective.

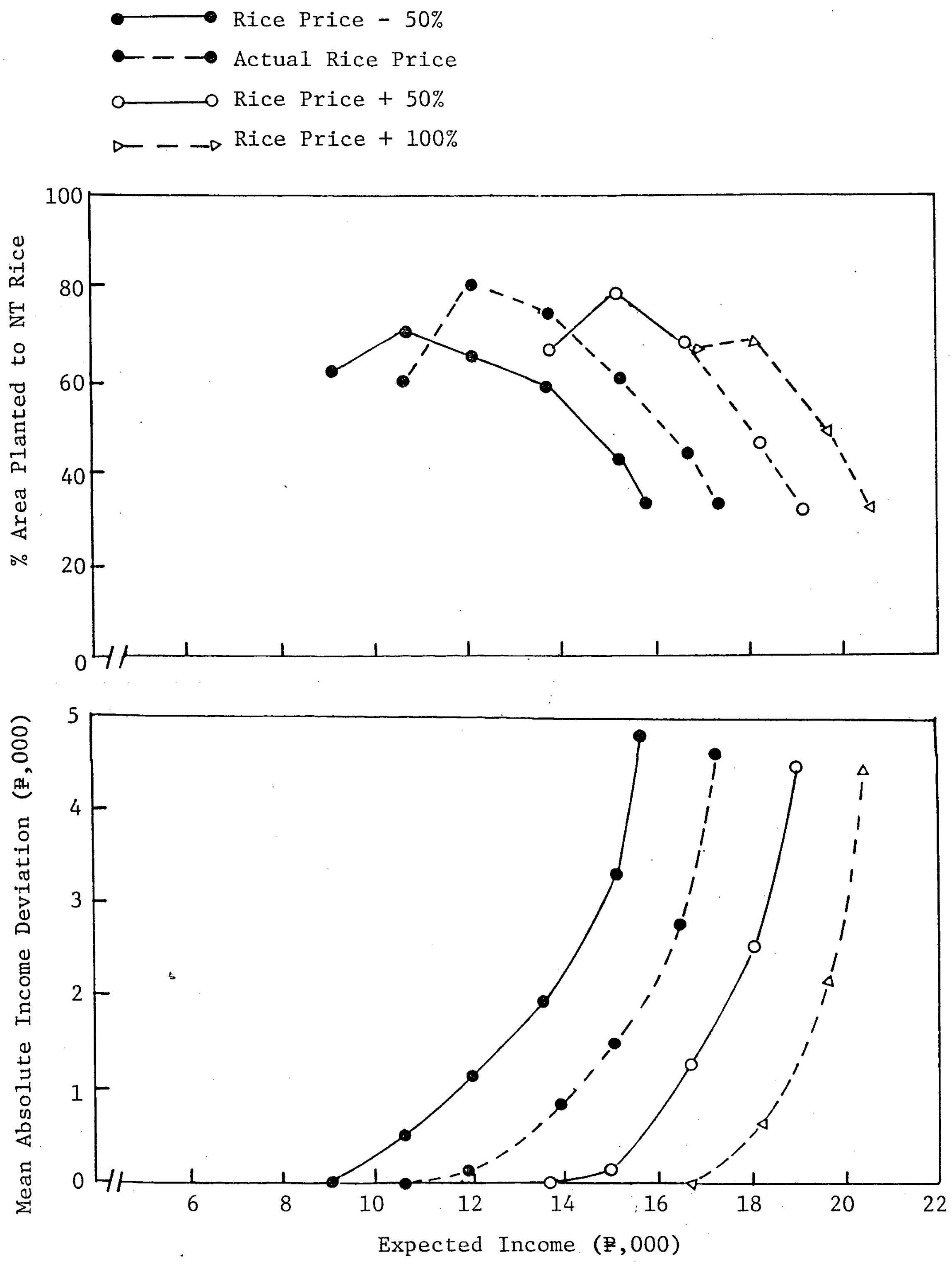

Fig. 6.11: Effects of changes in price of rice on percentage of area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

the price response is interesting. It shows that in the low income plans some rice is planted as a low risk crop, over and above the subsistence needs. This area is reduced as prices decline.

The price of sorghum is also changed in the second model (existing + available + potential new technology). Figure 6.12 shows the E-A frontiers and changes in land allocation pattern. As expected, a decrease/increase in price will shift the E-A frontier to the left/right of the original price frontier. There is a substantial decrease in area planted to sorghum with a 50% decrease in price. Increasing the price by 50% increases area planted to sorghum + ratoon in the lower to intermediate income plans; no sorghum was planted in the high income plans. However, when price is increased by 100%, some sorghum was planted even in the highest income plans indicating that at such prices it can compete with other high valued upland crops.

Simultaneous decreases/increases in price of both crops substantially decrease/increase the expected income at the same level of risk obtained at the original price level (Figure 6.13). Generally, more risk averse farmers who allocate more land to these crops gain most.

6.3.2 Changes in Yield

Results obtained in parameterizing yield in all runs are very similar to those obtianed in changing the price (Figures 6.14, 6.15, 6.16 and 6.17). As yields of the new rice variety decrease, farmers shift to traditional varieties. Comparing the effects of a change in yield with a similar change in price, the income effects are found not to be very different. This absence of difference is due to the fact that in the case of rice the associated changes in labour in

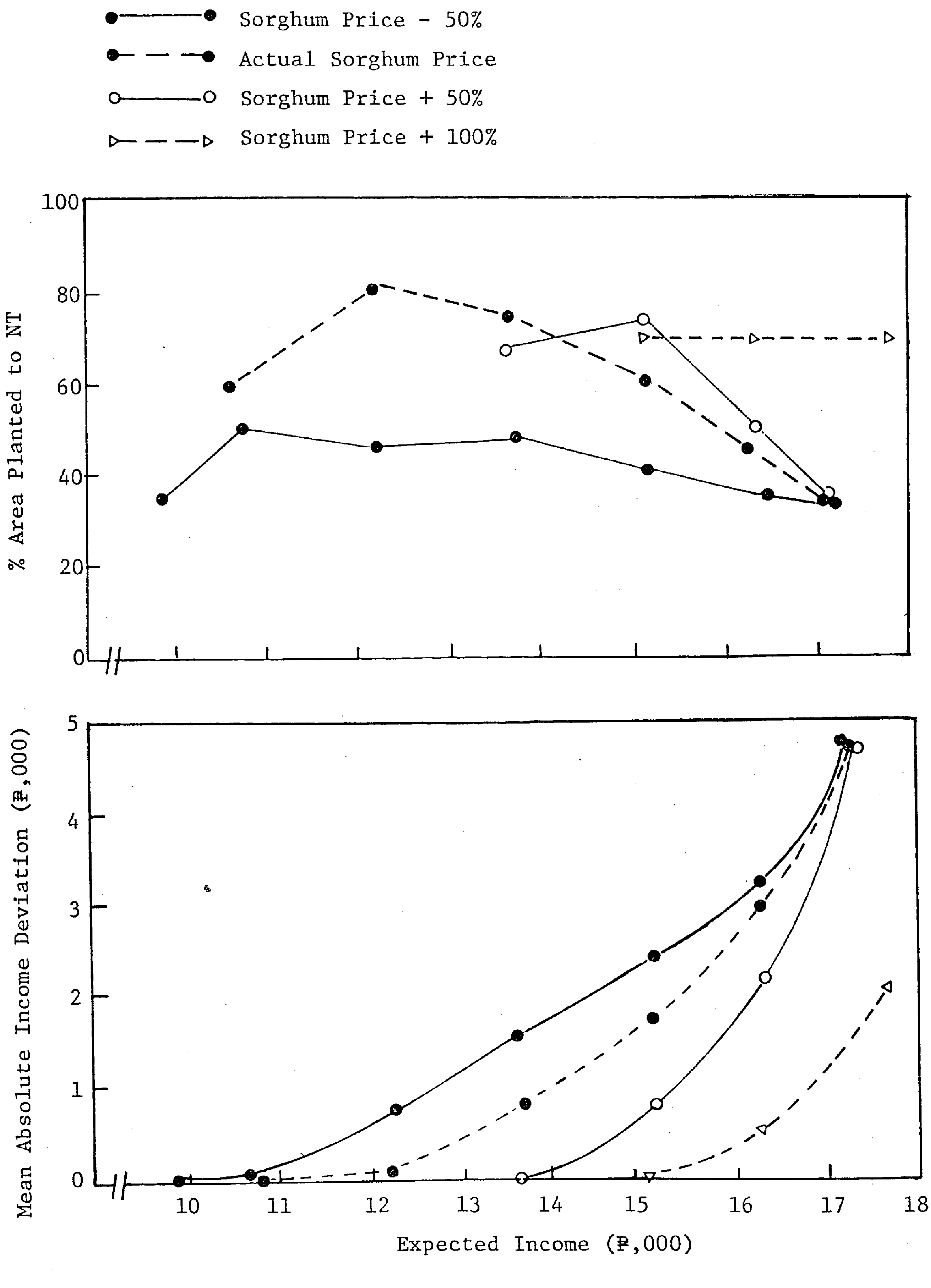

Fig. 6.12: Effects of changes in price of sorghum on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available new technologies, with subsistence objective.

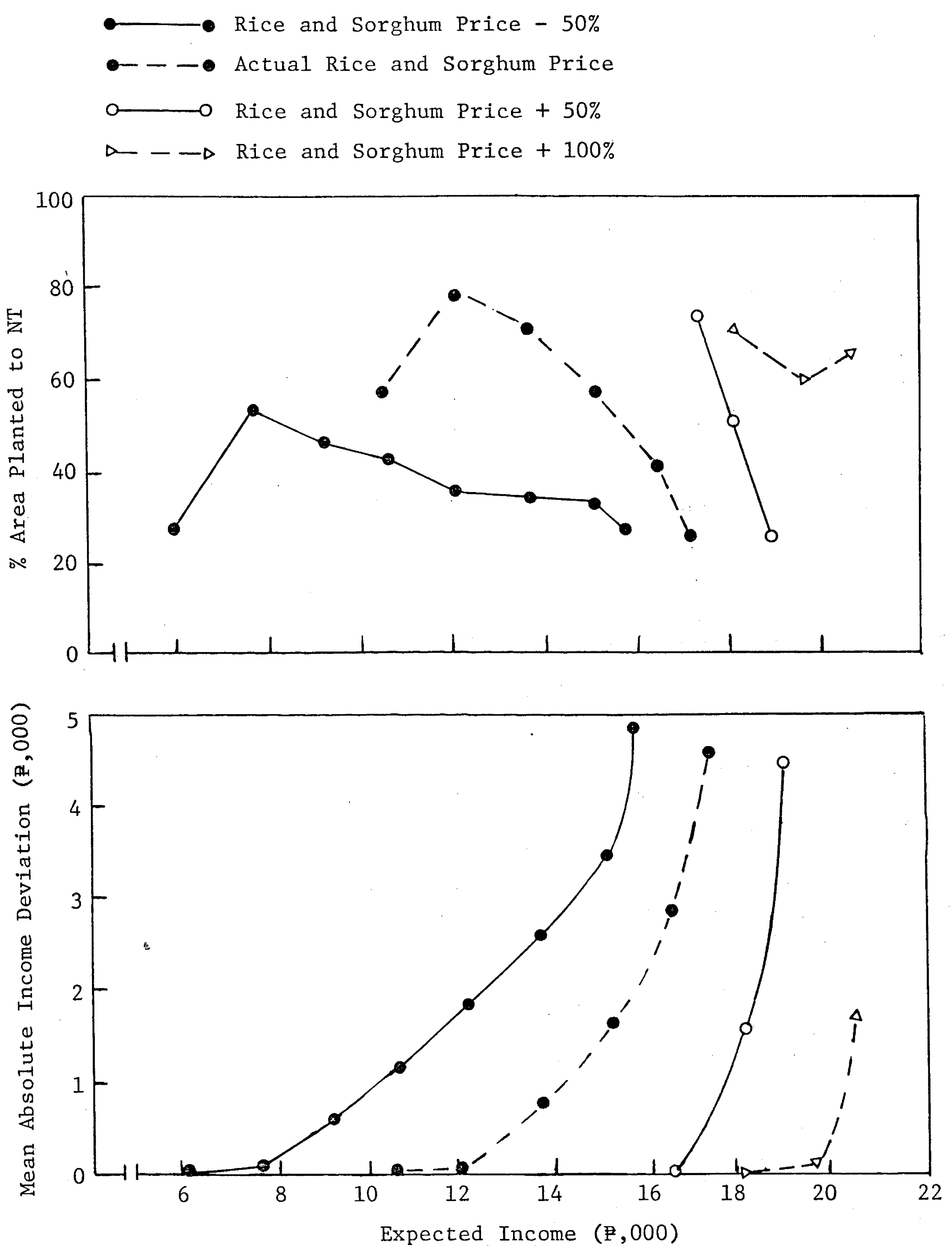

Fig. 6.13: Effects of changes in price of rice and sorghum on percentage of total area planted to NT, expected income, and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

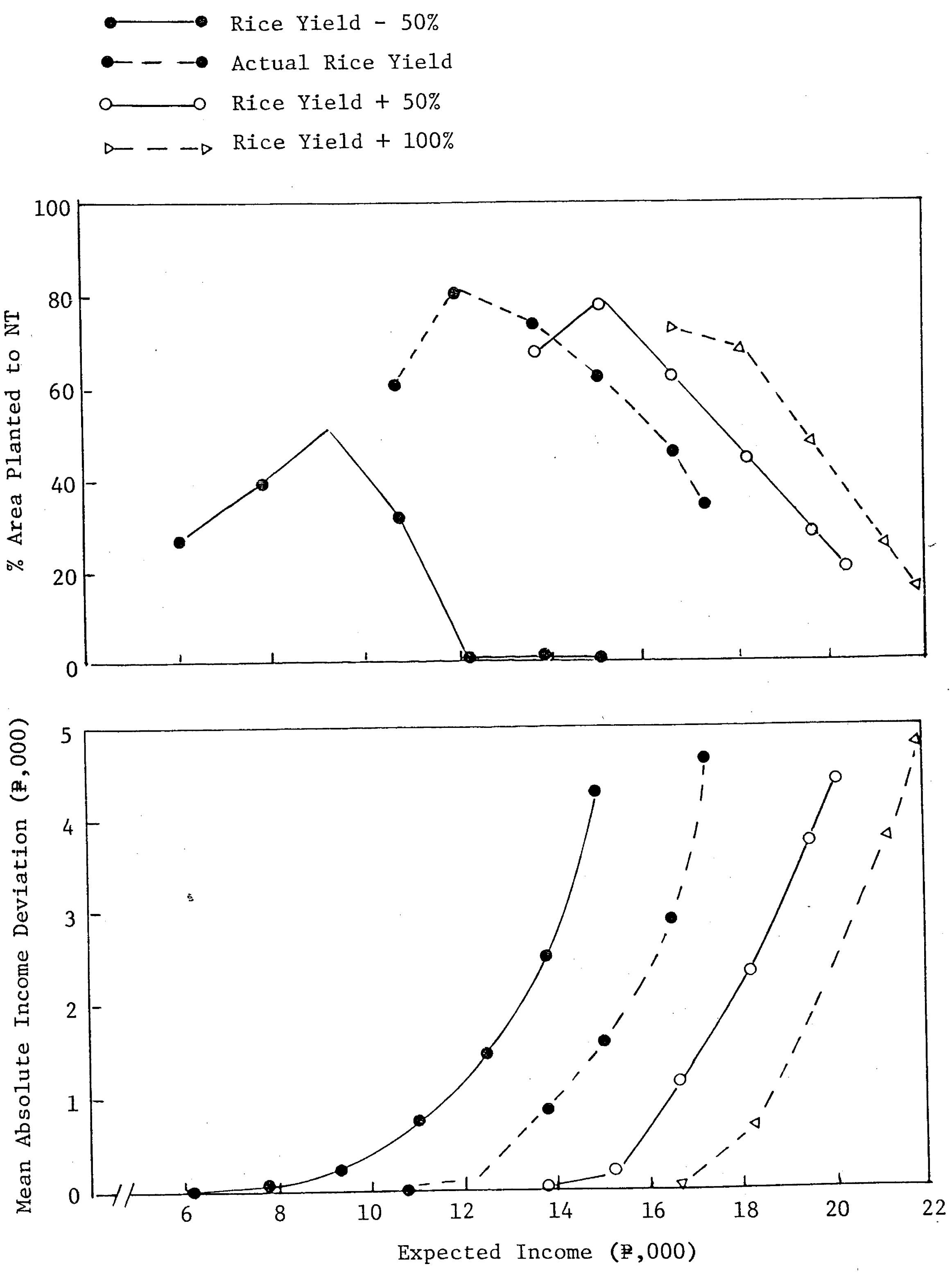

Fig. 6.14: Effects of changes in yield of rice on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technology, with subsistence objective.

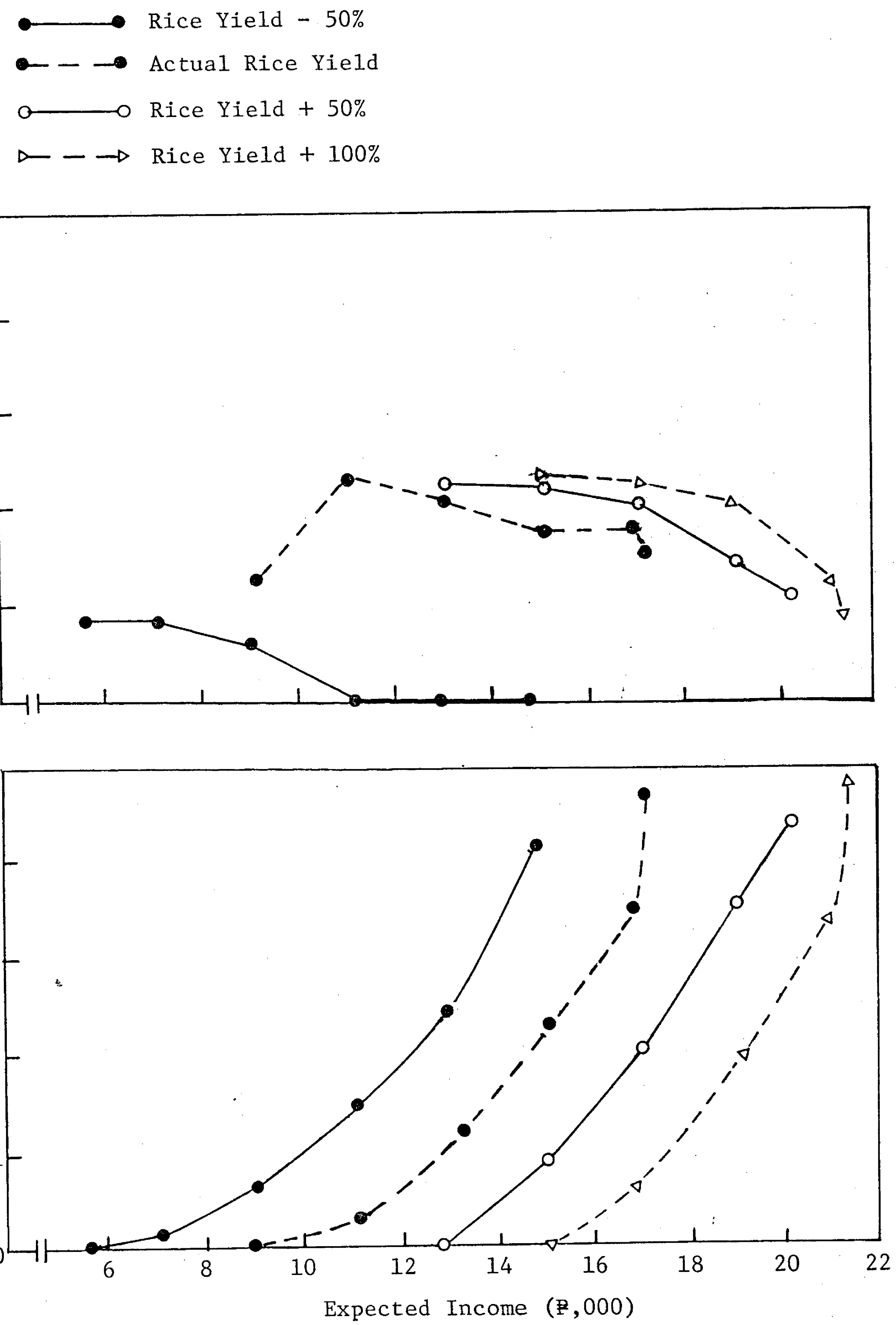

Fig. 6.15: Effects of changes in yield of rice on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available new technology, with subsistence objective.

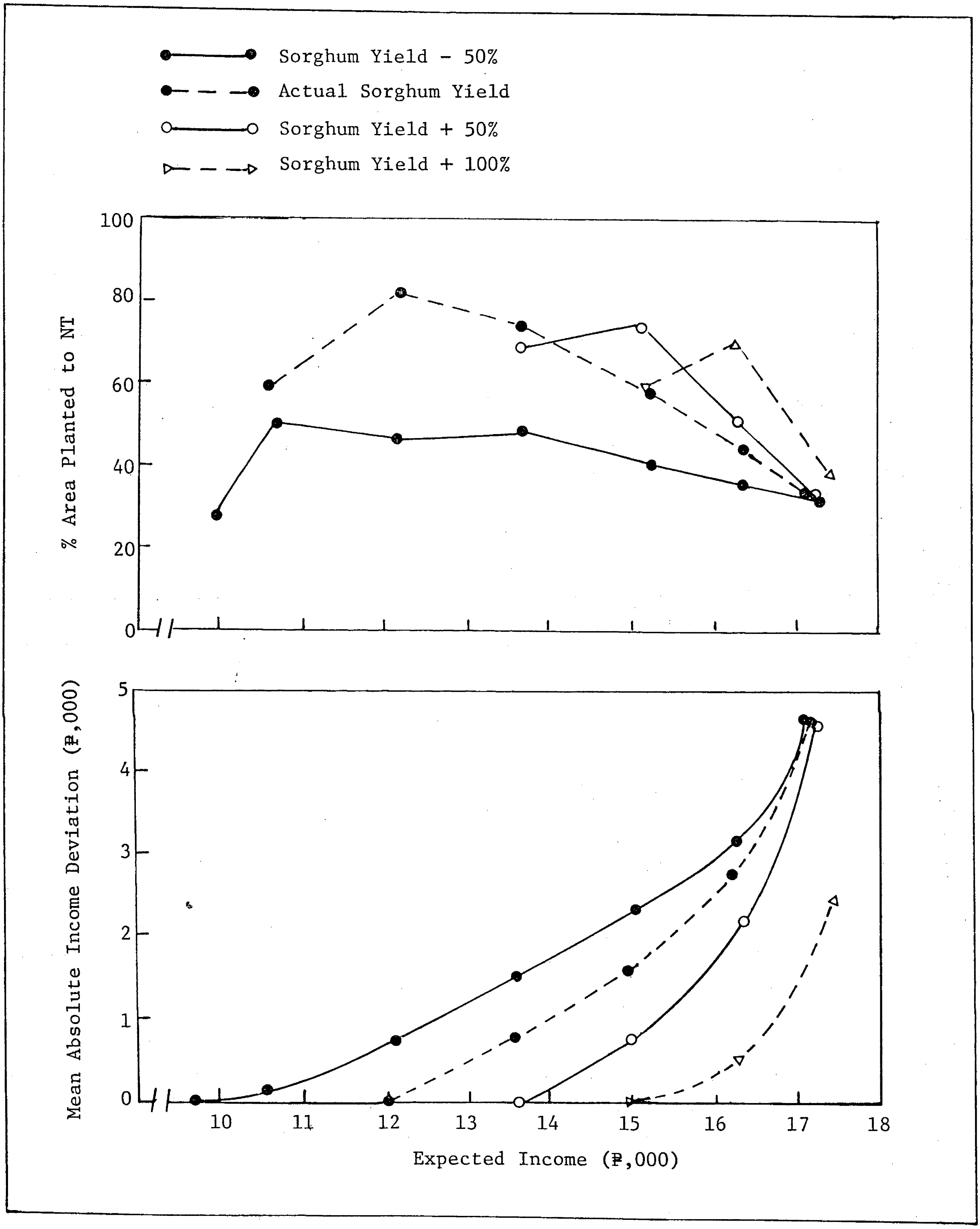

Fig. 6.16: Effects of changes in yield of sorghum on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

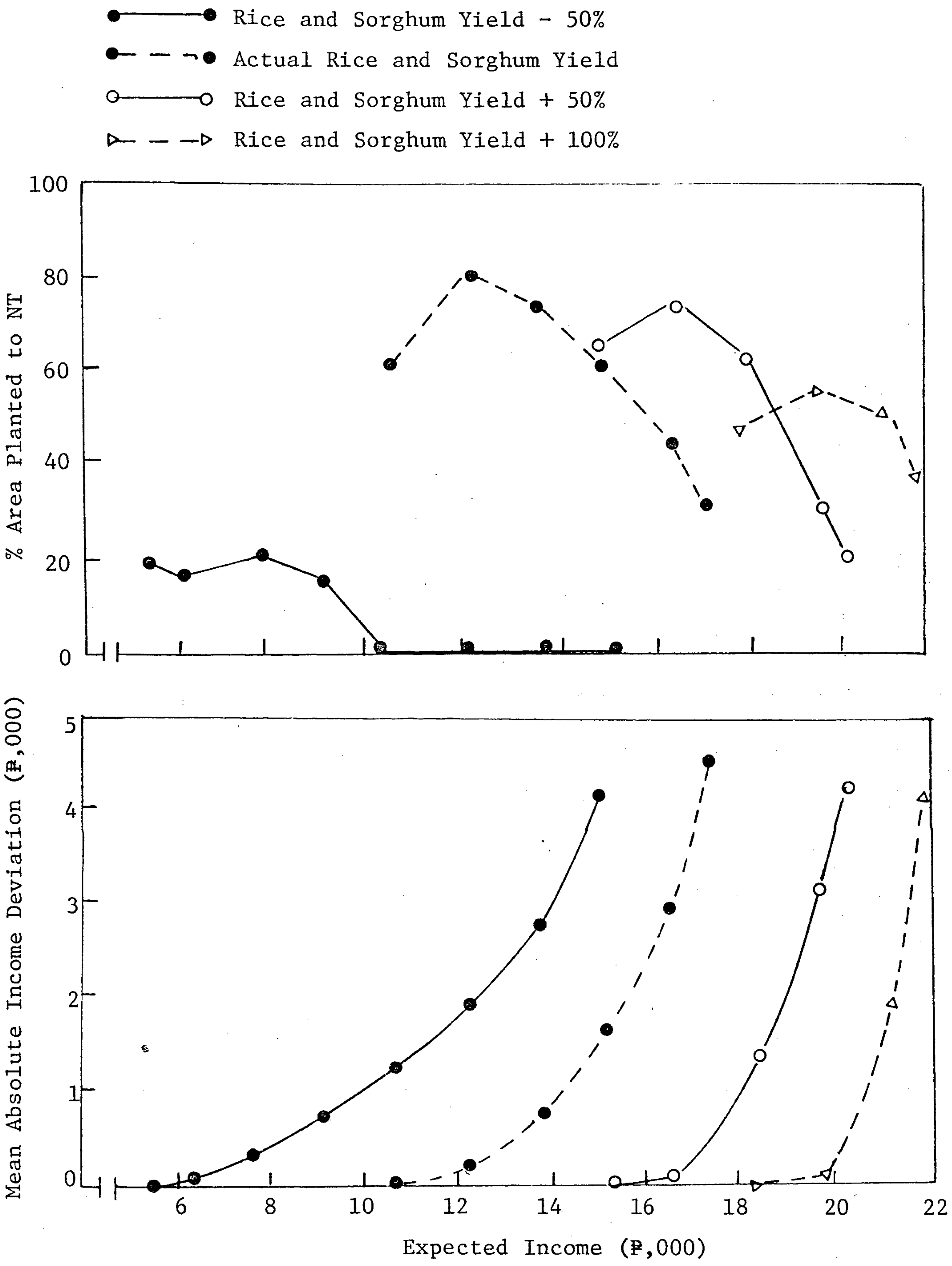

Fig. 6.17: Effects of changes in yield of rice and sorghum on percentage of total area planted to NT, expected income and mean absolute income deviation, existing + available + potential new technologies, with subsistence objective.

harvesting and threshing take place in the first season, when family labour is generally underutilized. While in the case where sorghum yields is increased, there is no increase in labour used because farmers planted more sorghum which is less labour using than any other upland crops. Hence, the changes in labour use do not result in significant changes in hired labour use. Consequently cash income effects are slight.

Appendix Tables G.1, G.2, H.1, I.1, J.1, J.2, K.1 and L.1 shows the crop combinations along the E-A frontier, with changes in price and yields of the new rice variety and sorghum.

CHAPTER 7

SUMMARY, CONCLUSIONS AND IMPLICATIONS

In the Philippines, as in many poorer countries the agricultural sector is dominated by problems of low productivity and low income. The introduction of new farming technologies is an important instrument for developing this sector. While many new technologies have been developed and introduced, not all such technologies have been widely adopted by farmers. Adoption of a new technology is influenced by many factors, and the high risk associated with some technologies is believed to be one of these factors that limit their adoption.

This study aims to evaluate some new technologies developed for upland farming systems in Batangas province in the Philippines. These are rainfed farming systems where risk can be an important factor affecting farmers' decision-making. The farm-households are modelled using mathematical programming techniques, where risk and subsistence factors are explicitly considered. Data used in the study come from the IRRI's cropping systems program. The data cover the period 1974-77. An average farm model is constructed, based on the records of five farmers who participated in a farm record-keeping project. New technologies are classified into two major groups; (i) available new technology, which includes a new upland rice variety which was introduced to farmers during the research project, and (ii) a potential new technology which is currently being developed or tested but which has not been widely made available to farmers. Those considered in the study were a single crop of sorghum and sorghum followed by a ratoon crop.

Four basic models are constructed in this study: (i) two ordinary deterministic LP models. In one model the farmers' objective is specified as maximization of farm income. In the other, a further priority objective is satisfaction of rice subsistence requirements estimated at 2 tons of palay (unmilled rice) per farm; (ii) a MOTAD model where the farmers' objective is to minimize risk at any given income level; and (iii) a MOTAD model where the farmers' objectives in addition to (ii) also includes the priority subsistence requirement for rice.

Evaluation of technologies is done by progressively including crop activity vectors representing (i) existing technologies; (ii) existing + available new technologies, and (iii) existing + available + potential new technologies. The potential of the new technologies is assessed by the area planted to the new technologies, together with the increased income over that obtained from the existing technology at a similar risk level. From the series of farm plans generated in the model, an E-A frontier was constructed which represents the minimum income deviation obtained for a range of expected incomes obtainable with the available resources. Whenever the addition of new technologies shifts the E-A frontier to the right of the frontier with existing technologies, farm plans with new technologies are preferable to those plans with only existing technologies.

While an average farm model is used, effects on technology adoption due to differences in resource endowments of the sample farmers are examined by parameterization of resources (i.e. land and labour).

The possible changes in adoption patterns likely to arise from changes in performance of the new crops and changes in the output price are explored by parameterization of yields and price. The results and conclusions from this study are summarized below.

The results obtained with the LP (deterministic) model with only existing technology show that farmers without a subsistence objective will not grow rice, as they can obtain higher income by growing other high valued upland crops. With the MOTAD model, however, it is found that as long as farmers are strongly risk averse, they will plant rice even without the subsistence objective. In both cases, the subsistence oriented farmers obtain lower cash income even after the valuation of their subsistence requirement for rice. When the model results are compared with the actual farm plans of a farmer with similar resources, it is observed that the MOTAD model generates some farm plans considerably similar to those actually practiced by farmers. In all cases, the farm plans generated in the LP models usually give higher incomes but (as indicated by MOTAD model results) also higher risk.

A number of recent studies of risk attitudes among small farmers, including a study of Filipino rice farmers (Sillers, 1980) show that farmers are generally moderately, rather than strongly risk averse. On this basis, the models with a subsistence objective appears to be better in simulating actual farmers' decision-making; it is necessary to assume very high risk aversion to explain observed farmers' behaviour in the model without the subsistence objective.

The evaluation of the new rice technology shows that even at the relatively low additional yield of 25% over the traditional variety assumed in the model, the new rice variety is likely to replace the traditional variety. In particular, it enables farmers to increase incomes without increasing risk; thus irrespective of the degree of risk aversion, the new technology appears to be acceptable to the farmers.

Parametric variations on farm resource endowment show that the new rice technology continues to be attractive to farmers in the range of resource situations generally found in the region.

If the yield of the new rice variety is lower than those with the traditional variety naturally adoption is marginal at best. However, if yields are substantially higher they not only replace the traditional variety but also tend to occupy a greater area; farm incomes, too, go up. Price increases have a broadly similar effect. Even though the subsistence constraint imposes a certain minimum level of rice production, there appears to be a small but significant price response.

The man-labour ratio in farm (available labour per household) has little effect on adoption. A new rice variety was found to replace the traditional variety and improve incomes to varying degrees. The broad conclusion which is drawn on the basis of these exercises, is that the new rice variety is likely to widely replace the traditional variety but may not greatly increase total rice area. Even if large-scale adoption leads to a decline in rice price through increased output the effects are not likely to affect adoption patterns to any important extent. In this sense, the new rice technology appears to have a good potential for adoption, and seems acceptable to the range of farm types in this area.

Adoption of the sorghum-ratoon technology appears to have promise only where farmers are significantly risk averse at present price/yield levels. Even at a 50% higher price level, its adoption appears to be quite small. However, a larger increase in price (100% of present price level), adoption is quite substantial. Yield increases has essentially the same effect. This leads us to conclude that widespread adoption of sorghum by farmers operating similar upland farming systems is greatly dependent on either government intervention which raises domestic sorghum price very substantially, or on the identification of much higher yielding varieties by the researchers.

According to the model results, the subsistence objectives of the farmers results in a fairly significant loss in potential net incomes. However, the magnitude of this loss may be over-estimated by the models as the possible differences between buying and selling prices of rice and associated marketing problems are not considered. The new technologies help to increase the incomes of farmers with a subsistence orientation or high risk aversion relatively more than those who are entirely market oriented or who are less risk averse. This is because the technologies are developed for subsistence rice and sorghum, which is a relatively low valued and low risk crop.

The employmemt effects of the new technology are not very significant. The overall labour use is actually slightly reduced.

Some of the limitations of this study, in addition to the methodological weaknesses of the MOTAD type models should be noted here.

While the use of the MOTAD approach required annual observations on net income and income deviation for each crop's production activity to reflect the historical pattern of variability associated with each activity, the relevant data available only covers a short period. In addition, individual farm level data were unavailable and thus only an average farm model are developed and used. Because the measure of variability are obtained from pooling observations from different farms, some variability may reflect inter-farm differences in land quality, management, planting dates, etc.

Furthermore, validation of the model results too, has a more subjective element due to the use of an average farm model.

The model is greatly simplified in that the year is divided into only two periods, which probably understates farm level supply constraints of labour and power, and overestimates hiring requirements.

Another limitation is that the effects of changes in input prices on new technolgy adoption are not explored, due to time constraints.

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APPENDIX TABLE A.1

CROP PRODUCTION VECTORS INCLUDED IN THE MODEL

EXISTING TECHNOLOGIES

1. First Crop
   a. Rice, traditional variety (Dagge)
   b. Green Corn
   c. Eggplant
   d. Yellow Corn, high yielding variety (HYV, UPCAVAR)

2. Second Crop
   a. Tomato
   b. Green Corn
   c. Yellow Corn, traditional variety (Tinumbaga)
   d. Yellow Corn (HYV)
   e. Garlic Intercrop with (+) Bitter Gourd
   f. Mung

3. Annual Intercrops
   a. Eggplant + Hyacinth Bean
   b. Corn + Hyacinth Bean
   c. String Bean + Bottle Gourd
   d. Palay + Sponge Gourd

4. Annual Single Crop
   a. Sweet Pepper

AVAILABLE NEW TECHNOLOGY

1. First Crop
   a. Rice, improved variety (C171-136)

POTENTIAL NEW TECHNOLOGIES

1. Second Crop
   a. Single cultivation of sorghum
   b. Sorghum followed by (+) a ratoon

APPENDIX B.1

PRICES OF OUTPUT USED IN THE MODEL

Item	Price Per Kilogram[1]
	(₱)
Palay (Traditional and Improved)[2]	1.60
Green Corn	0.61
Eggplant	1.13
Yellow Corn HYV	1.05
Tomato	0.60
Yellow Corn Traditional	1.05
Garlic (Green)	3.20
Bitter Gourd	0.49
Mung	4.74
Hyacinth Bean	0.81
Sweet Pepper	2.66
String Bean	2.23
Sponge Gourd	0.78
Bottle Gourd	0.60
Sorghum	1.05

1) Average of 1976-77 prices.

2) Unmilled rice.

APPENDIX B.2

PRICES OF INPUT USED IN THE MODEL

Item	Price Per Unit[2]
	(₱)
A. FERTILIZER, PER KG	
Urea (45 - 0.0)	1.73
Ammonium Sulfate (21 - 0 - 0)	1.15
Complete (14 - 14 - 14)	1.34
16 - 20 - 0	1.24
B. INSECTICIDES, PER CC	
Folidol, Sevin, Endrin, Eradex, Azodrin	0.05
Parapest, Perthane	0.04
C. CHEMICALS, PER KG	
Furadan	10.00
D. HIRED LABOUR, PER HOUR	1.00
E. HIRED LABOUR PLUS ANIMAL, PER HOUR	1.50
F. SEEDS	
Corn Yellow Traditional	1.25
Corn Yellow HYV	1.90
Corn White[2]	3.30
Garlic	10.00
Mung	3.90
Palay (Traditional and Improved)	1.60

1) Average of 1976-77 prices.

2) Seeds for green corn.

APPENDIX TABLE C.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN FAMILY LABOUR, EXISTING TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Tomato 2nd Crop	Green Corn 2nd Crop	Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Actual Family Labour						
1	1.28			0.43	0.38	0.50			0.18	3,200	0
2	1.32			0.43	0.39	0.50			0.18	5,200	43
3	1.36			1.02		0.22	0.12	0.05	0.14	7,200	216
4	1.45			1.13			0.32	0.14		9,200	716
5	1.36			1.05			0.31	0.14		11,200	1,434
6	1.31	0.05		0.64			0.70	0.22		13,200	2,517
7	1.28						1.28			14,883	4,196
					Family Labour + 50%						
1	1.31			0.43	0.38	0.50			0.38	3,200	0
2	1.31			0.81	0.38	0.50			0.38	5,700	43
3	1.28		0.13	1.13			0.29			8,200	403
4	1.50			0.77			0.73			10,700	1,156
5	1.36		0.01	0.57			0.80	0.13		13,200	2,022
6	1.33	0.09		0.19			1.23	0.08		15,700	3,338
7	1.28						1.28	0.22		16,130	4,196
					Family Labour + 100%						
1	1.32	0.07		0.43			0.46		0.18	3,200	0
2	1.32			0.43					0.18	5,700	43
3	1.27			1.13			0.29		0.08	8,200	403
4	1.50			0.77			0.73			10,700	1,156
5	1.42	0.01		0.43			1.00	0.07		13,200	1,969
6	1.36	0.06		0.20			1.22	0.08		15,700	2,876
7	1.28						1.28	0.22		17,383	4,196

APPENDIX TABLE C.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN FAMILY LABOUR, EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)						Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
				Actual Family Labour				
1	1.00	0.09	1.06		0.15	0.25	9,200	0
2	1.41	0.09	1.17	0.33			11,200	272
3	1.24	0.12	1.05	0.31	0.14		13,200	1,192
4	1.05	0.16	0.71	0.50	0.29		15,200	2,240
5	1.08	0.23	0.03	1.30	0.18		17,200	3,535
6	0.98	0.02		1.00	0.50		17,280	4,668
				Family Labour + 50%				
1	1.43	0.07	1.05	0.46			10,700	0
2	1.38	0.11	0.68	0.81			13,200	893
3	1.30	0.18	0.16	0.82	0.02		15,700	1,977
4	1.08	0.22	0.13	1.17	0.20		18,200	3,353
5	0.98	0.02		1.00	0.50		19,749	4,668
				Family Labour + 100%				
1	1.43		1.04				10,700	0
2	1.39	0.11	0.65	0.85			13,200	880
3	1.34	0.16	0.35	0.15			15,700	1,809
4	1.29	0.21	0.20	1.30			18,200	2,805
5	1.06	0.20		1.26	0.24		19,749	3,765

APPENDIX TABLE C.3

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN FAMILY LABOUR, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd crop	Sorghum + Ratoon 2nd crop	Sorghum 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Actual Family Labour						
1	0.86	0.25			0.25	0.40	0.43	0.86	0.25	9,200	0
2	1.07		0.05	0.32	0.48	0.96		0.06		11,200	1
3	1.37		0.11		0.49	0.99		0.02		13,200	511
4	1.07		0.13		0.44	0.76		0.30		15,200	1,648
5	1.09		0.23		1.30	0.02		0.18		17,200	3,516
6	0.98		0.02		1.00			0.50		17,280	4,668
					Family Labour + 50%						
1	0.87	0.25	0.05	0.10	0.35	0.92		0.08		10,700	0
2	1.41		0.09		0.88	0.62				13,200	401
3	1.34		0.16		0.92	0.58				15,700	1,598
4	1.07		0.22		1.13	0.16		0.21		18,200	3,226
5	0.98		0.02		1.00			0.50		18,530	4,668
					Family Labour + 100%						
1	1.29		0.06	0.10	0.35	0.50		0.08	0.14	10,700	0
2	1.41		0.09		0.88	0.62				13,200	401
3	1.35		0.15		1.16	0.34				15,700	1,534
4	1.29		0.21		1.33	0.17				18,200	2,694
5	1.06		0.20		1.26			0.24		19,749	3,765

APPENDIX TABLE D.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF FULLY OWNED LAND, EXISTING TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Tomato 2nd Crop	Green Corn 2nd Crop	Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
	Actual Land Area										
1	1.28			0.43	0.38	0.50			0.18	3,200	0
2	1.32			0.43	0.39	0.50			0.18	5,200	43
3	1.36			1.02		0.22	0.12	0.05	0.14	7,200	216
4	1.45			1.13			0.32	0.14		9,200	716
5	1.36			1.05			0.31	0.14		11,200	1,434
6	1.31	0.05		0.64			0.70	0.22		13,200	2,517
7	1.28						1.28			14,883	4,196
	Fully Owned Land Area + 50%										
1	1.19		0.37	0.70					0.47	7,200	0
2	0.92			1.29			0.25		0.21	9,200	277
3	1.61			1.41			0.20	0.14		11,200	912
4	1.43			1.26			0.17	0.32		13,200	1,594
5	1.36	0.02		1.14			0.24	0.37		15,200	2,400
6	1.27	0.09		0.74			0.61	0.40		17,200	3,490
7	1.24	0.15		0.19			1.20	0.36		19,200	4,687
8	1.19	0.06					1.25	0.50		19,684	5,567
	Fully Owned Land Area + 100%										
1	1.10			1.04				0.26	0.11	8,200	0
2	1.10			1.62			0.15	0.25		10,700	306
3	1.77			1.69			0.08	0.49		13,200	1,108
4	1.55			1.51			0.03	0.69		15,700	1,960
5	1.36	0.03		1.32			0.06	0.67		18,200	2,896
6	1.33	0.11		0.93			0.51	0.70		20,699	4,215
7	1.19	0.19		0.30			1.08	0.50		23,199	5,656
8	1.19	0.31					1.50			24,436	6,512

APPENDIX TABLE D.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF FULLY OWNED LAND, EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)						Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
				Actual Land Area				
1	1.00	0.09	1.06		0.15	0.25	9,200	0
2	1.41	0.09	1.17	0.33			11,200	272
3	1.24	0.12	1.05	0.31	0.14		13,200	1,192
4	1.05	0.16	0.71	0.50	0.29		15,200	2,240
5	1.08	0.23	0.03	1.30	0.18		17,200	3,535
6	0.98	0.02		1.00	0.50		17,280	4,668
				Fully Owned Land Area + 50%				
1	1.28	0.11	1.28	0.24	0.18	0.29	11,200	0
2	1.57	0.10	1.46	0.21	0.08		13,200	290
3	1.36	0.12	1.31	0.17	0.27		15,200	1,228
4	1.15	0.14	1.15	0.14	0.45		17,200	2,166
5	1.07	0.20	0.78	0.49	0.48		19,200	3,246
6	0.97	0.27	0.26	0.99	0.50		21,200	4,413
7	0.98	0.27		1.25	0.50		22,031	5,057
				Fully Owned Land Area + 100%				
1	1.30	0.09	1.63	0.07	0.26	0.11	13,200	0
2	1.64	0.10	1.67	0.03	0.25		15,700	560
3	1.38	0.13	1.48	0.03	0.49		18,200	1,733
4	1.14	0.16	1.28	0.48	0.69		20,700	2,918
5	1.09	0.24	0.50	1.10	0.67		23,200	4,252
6	0.98	0.32	0.20	1.50	0.70		25,700	5,711
7	0.98	0.52			0.50		26,784	6,585

APPENDIX TABLE D.3

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF FULLY OWNED LAND, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Sorghum + Ratoon 2nd Crop	Sorghum 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Actual Land Area						
1	0.86	0.25			0.25	0.40	0.43	0.86	0.25	9,200	0
2	1.07		0.05	0.32	0.48	0.96		0.06		11,200	1
3	1.37		0.11		0.49	0.99		0.02		13,200	511
4	1.07		0.13		0.44	0.76		0.30		15,200	1,648
5	1.09		0.23		1.30	0.02		0.18		17,200	3,516
6	0.98		0.02		1.00			0.50		17,280	4,668
					Fully Owned Land Area + 50%						
1	0.82		0.03	0.30		1.24		0.51		13,200	0
2	1.54		0.10		0.40	1.24		0.11		15,200	326
3	1.31		0.13		0.34	1.09		0.31		17,200	1,397
4	1.08		0.17		0.42	0.83		0.50		19.200	2,598
5	0.97		0.26		0.94	0.29		0.02		21,200	4,183
6	0.98		0.27		1.25			0.50		22,032	5,057
					Fully Owned Land Area + 100%						
1	1.03		0.04	0.35		1.43		0.57		15,700	0
2	1.58		0.11		0.29	1.40		0.31		18,200	678
3	1.29		0.14		0.21	1.22		0.56		20,700	2,016
4	1.11		0.20		0.41	0.91		0.68		23,200	3,548
5	0.93		0.30		0.94	0.30		0.26		25,700	5,513
6	0.98		0.52		1.50			0.50		26,784	6,586

APPENDIX TABLE E.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF SHARE TENANTED LAND (3:1), EXISTING TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Tomato 2nd Crop	Green Corn 2nd Crop	Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
	Actual Land Area										
1	1.28			0.43	0.38	0.50			0.18	3,200	0
2	1.32			0.43	0.39	0.50			0.18	5,200	43
3	1.36			1.02		0.22	0.12	0.05	0.14	7,200	216
4	1.45			1.13			0.32	0.14		9,200	716
5	1.36			1.05			0.31	0.14		11,200	1,434
6	1.31	0.05		0.64			0.70	0.22		13,200	2,517
7	1.28						1.28			14,883	4,196
	Share Tenanted Land Area + 50%										
1	1.28		0.06	0.86		0.45	0.03		0.40	7,200	0
2	1.26		0.38	1.40			0.24		0.08	9,200	401
3	1.57			1.38			0.19	0.18		11,200	1,060
4	1.42			1.25			0.16	0.33		13,200	1,750
5	1.26	0.05		0.88			0.46	0.41		15,200	2,799
6	1.31	0.12		0.29			1.13	0.32		17,200	4,023
7	1.25						1.25	0.50		17,990	5,286
	Share Tenanted Land Area + 100%										
1	1.31		0.16	1.10		0.38		0.01	0.50	8,200	0
2	1.50		0.39	1.79			0.10	0.10		10,700	564
3	1.70			1.64			0.06	0.30		13,200	1,404
4	1.47			1.45			0.02	0.54		15,700	2,268
5	1.31	0.08		0.81			0.58	0.60		18,200	3,706
6	1.31	0.17		0.10			1.38	0.52		20,700	5,225
7	1.31	0.19					1.50	0.50		21,050	5,444

APPENDIX TABLE E.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF SHARE TENANTED LAND (3:1), EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)						Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
				Actual Land Area				
1	1.00	0.09	1.06		0.15	0.25	9,200	0
2	1.41	0.09	1.17	0.33			11,200	272
3	1.24	0.12	1.05	0.31	0.14		13,200	1,192
4	1.05	0.16	0.71	0.50	0.29		15,200	2,240
5	1.08	0.23	0.03	1.30	0.18		17,200	3,535
6	0.98	0.02		1.00	0.50		17,280	4,668
				Share Tenanted Land Area + 50%				
1	1.32	0.10	1.25	0.17	0.11	0.12	11,200	0
2	1.52	0.10	1.42	0.20	0.12		13,200	563
3	1.31	0.12	1.27	0.17	0.31		15,200	1,502
4	1.10	0.16	0.92	0.34	0.33		17,200	2,551
5	1.05	0.23	0.36	0.92	0.46		19,200	3,743
6	1.04	0.21		1.25	0.50		20,340	4,783
				Share Tenanted Land Area + 100%				
1	1.78	0.08	1.68	0.12	0.10	0.57	13,200	0
2	1.54	0.11	1.60	0.05	0.31		15,700	1,108
3	1.15	0.20	1.36		0.50		18,200	2,314
4	1.10	0.22	0.71	0.60	0.66		20,700	3,753
5	1.10	0.30		1.40	0.53		23,200	5,274
6	1.10	0.40		1.50	0.50		23,400	5,509

APPENDIX TABLE E.3

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN AREA OF SHARE TENANTED LAND (3:1), EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Sorghum + Ratoon 2nd Crop	Sorghum 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Actual Land Area						
1	0.86	0.25			0.25	0.40	0.43	0.86	0.25	9,200	0
2	1.07		0.05	0.32	0.48	0.96		0.06		11,200	1
3	1.37		0.11		0.49	0.99		0.02		13,200	511
4	1.07		0.13		0.44	0.76		0.30		15,200	1,648
5	1.09		0.23		1.30	0.02		0.18		17,200	3,516
6	0.98		0.02		1.00			0.50		17,280	4,668
					Share Tenanted Land Area + 50%						
1	1.32		0.08	0.34	0.44	1.31				13,200	0
2	1.45		0.11		0.38	1.18		0.18		15,200	692
3	1.12		0.13		0.29	0.96		0.50		17,200	1,798
4	1.04		0.22		0.86	0.40		0.49		19,200	3,412
5	1.04		0.21		1.25			0.50		20,340	4,783
					Share Tenanted Land Area + 100%						
1	0.55	0.52		0.43	0.06	1.45		0.44	0.04	13,200	0
2	1.76		0.09		0.34	1.51		0.15		15,700	47
3	1.37		0.12		0.22	1.25		0.51		18,200	1,426
4	1.06		0.18		0.40	0.84		0.59		20,700	3,101
5	1.07		0.30		1.32	0.05		0.63		23,200	5,261
6	1.10		0.40		1.50			0.50		23,400	5,509

APPENDIX TABLE F.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN ALL LAND TYPES, EXISTING TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Tomato 2nd Crop	Green Corn 2nd Crop	Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
Actual Land Area											
1	1.28			0.43	0.38	0.50			0.18	3,200	0
2	1.32			0.43	0.39	0.50			0.18	5,200	43
3	1.36			1.02		0.22	0.12	0.05	0.14	7,200	216
4	1.45			1.13			0.32	0.14		9,200	716
5	1.36			1.05			0.31	0.14		11,200	1,434
6	1.31	0.05		0.64			0.70	0.22		13,200	2,517
7	1.28						1.28			14,883	4,196
All Land Area + 50%											
1	1.27	0.04	0.05	1.36		0.25			0.64	9,200	0
2	1.85		0.17	2.02				0.15	0.08	12,200	639
3	1.86			1.86				0.39		15,200	1,687
4	1.60	0.01		1.61				0.64		18,200	2,757
5	1.36	0.10		1.07			0.39	0.79		21,200	4,307
6	1.25	0.20		0.25			1.20	0.80		24,200	6,098
7	1.37	0.48					1.85	0.40		25,217	7,083
All Land Area + 100%											
1	1.35		0.44	1.79		0.96		0.06	0.19	11,200	0
2	1.77		0.43	2.21				0.22	0.57	15,200	783
3	1.27	0.01	1.14	2.43				0.57		19,200	2,268
4	1.44	0.07	0.61	2.12				0.88		23,200	3,876
5	1.49	0.17	0.03	1.69				1.31		27,200	5,575
6	1.31	0.26		0.67			0.89	1.43		31,200	7,900
7	1.53	1.47					3.00			34,572	11,426

APPENDIX TABLE F.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN ALL LAND TYPES, EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)							Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Corn HYV 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
				Actual Land Area					
1	1.00		0.09	1.06		0.15	0.25	9,200	0
2	1.41		0.09	1.17	0.33			11,200	272
3	1.24		0.12	1.05	0.31	0.14		13,200	1,192
4	1.05		0.16	0.71	0.50	0.29		15,200	2,240
5	1.08		0.23	0.03	1.30	0.18		17,200	3,535
6	0.98		0.02		1.00	0.50		17,280	4,668
				All Land Area + 50%					
1	1.12		0.19	1.42		0.08	0.75	12,200	0
2	1.93		0.09	2.02		0.23		15,200	74
3	1.64		0.13	1.77		0.48		18,200	1,496
4	1.29		0.23	1.52		0.73		21,200	2,932
5	1.09		0.25	0.89	0.44	0.91		24,200	4,557
6	1.04		0.35	0.05	1.33	0.86		27,200	6,355
7	1.04		0.46		1.50	0.75		27,627	6,745
				All Land Area + 100%					
1	2.60	0.04	0.12	2.67		0.29		19,200	0
2	2.20		0.17	2.37		0.63		23,200	1,963
3	1.88		0.25	1.88	0.25	0.86		27,200	4,072
4	1.25		0.31	1.25	0.31	1.44		31,200	6,354
5	1.15		0.44	0.18	1.41	1.41		35,200	8,742
6	1.25		1.75		3.00			37,176	11,550

APPENDIX TABLE F.3

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN ALL LAND TYPES, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Rice ET 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Sorghum + Ratoon 2nd Crop	Sorghum 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Actual Land Area						
1	0.86	0.25			0.25	0.40	0.43	0.86	0.25	9,200	0
2	1.07		0.05	0.32	0.48	0.96		0.06		11,200	1
3	1.37		0.11		0.49	0.99		0.02		13,200	511
4	1.07		0.13		0.44	0.76		0.30		15,200	1,648
5	1.09		0.23		1.30	0.02		0.18		17,200	3,516
6	0.98		0.02		1.00			0.50		17,280	4,668
					All Land + 50%						
1	0.72		0.03	0.63		1.43		0.58	0.07	15,200	0
2	1.84		0.09		0.23	1.71		0.31		18,200	254
3	1.49		0.14		0.14	1.49		0.62		21,200	1,862
4	1.10		0.21		0.36	0.95		0.94		24,200	3,804
5	1.04		0.35		1.32	0.06		0.86		27,200	6,307
6	1.04		0.46		1.50			0.75		27,627	6,745
					All Land + 100%						
1	1.07		0.05			2.47		0.52		19,200	0
2	2.31		0.09			2.40		0.60		23,200	66
3	1.83		0.20			2.03		0.97		27,200	2,525
4	1.18		0.30		0.09	1.39		1.52		31,200	5,273
5	1.10		0.43		1.32	0.21		1.47		35,200	8,573
6	1.25		1.75		3.00					37,176	11,551

APPENDIX TABLE G.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN PRICE OF NT RICE, EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)							Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice NT 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Eggplant + H. Bean	Corn + H. Bean	Corn HYV 1st Crop		
				Rice Price - 50%					
1	1.12	0.04	1.19	0.22		0.08	0.25	7,200	0
2	1.33	0.06	1.08	0.31	0.10			9,200	611
3	1.16	0.09	0.96	0.29	0.25			11,200	1,346
4	1.08	0.14	0.80	0.42	0.28			13,200	2,272
5	1.07	0.21	0.20	1.07	0.22			15,200	3,499
6	0.98	0.02		1.00	0.50			15,680	4,874
				Actual Rice Price					
1	1.00	0.09	1.06		0.15	0.25		9,200	0
2	1.41	0.09	1.17	0.33				11,200	272
3	1.24	0.12	1.05	0.31	0.14			13,200	1,192
4	1.05	0.16	0.71	0.50	0.29			15,200	2,240
5	1.08	0.23	0.03	1.30	0.18			17,200	3,535
6	0.98	0.02		1.00	0.50			17,280	4,668
				Rice Price + 50%					
1	1.34	0.09	1.11	0.32	0.07			13,200	0
2	1.35	0.15	0.97	0.53				15,200	946
3	1.25	0.21	0.46	1.00	0.04			17,200	2,199
4	0.98	0.02		1.00	0.50			17,280	4,463
				Rice Price + 100%					
1	1.38	0.12	0.48	0.53				15,200	0
2	1.36	0.14	0.97	0.53				17,200	657
3	1.27	0.23	0.37	1.13				19.200	2,024
4	0.98	0.02		1.00	0.50			20,480	4,258

APPENDIX TABLE G.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN PRICE OF NT RICE, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)								Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Sorghum + Ratoon	Eggplant + H. Bean	Corn + H. Bean		
					Rice Price - 50%					
1	0.19	0.91	0.02	0.31	0.47	0.95	0.07		9,200	0
2		1.26	0.06		0.44	0.88	0.18		10,700	566
3		1.14	0.08		0.41	0.80	0.28		12,200	1,194
4		1.05	0.13		0.46	0.72	0.32		13,700	1,987
5		1.06	0.20		1.02	0.24	0.24		15,200	3,305
6		0.98	0.02		1.00		0.50		15,680	4,874
					Actual Rice Price					
1	0.25	0.88	0.05	0.10	0.36	0.92	0.08	0.14	10,700	0
2		1.42	0.08		0.49	1.01			12,200	20
3		1.30	0.11		0.47	0.94	0.09		13,700	788
4		1.06	0.14		0.44	0.76	0.30		15,200	1,648
5		1.07	0.20		0.98	0.29	0.23		16,700	2,946
6		0.98	0.02		1.00		0.50		17,280	4,668
					Rice Price + 50%					
1		1.12	0.09		0.44	0.77	0.19	0.10	13,700	0
2		1.38	0.12		0.50	1.00			15,200	147
3		1.11	0.15		0.50	0.76	0.24		16,700	1,301
4		1.07	0.21		0.95	0.33	0.22		18,200	2,597
5		0.98	0.02		1.00		0.50		18,880	4,463
					Rice Price + 100%					
1		1.16	0.10		0.42	0.84	0.24		16,700	0
2		1.33	0.17		0.76	0.74			18,200	703
3		1.12	0.22		1.00	0.34	0.16		19,700	2,211
4		0.98	0.02		1.00		0.50		20,480	4,257

APPENDIX TABLE H.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN PRICE OF SORGHUM, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)										Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Sorghum 2nd Crop	Sorghum + Ratoon 2nd Crop	Tomato 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
Sorghum Price - 50%												
1	0.02	1.05	0.11		0.18			0.99		0.32	9,200	0
2		1.39	0.07		0.35		0.14	0.97	0.04		10,700	108
3		1.24	0.09		0.33		0.17	0.83	0.16		12,200	814
4		1.14	0.12		0.35		0.37	0.54	0.23		13,700	1,545
5		1.14	0.17		0.69		0.12	0.50	0.19		15,200	2,333
6		1.07	0.22		1.04			0.25	0.21		16,700	3,172
7		0.98	0.02		1.00			0.50			17,280	4,668
Actual Sorghum Price												
1	0.25	0.88	0.05	0.10	0.36		0.92		0.08		10,700	0
2		1.42	0.08		0.49		1.01				12,200	20
3		1.30	0.11		0.47		0.94		0.09		13,700	788
4		1.06	0.14		0.44		0.76		0.30		15,200	1,648
5		1.07	0.20		0.98		0.29		0.23		16,700	2,946
6		0.98	0.02		1.00				0.50		17,280	4,668
Sorghum Price + 50%												
1	0.25	0.93	0.02		0.08		1.12		0.30		13,700	0
2		1.28	0.17		0.49		0.98		0.03		15,200	596
3		1.05	0.16		0.68		0.53		0.29		16,700	2,099
4		0.98	0.02		1.00				0.50		17,280	4,668
Sorghum Price + 100%												
1		1.14	0.08		0.17	0.06	1.00		0.28		15,200	0
2		1.14	0.13		0.28		1.00		0.22		16,700	407
3		1.14	0.36		0.50		1.00				17,656	1,894

APPENDIX TABLE I.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN PRICE OF NT RICE AND SORGHUM, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)										Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	Sorghum + Ratoon 2nd Crop	Corn HYV 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
						Rice and Sorghum Price - 50%						
1	0.16	0.92	0.08		0.86	0.07				0.34	6,200	0
2		1.45	0.05		1.00	0.31	0.19		0.08		7,700	139
3		1.35	0.07		0.92	0.34	0.16		0.08		9,200	669
4		1.22	0.09		0.81	0.32	0.17		0.19		10,700	1,225
5		1.14	0.12		0.76	0.46		0.04	0.24		12,200	1,861
6		1.14	0.16		0.56	0.75			0.20		13,700	2,644
7		1.07	0.21		0.21	1.07			0.22		15,200	3,499
8		0.98	0.02			1.00			0.50		15,680	4,874
						Actual Rice and Sorghum Price						
1	0.25	0.88	0.05	0.10		0.36	0.92		0.08	0.14	10,700	0
2		1.42	0.08			0.47	1.01				12,200	20
3		1.30	0.11			0.47	0.94		0.09		13,700	788
4		1.06	0.14			0.44	0.76		0.30		15,200	1,648
5		1.07	0.20			0.98	0.29		0.23		16,700	2,046
6		0.98	0.02			1.00			0.50		17,280	4,668
						Rice and Sorghum Price + 50%						
1		1.32	0.10			0.45	0.97		0.08		16,700	0
2		1.04	0.16			0.61	0.59		0.30		18,200	1,631
3		0.98	0.02			1.00			0.50		18,880	4,463
						Rice and Sorghum Price + 100%						
1	0.14	0.93	0.07			0.20	0.79		0.36		18,200	0
2		1.05	0.09			0.25	0.89		0.36		19,700	100
3		1.14	0.36			0.50	1.00				20,856	1,759

APPENDIX TABLE J.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN YIELD OF NT RICE, EXISTING + AVAILABLE NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)									Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Tomato 2nd Crop	Garlic + B. Gourd 2nd Crop	G. Corn 2nd Crop	Corn HYV 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
					Rice Yield - 50%						
1	0.96	0.50		0.42		0.49	0.44			5,200	0
2	0.99	0.51		0.84	0.22		0.43			7,200	167
3	1.11	0.34		1.13	0.32			0.05		9,200	678
4	1.36			1.05	0.31			0.14		11,200	1,434
5	1.31		0.05	0.64	0.72			0.14		13,200	2,517
6	1.28				1.28			0.22		14,883	4,196
					Actual Rice Yield						
1		1.00	0.09	1.06				0.15	0.25	9,200	0
2		1.41	0.09	1.17	0.33					11,200	272
3		1.24	0.12	1.05	0.31			0.14		13,200	1,192
4		1.05	0.16	0.71	0.50			0.29		15,200	2,240
5		1.08	0.23	0.03	1.30			0.18		17,200	3,535
6		0.98	0.02		1.00			0.50		17,280	4,668
					Rice Yield + 50%						
1		1.34	0.11	0.92	0.39		0.20			13,200	0
2		1.35	0.15	0.97	0.53					15,200	946
3		1.25	0.21	0.46	1.00			0.04		17,200	2,199
4		0.89	0.24	0.13	1.00			0.37		19,200	3,492
5		0.69	0.31		1.00			0.50		20,320	4,316
					Rice Yield + 100%						
1		1.38	0.11	1.22	0.14			0.14		15,200	0
2		1.36	0.14	0.97	0.53					17,200	657
3		1.27	0.23	0.37	1.13					19,200	2,024
4		0.75	0.26		1.01			0.49		21,200	3,837
5		0.55	0.45		1.00			0.50		21,838	4,878

APPENDIX TABLE J.2

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN YIELD OF NT RICE, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)										Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Corn HYV 2nd Crop	Garlic + B. Gourd 2nd Crop	G. Corn 2nd Crop	Sorghum + Ratoon 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
Rice Yield - 50%												
1	0.95	0.55			0.50	0.10	0.48	0.32			6,200	0
2	0.99	0.51			0.13	0.20	0.50	0.66			7,700	73
3	0.99	0.51				0.31	0.14	1.05			9,200	191
4	1.32	0.04				0.46		0.91	0.13		10,700	631
5	1.36					0.45		0.91	0.14		12,200	1,289
6	1.30		0.05			0.82		0.53	0.15		13,700	2,409
7	1.28					1.28			0.22		14,882	4,196
Actual Rice Yield												
1	0.25	0.88	0.05	0.10		0.36		0.92	0.08	0.14	10,700	0
2		1.42	0.08			0.49		1.01			12,200	20
3		1.30	0.11			0.47		0.94	0.09		13,700	788
4		1.06	0.14			0.44		0.76	0.30		15,200	1,648
5		1.07	0.20			0.98		0.29	0.23		16,700	2,946
6		0.98	0.02			1.00			0.50		17,280	4,668
Rice Yield + 50%												
1		0.99	0.06			0.04		1.01	0.45		13,700	0
2		1.38	0.12			0.50		1.00			15,200	147
3		1.11	0.15			0.50		0.76	0.24		16,700	1,301
4		0.83	0.17			0.50		0.50	0.50		18,200	2,464
5		0.66	0.22			0.68		0.20	0.62		19,700	3,726
6		0.69	0.31			1.00			0.50		20,321	4,316
Rice Yield + 100%												
1		1.18	0.11			0.31		0.97	0.21		16,700	0
2		1.33	0.17			0.76		0.74			18,200	703
3		1.12	0.22			1.00		0.34	0.16		19,700	2,211
4		0.74	0.26			1.00			0.50		21,200	3,836
5		0.55	0.45			1.00			0.50		21,839	4,878

APPENDIX TABLE K.1

CROP COMBINATIONS ALONG THE E-A FRONTIER WITH INCREASES IN YIELD OF SORGHUM, EXISTING + AVAILABLE + POTENTIAL NEW TECHNOLOGIES, WITH SUBSISTENCE OBJECTIVE

Farm Plan	Area Planted (Hectares)										Expected Income (₱)	Mean Absolute Income Deviation (₱)
	Rice ET 1st Crop	Rice NT 1st Crop	Eggplant 1st Crop	Corn HYV 1st Crop	Garlic + B. Gourd 2nd Crop	Tomato 2nd Crop	Sorghum 2nd Crop	Sorghum + Ratoon 2nd Crop	Eggplant + H. Bean	Corn + H. Bean		
						Sorghum Yield - 50%						
1	0.02	1.05	0.11		0.18	1.00				0.32	9,200	0
2		1.40	0.08		0.36	0.97		0.14	0.02		10,700	98
3		1.25	0.09		0.34	0.84		0.16	0.16		12,200	804
4		1.14	0.12		0.35	0.60		0.31	0.24		13,700	1,518
5		1.14	0.17		0.69	0.50		0.12	0.19		15,200	2,322
6		1.07	0.22		1.04	0.25			0.21		16,700	3,172
7		0.98	0.02		1.00				0.50		17,280	4,668
						Actual Sorghum Yield						
1	0.25	0.88	0.05	0.10	0.36			0.92	0.08		10,700	0
2		1.42	0.08		0.49			1.01			12,200	20
3		1.30	0.11		0.47			0.94	0.09		13,700	788
4		1.06	0.14		0.44			0.76	0.30		15,200	1,648
5		1.07	0.20		0.98			0.29	0.23		16,700	2,946
6		0.98	0.02		1.00				0.50		17,280	4,668
						Sorghum Yield + 50%						
1	0.25	0.93	0.02		0.08			1.12	0.30		13,700	0
2		1.24	0.16		0.41			1.00	0.09		15,200	617
3		1.05	0.17		0.74			0.48	0.28		16,700	2,260
4		0.98	0.02		1.00				0.50		17,280	4,668
						Sorghum Yield + 100%						
1	0.50	0.71			0.17		0.06	1.00	0.28		15,200	0
2		1.14	0.13		0.28			0.99	0.22		16,700	407
3		1.14	0.36		1.00			0.50			17,442	2,507