PN-ABJ-051
73235

631.5
K96

ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station
New Haven, Connecticut

Center Discussion Paper No. 115

Risk Taking and Farmers' Crop Growing Decisions

Howard Kunreuther
University of Chicago

June, 1971

Note: Center Discussion Papers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Discussion Papers should be cleared with the author to protect the tentative character of these papers.

A.I.D.
Reference Center
Room 1656 NS

Risk taking and farmers' crop growing decisions.
631.5 Yale Univ. Economic Growth Center. NTIS
K96 Risk Taking and Farmers' Crop Growing
Decisions. Howard Kunreuther. June 1971.
30 p.
Yale discussion paper no. 115.
Bibliography: p. 28-30.

1. Innovations - agriculture. 2. Crop yields. 3. Farm
management. I. Kunreuther, Howard. II. Title.

Comments Invited

June 1971

Risk-Taking and Farmers' Crop Growing Decisions[1]

by

Howard Kunreuther

1. Introduction

Recently there has been a growing interest by economists in the role uncertainty plays with respect to farmers' allocation decisions. Porter (16) and Wharton (23) have suggested that a farmer will decide whether or not to adopt new innovations by considering both the mean and variance of returns. Mellor (14) has indicated that seasonal fluctuations in prices may lead a farmer to plant a subsistence crop rather than a cash crop which would purchase grain on the market. Falcon (4) and Lipton (10) (11) argue that the variance in prices and yields play a key role in subsistence farmers' planting decisions. Lipton makes the interesting point that the optimizing peasant seeks survival algorithms rather than maximizing ones and supports this contention with empirical evidence from seven months field observations in a small Indian village.

This paper deals with the farmer's crop growing decision at the beginning of a particular season. Specifically we will demonstrate that risk and uncertainty can justify diversification even if land is homogeneous. The analysis will be especially relevant for the subsistence farmer whose cropping pattern will be strongly influenced by a concern for having a large enough return from his land to feed his family. However, the basic

---

[1] This paper was written while I was a research advisor at the Pakistan Institute of Development Economics under the Yale University Pakistan Project. I would like to express my appreciation to my colleagues at PIDE and the Ford Foundation for their valuable comments and suggestions during the period when these ideas were being sown and were maturing. Special thanks goes to my research assistant, Mohammad Ilyas, for his computational assistance.

model can be utilized in structuring a much broader range of problems.

The problem discussed here will be couched in terms of a farmer who must decide at the beginning of a particular season what proportion of his homogeneous land will be allocated to each of two crops. Variance will be used as the sole measure of uncertainty. In this sense the model can be viewed as an extension of mean-variance analysis for specifying optimal portfolios. [See Tobin (20) and Markowitz (12), (13)][1] We have purposely restricted the analysis to the two variable case in order to simplify the theoretical exposition and to relate the results to the jute-rice growing decision facing farmers in East Pakistan. But the general conclusions to be discussed in the final portion of the paper also hold for the multi-variate problem.[2]

2. A Mean-Variance Decision Model for the Farmer

Consider a farmer who must decide what proportion of his land should be devoted to crops x and y given that the net return from each crop j is a random variable J with mean u_j and variance σ_j.

---

[1]Within the past two years there has been a controversy in the literature as to whether mean-variance analysis adequately describes decision makers' behavior. [See Borch (1), Feldstein (5), Tobin (21) and Samuelson (19)]. In order to sidestep this mathematical debate we will argue that decision makers have a difficult time assimilating large amounts of information. Consequently, we will assume that they base their actions on the first two moments of the probability distribution. In the empirical section of the paper we will show that each of the variables of interest can be approximated by a normal distribution which satisfies the mathematical requirements for using only the mean and variance to determine allocation decisions under uncertainty.

[2]After completing this paper I came across an interesting study by Nowshirvani (15a) which discusses the same land allocation problem but under some rather restrictive assumptions. Specifically Nowshirvani determines the optimum proportion of land allocated to each crop if the farmer's utility function is quadratic, prices and yields are independently distributed and the farmer is not permitted to consume more than his minimum food requirements. The models to be developed here introduce risk through probabilistic constraints rather than by an explicit utility function, the net return from the two crops in any one year can be positively or negatively correlated and the farmer is allowed to consume more than his minimum requirements.

Let Z be a random variable representing the net return per unit of land when m is the proportion of total acreage devoted to crop x. Thus

$$Z = mX + (1-m)\ Y$$

with mean μ_z and variance σ_z^2

We will first treat the case where $\mu_x = \mu_y$ to see how the coefficient of correlation (ρ) between X and Y determines the proportion of land allocated to each crop. The more interesting case where both the expected returns and variances of the two crops differ will then be analyzed:

a. Minimizing the Variance

When $\mu_x = \mu_y$ then the farmer who is a risk averter wants to find the value of m which minimizes σ_z^2 where

$$\sigma_z^2 = m^2\ \sigma_x^2 + (1-m)^2\ \sigma_y^2 + 2\ \rho m(1-m)\ \sigma_x\ \sigma_y \qquad (1)$$

$$0 \leq m \leq 1$$

$$-1 \leq \rho \leq 1$$

Setting $d\sigma_z^2\ /\ dm^2 = 0$ in (1) we obtain the following simple expression for the value m^* which minimizes variance

$$m^* = (1 - \rho w)/(1 - 2\rho w + w^2) \qquad (2)$$

$$\text{where } w = \sigma_x\ /\ \sigma_y$$

Since $0 \leq m \leq 1$ the following boundary solutions are found directly from (2):

$$m^* = 1 \qquad \text{if} \qquad w \leq \rho$$

$$m^* = 0 \qquad \text{if} \qquad w \geq 1/\rho$$

Given ρ there will thus be a range of values for w where the farmer will want to grow crops x and y, as seen graphically in Figure 1.

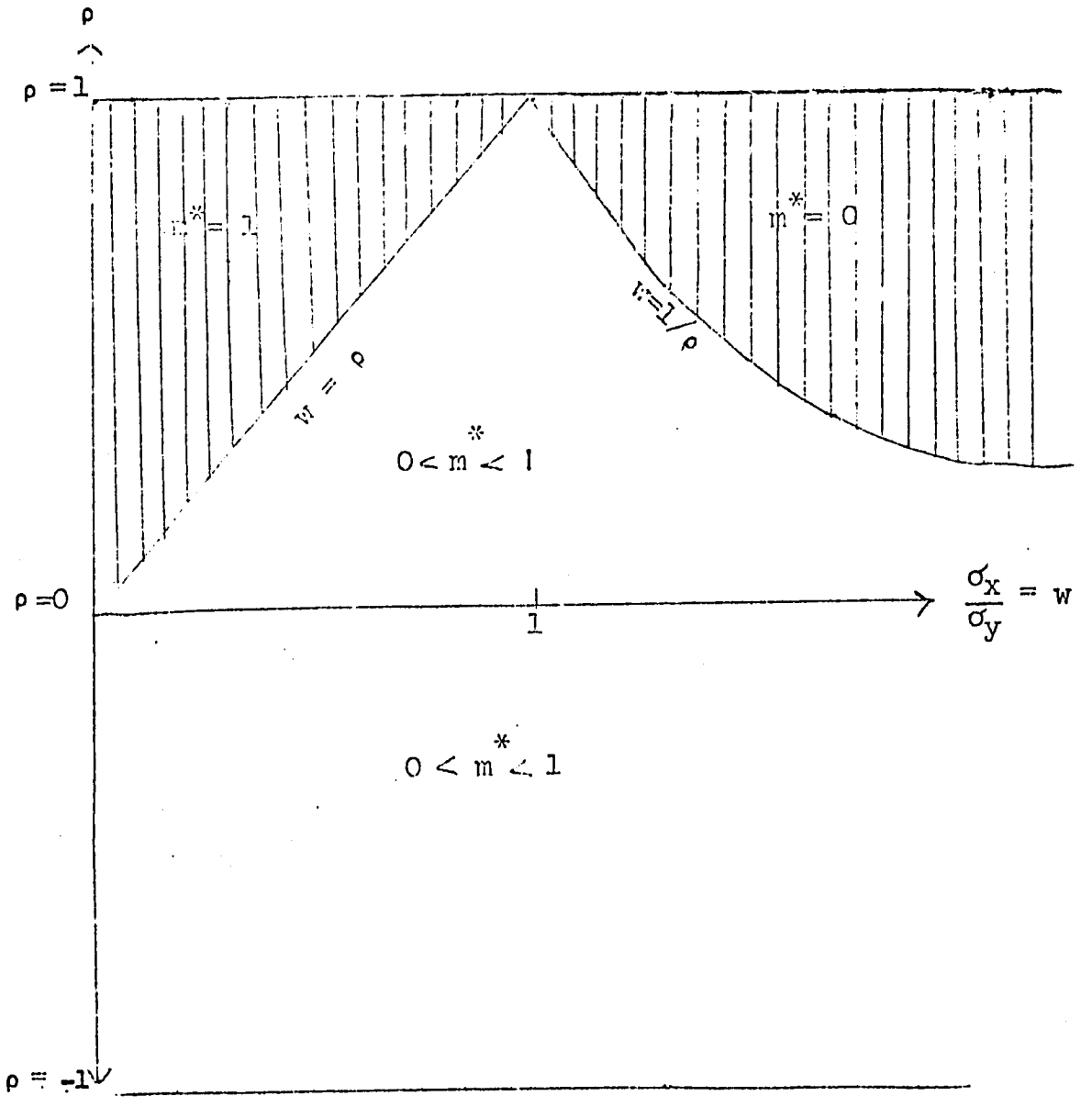


Figure 1

Specifically if $\rho < w < 1/\rho$ (the non-shaded area in the diagram) then the farmer will want to cultivate some land (perhaps very little) with the high variance crop. Only when the ratio σ_x / σ_y is sufficiently high or low to counteract the less than perfect correlation between the return from the two crops will the farmer prefer not to diversify at all.[1]

b. Differences in Expected Returns

The problem becomes more interesting and relevant if the crops have different expected returns as well as variances. Every value of m then implies a specific point in the μ_z - σ_z plane and all feasible points taken together form an opportunity locus illustrated by the curve OL in Figure 2. If the peasant had unlimited reserves at his disposal and wanted to maximize long-run expected profits then he would devote his entire land to the crop with the highest expected net return no matter what the shape of the opportunity locus. But most farmers are not in this enviable position and short-run considerations may lead them to diversify. To see this in more concrete terms, let us postulate that the optimal value of m is chosen so as to maximize the return per unit of land at a point t standard deviations from the mean. In other words the objective function becomes

$$\max \quad \{\mu_z - t\sigma_z\} \tag{3}$$

[1]The risk-lover, on the other hand, will never want to diversify when $\mu_x = \mu_y$ since σ_z^2 is maximized at the extreme values of m. His decision rule will thus be $m^* = 0$ if $\sigma_x < \sigma_y$, $m^* = 1$ if $\sigma_x > \sigma_y$ and indifference between planting only x or y if $\sigma_x = \sigma_y$.

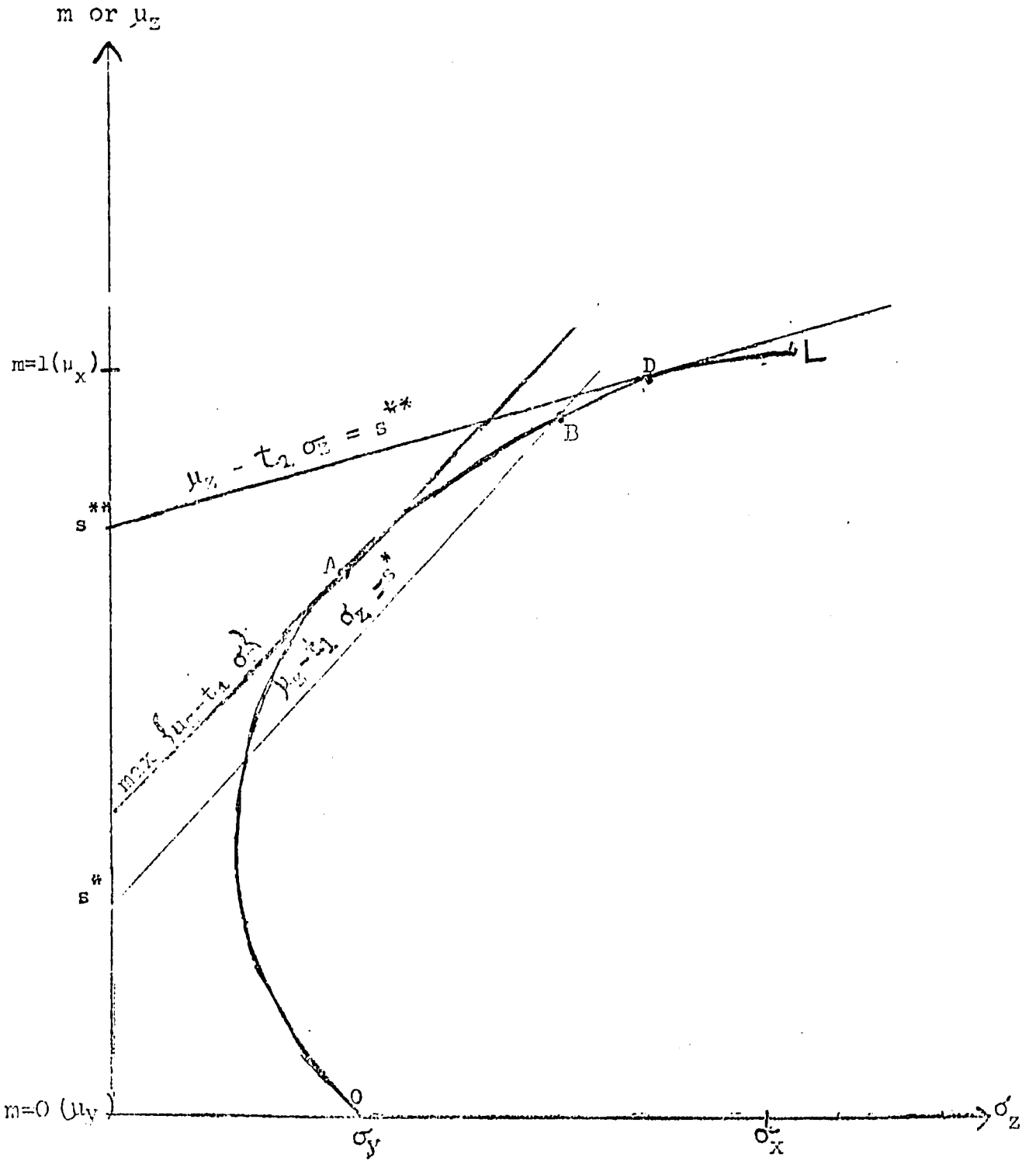

m or μ_z
m=1(μ_x)
s^{**}
s^{*}
m=0 (μ_y)
$\mu_z - t_2 \sigma_z = s^{**}$
$\mu_z - t_2 \sigma_z = s^{*}$
max $\{\mu_z - t_2 \sigma_z\}$
A
B
D
L
O
σ_y
σ_x
σ_z

Figure 2

with the value of t used as a proxy for the risk level α .[1]

The objective given by (3) implies that the farmer is following a type of minimax strategy by sacrificing some long-run expected profits in order to maximize the minimum return at a given risk level.[2] Farmers who have large reserve stocks and/or supplementary income from sources outside of their own land will most likely choose a lower value of t than subsistence farmers who depend almost entirely on the return from their land for their income.

To determine the optimal value of m^* which satisfies (3) we need only construct a set of indifference lines in Figure 2 of the form $\mu_z - t\sigma_z$. The farmer would like to be on the highest indifference line that still touches the opportunity locus, OL. As t becomes smaller the indifference line becomes more horizontal and m^* will be determined primarily by expected return considerations. Conversely as t increases, so that the indifference lines become steeper, the proportion of land devoted to each crop will be determined primarily by the variance component, σ_z.

---

[1]If Z is distributed as a normal variate then a risk level $\alpha = .05$ would correspond to $t = 1.645$. There would thus be a 5% chance that the return per acre would fall below $\mu_z - t\sigma_z$ units.

[2]This criteria is analogous to the one which Ratna (18) has found to be satisfactory in describing land use patterns in India. He used a game theoretic approach modeled after Davenport (2) to examine farmers' crop growing decisions in six districts of the country.

Suppose a specific risk level, α_1, corresponds to t_1 standard deviations from μ_z. Then the farmer will maximize $\{\mu_z - t_1 \sigma_z\}$ at point A in Figure 2 and will grow both crops x and y. For this example the farmer would want to grow only crop x if the slope of the indifference line, t , is less than or equal to the slope of OL at m = 1 denoted by t^* where

$$t^* = d\mu_z \,/\, d\sigma_z\Big|_{m=1} = (\mu_x - \mu_y)/(\sigma_x - \rho\sigma_y) \qquad (4)^1$$

The objective function given by (3) will not be appropriate for describing the crop-growing decisions of a subsistence farmer whose chief concern is receiving a return of at least s per unit of land with a certain probability. The value of s will be determined by consumption needs, reserves on hand at the time of planting and expected sources of income other than from the crops in question. His objective might then be to

$$\max\ (\mu_z) \qquad (5a)$$

subject to (5)

$$\text{Probability } (Z \leq s) \leq \alpha \qquad (5b)$$

1

$$\frac{d\mu_z}{d\sigma_z} = \frac{d\mu_z \,/\, dm}{d\sigma_z \,/\, dm} = \frac{\mu_x - \mu_y}{\dfrac{m\sigma_x^2 - (1-m)\,\sigma_y^2 + \rho(1-2m)\,\sigma_x\,\sigma_y}{[m^2\sigma_x^2 + (1-m)^2\,\sigma_y^2 + 2\rho(1-m)m\,\sigma_x\,\sigma_y]^{1/2}}}$$

$$\frac{d\mu_z}{d\sigma_z}\Big|_{m=1} = \frac{\mu_x - \mu_y}{\sigma_x - \rho\sigma_y}$$

where α is again a measure of the risk level.[1] If t is used as a proxy for α then (5b) can be written as

$$\mu_z - t\,\sigma_z \geq s$$

and the optimal value of m can be obtained directly from a diagram such as Figure 2. For a value of $t = t_1$ and $s = s^*$ the farmer will choose the combination of x and y given by point B. Suppose the minimum return increases to s^{**} so that the farmer cannot satisfy equation (5b). He must then either reduce his return per acre to the value implied by point A in Figure 2 or he must increase his risk level to α_2 and follow the policy implied by point D. If s represents the minimum return required for survival then the farmer would have to follow the latter alternative. He may then be forced to gamble by growing a larger proportion of the crop with the higher expected return than he would have if s had assumed a somewhat lower value. Thus from Figure 2 we see that the value of μ_z implied by s^{**} (point D) is greater than μ_z implied by s^* (point B) despite the fact that $s^{**} > s^*$. It is thus conceivable that extremely rich and poor farmers will follow a similar cropping pattern but for entirely different reasons. The rich farmer can afford to tolerate a higher variance in return for greater expected benefits; the poor farmer requires a higher expected return in order to feed his family and thus is forced to increase the risk of not having enough to meet his needs.

---

[1] If the minimum required return is low enough then the farmer will devote his entire land to the crop with the highest expected return. Then his risk level may actually be less than his desired value of α in which case (5b) becomes $Pr(Z \leq s) < \alpha$. Whenever s is high enough so that μ_z is constrained to be less than its theoretical maximum then (5b) will be $Pr(Z \leq s) = \alpha$.

c. Summary

On the basis of this theoretical discussion we can provide a preliminary answer to the question - When will a farmer want to diversify his land? Individuals who desire a low risk level, α , and/or require a high minimum return, s, will very likely want to grow more than one crop simultaneously on their land. Their actual decision will, of course, depend on the relative means and variances of the crops as well as the correlation coefficient of the returns. For the two crop problem the farmer will be most interested in diversification if the crop with the higher expected return also has a higher variance and when the coefficient of correlation between X and Y is negative.

3. The Jute-Rice Planting Decision in East Pakistan

a. Setting the Scene

The theoretical model discussed in the last section has a direct application to East Pakistan where farmers must decide how much of their land should be allocated to jute and the aus variety of rice. Aus is sown between the middle of February and the middle of April while jute is planted between early March and early May. Both crops are harvested between July 1st and early October. Their characteristics are such that, in general, land, labor and equipment are readily interchangeable between their cultivation. There is some land suitable only for growing rice or jute alone, but these areas are very small compared to the land where a decision must be made. For most farmers in the jute belt, the choice is thus between cultivation of the

stable food crop (rice) or a cash crop (jute) whose proceeds can be utilized for purchasing consumption needs.[1]

In East Pakistan jute and rice are both predominantly grown by farmers with limited holdings. Although the average size of jute growers' plots is somewhat larger than the average of all farmers' holdings, it rarely exceeds ten acres with 3 to 6 acres being the most common size.[2] We are thus dealing with a problem facing the subsistence farmer.

There has been a surprisingly large number of studies by economists dating from the 1930's which have analyzed the changes in jute acreage observed annually in India and Pakistan. Most authors have suggested that the farmers' decision on what proportion of their land to plant with jute and rice in year t is largely determined by the jute/rice price ratio in year t - 1. They have provided statistical evidence for this cobweb-type behavior by showing that there is a significant relationship between last

---

[1]Although we will treat jute as a single variable there are actually two varieties of the crop: White jute grows equally well on high land (normally no flooding) or low land (subject to flooding), while tossa jute is grown only on high land since it does not tolerate flooding. In East Pakistan white jute normally accounts for 2/3 of the total production. Tossa jute is normally of finer quality and therefore commands a higher price than white jute but is subject to severe fluctuations in yield due to weather variability. The available statistical data does not distinguish between the two varieties.

[2]For a more detailed description of the economic characteristics of those farmers who grow jute and rice see Rabbani (17) and Economy of Jute (27).

year's price ratio and this year's relative acreage.[1] These findings are interesting but they make the heroic assumption that uncertainty with respect to either the yields or the prices of jute and rice are not critical to a farmer's decision.

The mean-variance model of the previous section provides an alternative way of looking at the problem while still recognizing the importance of last year's jute/rice price ratio. If we assume that a farmer's crop growing decision is affected by reserves on hand, then a relatively high jute/rice price ratio in year t - 1 will provide the farmer with excess cash at the beginning of year t. The empirical evidence to be presented in this section suggests that jute has a higher net return but also a higher variance than rice. Hence the farmer is likely to plant a larger proportion of his land with jute in year t if the jute/rice price ratio was high in t - 1--the larger buffer stock enables him to incur greater risks in exchange for an increase in net expected return. The reverse argument can be made if the jute/rice price ratio is low in year t - 1.

---

[1]Two of the most recent papers on the subject are Hussain (7) and Rabbani (17). Hussain uses regression analysis to test a simple model where the proportion of land allocated to jute this year is a function solely of last year's jute/price ratio. Rabbani formulates the problem in terms of distributed lags so that decreasing weights are given to price ratios further back in time. However, from his regression results he concludes that "the principal determinant of jute acreage in India or Pakistan is the jute farmer's expectation of the relative price of jute and rice that is largely based on the preceding season's ratio of the two." [(17) p. 221]

b. Developing a Model

Since most farmers in East Pakistan are at a subsistence level their decision as to how they should divide their land between jute and rice is determined principally by a concern for having enough to feed their families over the next year.[1] If they decide to grow rice they can consume the crop directly and hence must only worry about the variability of the rice yield over time. On the other hand, if they plant jute then they must sell the crop and use the proceeds to purchase rice. In this case they are affected not only by jute yield variation but also by fluctuations in the selling price of jute and the retail price of rice over time. Given our concern with minimum consumption requirements, rice will be treated as a numeraire good and the net return from jute will be converted into an equivalent yield of rice. The following notation will enable us to structure the analysis.

j = yield of jute per acre (in maunds)

r = yield of aus rice per acre (in maunds)

P_j = price per maund of jute at the grower's level

P_r = retail price of rice per maund

C = cost differential per acre of growing jute rather than rice

---

[1]Evidence on this point has been provided by Hussain (8).

Letting X and Y represent the net return from jute and rice respectively, we can define

$$X = (jP_j - C)/P_r \tag{6}$$

$$Y = r \tag{7}$$

The random variable X represents the net yield of jute in terms of rice under the assumption that the entire proceeds of jute are used to purchase rice. In reality the cash from some of the jute may be used for other purposes. For this portion of the jute crop the harvest price of rice would be the appropriate divisor in (6). There may be a substantial difference between the two prices; however, since we have assumed that the minimum consumption constraint is the critical factor affecting the crop-growing decision it is appropriate to use the retail price of rice for conversion purposes.

Letting $Z = mX + (1 - m)Y$ the problem is converted into the notation of the previous section and the optimal value of m can be determined either by the objective function specified by (3) or the model defined by (5).

To illustrate the analysis, data has been assembled on rice yields and jute returns for the Faridpur district, one of the largest jute-growing regions in East Pakistan. If the variables of interest do not show any trend over time then one can estimate the mean and variance using all the sample data.

For aus rice this criterion appears to be satisfied as seen from Figure 3 where yields have been plotted from 1947-48 through 1969-70.[1] We can thus compute μ_y and σ_y directly from the values displayed in this diagram.[2]

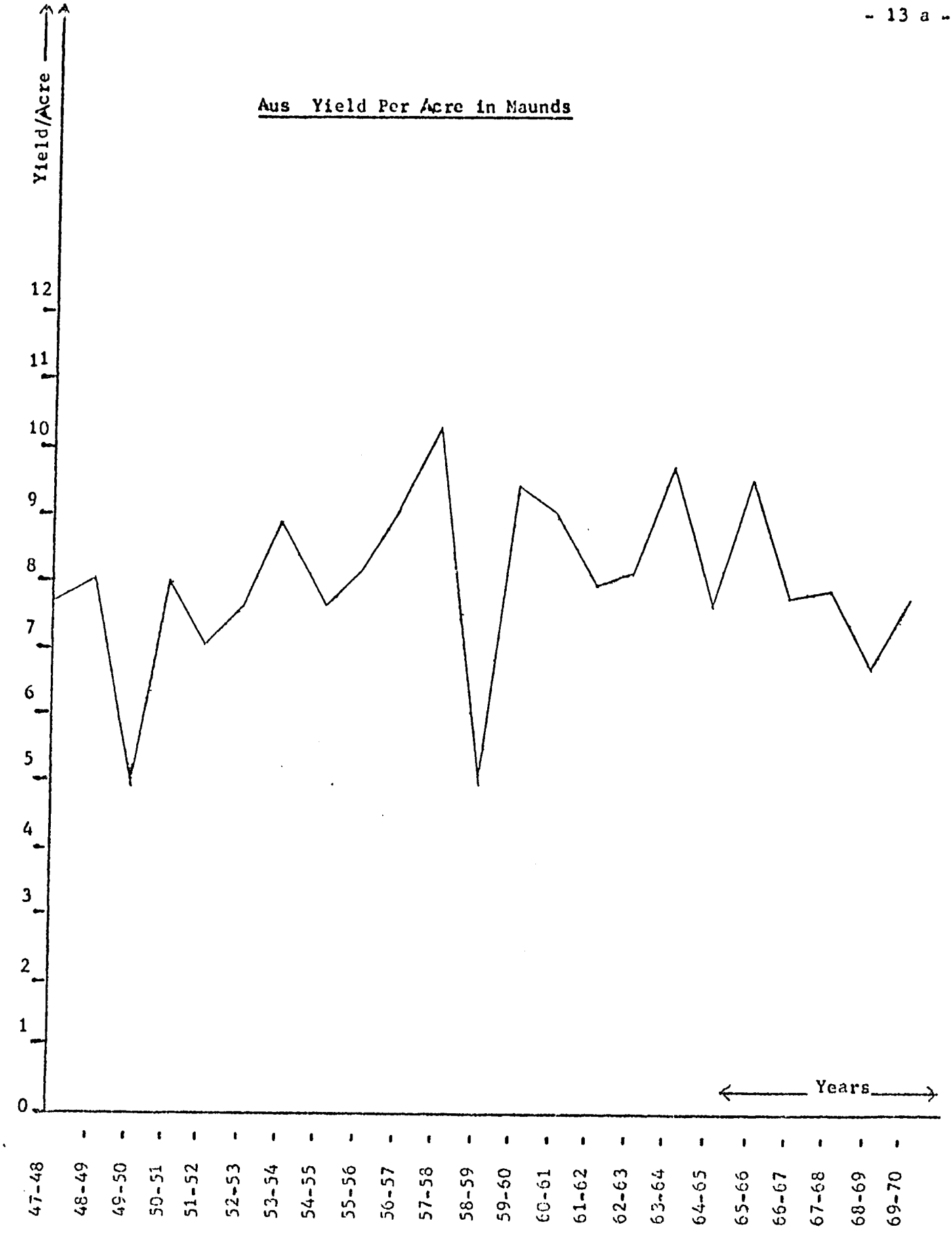
The random variable X does not present such a neat picture. Although one of its components, the return from jute (jP_j), has not displayed any definite trend over time as seen from Figure 4, the other variables have special problems associated with them. Rice prices have followed an almost continuously upward trend since 1957 as shown in Figure 5 where data has been plotted on the average retail price of rice at Dacca and the internal procurement price of coarse milled rice in the villages. The standard deviation of either series would be meaningless unless the figures were adjusted for trend.

An estimate of the cost differential, C, between growing rice and jute also poses problems. To my knowledge the only detailed figures currently available are from a comprehensive

---

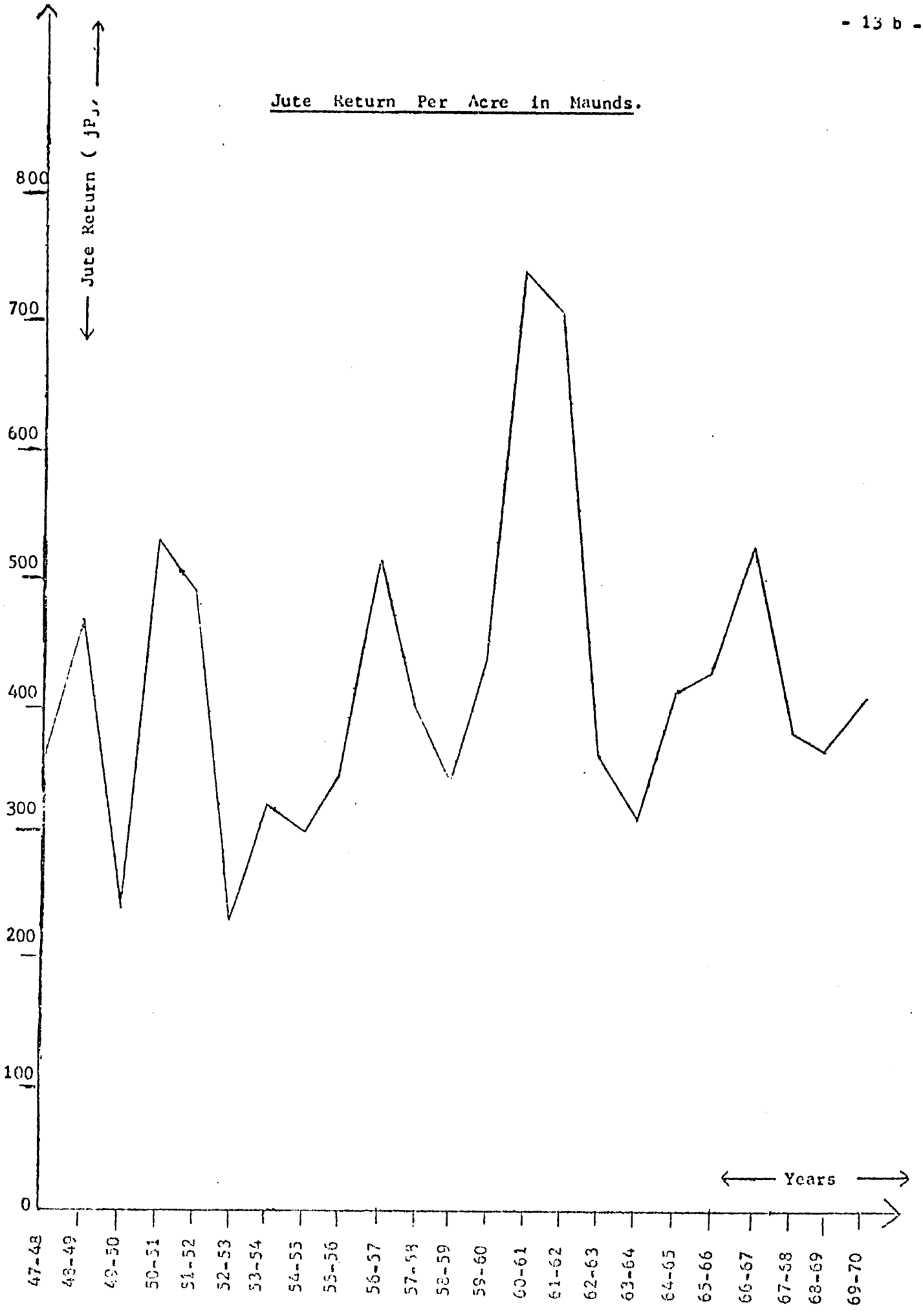
[1]The crop year starts on July 1 and terminates on June 30. The harvest months of a crop determines the year for which its estimates refer.

[2]Recently efforts have been made to introduce new varieties of rice into East Pakistan which will produce significantly higher average yields. [Efferson (3) pp. 3-5] Farmers using these special Irri seeds would not be able to rely on the earlier figures as guides to the mean and variance of the aus yield However, the amount of Irri aus grown in 1969-70 for East Pakistan was only 0.5% of the total aus rice acreage.

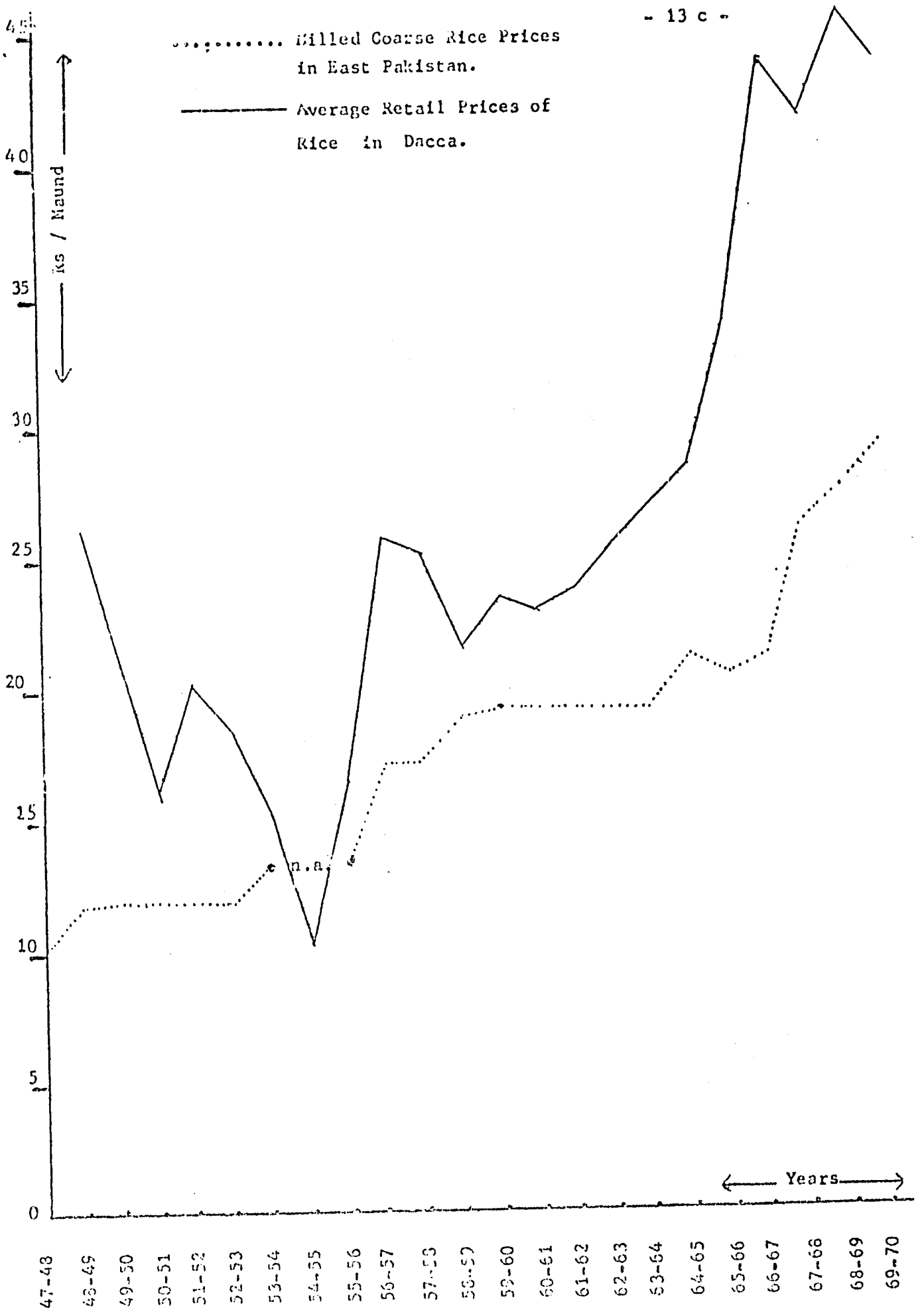


Aus Rice Yield for Faridpur (1947 - 70)

Figure 3



Jute Return for Faridpur District (1947 - 70)



Prices of Rice in East Pakistan (1947 - 70)

n.a. = not available

Figure 5

survey of 142 small farmers in the Phulpur area (a part of Mymensingh district) taken during the 1969-70 season.[1] There the cost of cultivating jute exceeds the cost of producing aus by an average of 93 rupees per acre (172-79 rupees) but the difference may be as low as 28 rupees (for very small farms) and as high as 110 rupees (for larger farms). Most of the cost discrepancy between farms lies on the labor side. Jute requires considerably more human labor in its cultivation and harvest than rice does. Hence if the family has surplus manpower available the cost differential between the two crops will be close to zero. If they are forced to hire more workers for a short period of time then the value of C will be quite high.

Given the above data limitations, we will treat $V = jP_j$ as the random component of X with its mean μ_v and standard deviation σ_v determined by the figures plotted in Figure 4. Both P_r and C will be point estimates based on latest available figures so that the relevant statistical moments of X are

$$\mu_x = (\mu_v - C)/P_r \quad \text{and} \quad \sigma_x = \sigma_v / P_r$$

In summary, the model we have postulated with respect to jute and rice planting decisions assumes that the farmer uses time series data to estimate the mean and variance of rice yields and

---

[1]Irshad Khan of the Pakistan Institute of Development Economics was kind enough to assemble the cost figures for me. Surveys were also undertaken in Demra in Dacca district and Thakurgaon in Dinajpur district but these data have not yet been completed. For a more detailed description of the general purpose of this study and preliminary findings see Khan (9).

jute returns while relying on the most recent data to predict next season's price of rice and the cost differential between jute and rice. The approach thus combines elements of the mean-variance analysis of portfolio theory with the cobweb models which have been traditionally used to predict the allocation of land between jute and rice.

c. Analysis of the Data

Table I summarizes the statistical information for jute and rice in the Faridpur district based on published agricultural data from 1947-48 through 1969-70.

Table I

	Jute (X)	Rice (Y)
Number of observations	23	23
Sample mean (μ)	$\frac{419-C}{P_r}$	8.1
Sample standard deviation (σ)	$\frac{124}{P_r}$	1.24
Coefficient of correlation between X and Y (ρ)	.27	
Coefficient of Skewness (γ_1)	1.0	.34
Coefficient of Excess (γ_2)	.84	.51
Chi-square value (χ^2)	4.19	2.36
(Significance Level)	(.24)	(.50)

For a normal curve both the coefficient of skewness and the coefficient of excess are zero. The values of γ_1 and γ_2 indicate that both X and Y have some skewness and kurtosis; however, their chi-square values are sufficiently low to warrant the conclusion that the samples could have come from populations having a normal distribution.[1] Hence only two parameters--mean and variance--are needed to determine the optimal crop growing decision.[2]

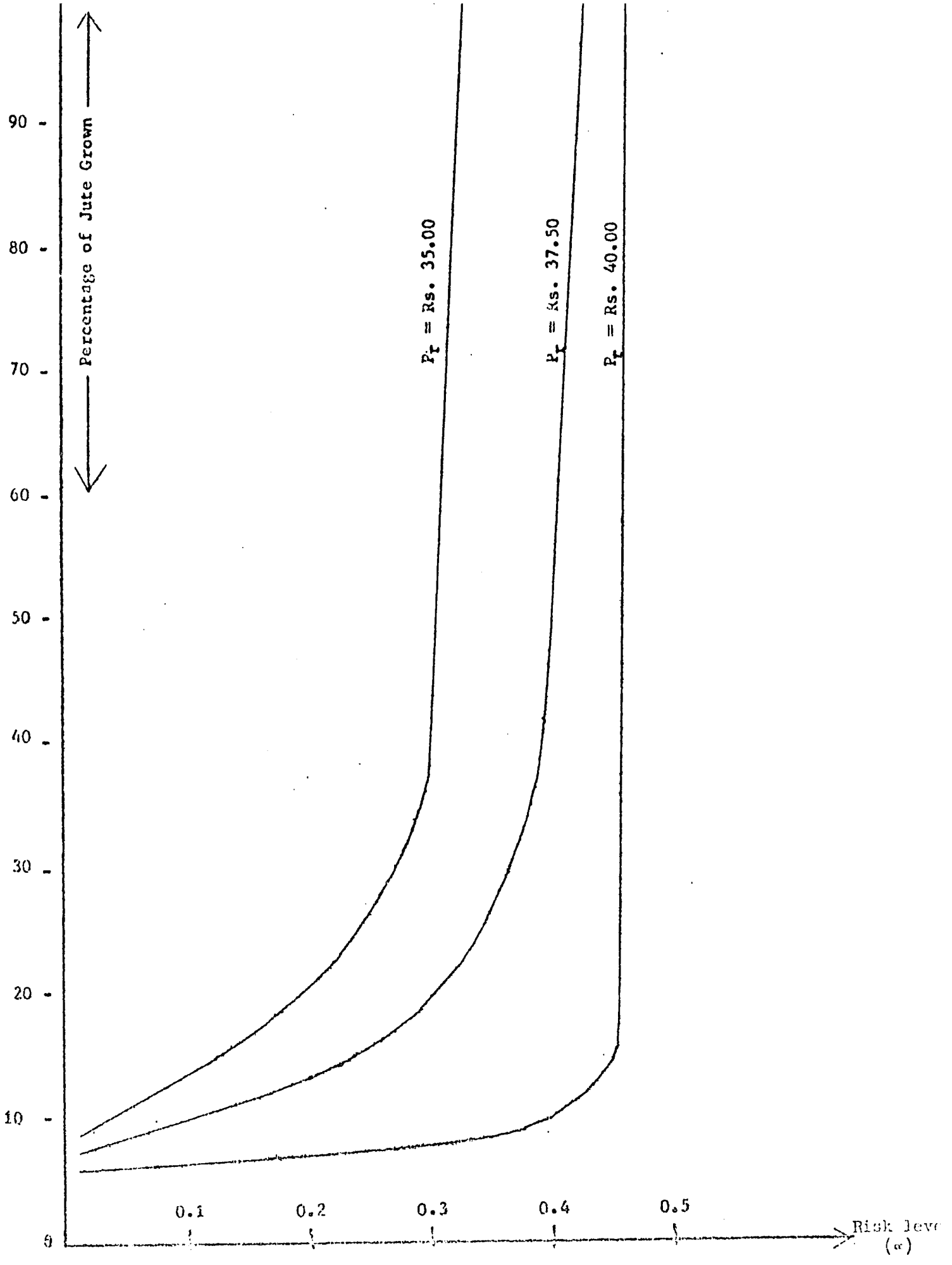
Let us now turn to the actual decision. A farmer who follows the minimax strategy implied by (3) will allocate his land between jute and rice on the basis of his risk level, α. On the other hand, if model (5) depicts his behavior then both s and α will influence his actions. We will first examine the case where the objective function is given by (3) to see how the proportion of jute and rice grown varies with the risk level. Figure 6 shows how sensitive the decision is to changes in the price of rice (P_r) assuming the average cost differential of C = 93. According to a recent survey of rice prices in East Pakistan during 1970, [Efferson (3)], farmers in villages were paying anywhere from 35 to 40 rupees per maund for rice[3] so

---

[1]In making the chi-square test we chose six intervals of equal length for both X and Y.

[2]We are implicitly assuming that there is no autocorrelation in either X or Y. The time series plots of Figures 3 and 4 support this point.

[3]This range is still below the average retail price of 43.83 rupees per maund in the Dacca market during 1969-70. The reduced village price may be explained by lower transportation costs and perhaps discounts to farmers for bulk purchases.



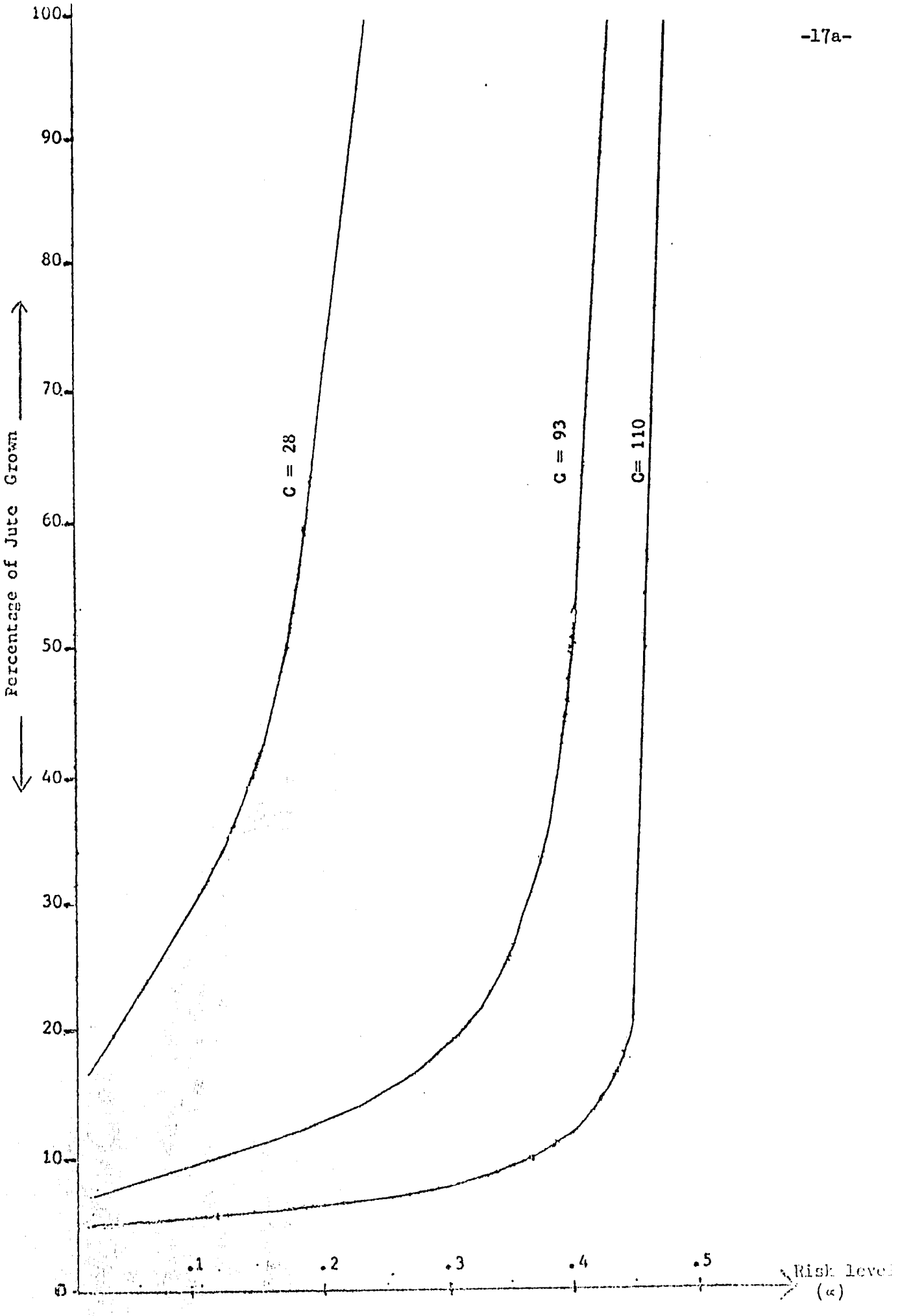
Effect of Retail Price of Rice on Per Cent of Jute Planted for C = 93

Figure 6

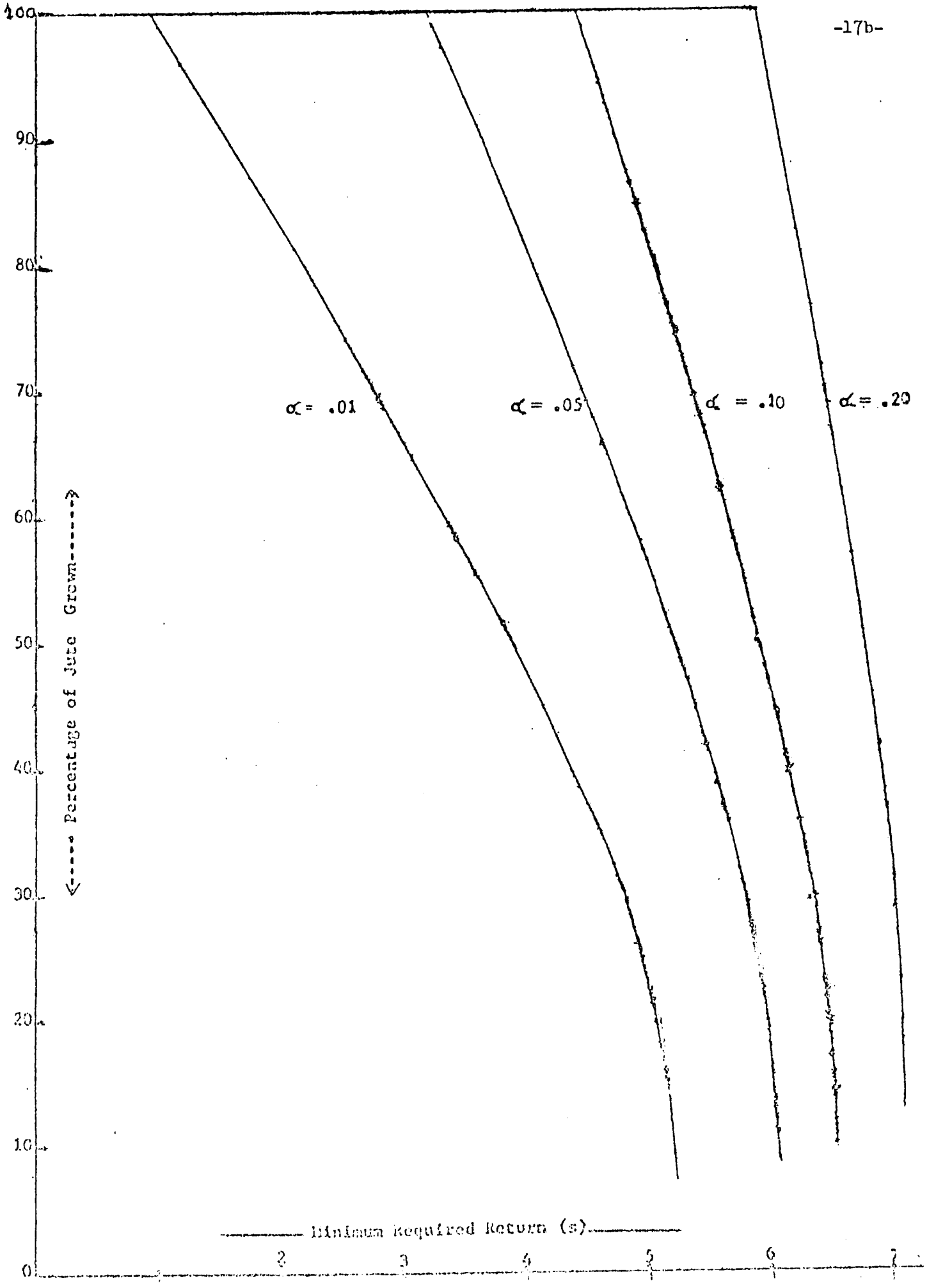
that P_r takes on values of 35, 37.5 and 40 in Figure 6. We see that the farmer's decision on how much jute to plant is very sensitive to his estimate of the retail price of rice. Consider the case where $\alpha = .20$. If $P_r = 40$ he will plant only four per cent of his land with jute while if P_r falls to 35 the percentage of land devoted to jute will rise to 21%.

The same type of analysis for variations in the value of C is presented in Figure 7 assuming a price of rice equal to 37.5. The three values of C represent a minimum, average and maximum cost differential for individual farmers in the Phulpur area. The proportion of jute planted is quite sensitive to the cost differential between cultivating and harvesting the two crops. For example, at a risk level of $\alpha = .10$ the proportion of land devoted to jute increases from 6% to 31% as the value of C decreases from 110 to 28 rupees per acre.

The implications of a minimum return constraint, s, are shown graphically in Figure 8. Here the proportion of land devoted to jute is plotted as a function of s for four different risk levels when $P_r = 37.5$ and $C = 93$. The crop growing decision is quite sensitive to changes in the minimum return. For example, if $s = 6.0$ and $\alpha = .05$ then the farmer would plant approximately 20% of his land with jute; for the same risk level but a value of $s = 5.5$ he would increase the proportion of his land devoted to jute to 47%. Figure 8 also shows when the minimum return constraint cannot be satisfied. Specifically if the farmer wants his risk level to be $\alpha = .05$ then he will <u>not</u> be able to set $s > 6.1$. At the other extreme if $\alpha = .05$ then a value of $s \leq 3.2$ will permit the farmer to plant only jute and hence maximize his expected return while still satisfying the minimum return constraint given by (5b).



Effect of Cost Differential on Percent of Jute Planted for P_r =37.50



Effect of Minimum Required Return on Percent of Jute Planted for E_r = 37.50 & C = 93

Aside from the preliminary results of the Small Farmer's Survey described by Khan (9) little data is available on individual farmer behavior in East Pakistan so it is difficult to compare the actual cropping pattern with the values implied by Figures 6 through 8. However, a crude test of the model can be made using aggregate data. In Table II we have ranked the 11 principal jute growing districts in East Pakistan on the basis of the average percentage of area devoted to jute over the years 1965-66 through 1969-70.[1] If uncertainty plays a role in farmers' crop growing decisions then some measure which incorporates the variance and correlation between rice and jute would rank these districts more accurately than a measure based solely on the difference in expected returns. We have seen from (4) that the farmer will plant his entire land with jute only if $t^* = (\mu_x - \mu_y)/(\sigma_x - \rho\sigma_y) > t$. The larger the value of t^* the larger the proportion of land the farmer will devote to jute at any given risk level α. The value t^* thus indicates the effect of expected return and variance on the farmer's decision. We have ranked each of the districts with respect to this ratio in Table II, the region having the highest value of t^* being ranked number one. The rank correlation between the actual percentages and the predictions based on t^* is R = .851, significant at the .0001 level. If these districts are ranked solely on the basis of differences in expected return then R = .318, a value not significantly

---

[1] We have included all districts where the average jute acreage between the years 1965-66 and 1969-70 has been over 50,000.

Table II

Ranking of Principal Jute Growing Districts in East Pakistan by Average Percentage of Aus-Jute Land Devoted to Jute

District	Average Actual Percentage (1965-1970) (a)	Rank	$t^* = \frac{\mu_x - \mu_y}{\sigma_x - \rho\sigma_y}$ (b)	Rank	$\mu_x - \mu_y$ (b)	Rank
Kishoreganj	44.5	1	0.99	2	1.29	9
Dacca	33.4	2	0.83	4	2.05	5
Faridpur	31.6	3	1.05	1	3.11	1
Mymensingh	28.5	4	0.84	3	2.36	3
Comilla	26.3	5	0.81	6	2.41	4
Rangpur	25.9	6	0.56	9	1.61	7
Bogra	22.6	7	0.74	7	1.74	6
Pabna	21.0	8	0.82	5	2.84	2
Dinajpur	20.8	9	0.41	10	0.82	11
Jessore	19.8	10	0.62	8	1.48	8
Rajshahi	18.1	11	0.37	11	0.93	10

Rank correlation between Actual and t^* R = .851

Rank correlation between Actual and $\mu_x - \mu_y$ R = .375

Source: (a) Bureau of Agricultural Statistics, Government of East Pakistan.

(b) Based on $p_r = 37.5$ $C = 0$ using data from 1947-70 The rankings are independent of the value of C.

different from zero at the .20 level.[1] It is interesting to note that t^* provides an accurate ranking despite the simplifying assumptions of identical prices, costs and the same population density for all districts.[2]

Aggregate data is also available from the last agricultural census (1960) on the relationship between jute acreage and size of farm in East Pakistan. Farms under 2.5 acres devoted 16.0 per cent of their aus-jute land to jute while those farms with more than 2.5 acres planted jute on only 15.2 per cent of their land.[3] This result suggests that poorer farmers may have to gamble so that they have enough to feed their families for another season. Other factors may play a role in this decision. If the farmer needed cash for other purposes such as repaying old debts, then the harvest price rather than the retail price would be the relevant figure to use. During 1969-70 the price of aus paddy was about 20 rupees per maund while coarse milled rice was marketed at about 30 rupees. Either of these prices would lead to a higher proportion of jute grown than if the retail price of rice was used. Small farms are also likely to have

---

[1]A t-test was used to specify the significance of the rank correlation coefficient. If R is the rank correlation coefficient from a sample of size n and the hypothesis is correct that the population rank correlation coefficient is zero then $t = R[(n-2)/(1-R^2)]^{1/2}$ conforms to the t - distribution with n-2 degrees of freedom.

[2]The mean-variance model suggests that if other factors remain the same, the percentage of jute land declines as its population density increases. Published data is not available on jute-aus land densities by district, so this hypothesis could not be tested empirically.

[3]For more detailed figures on the jute and rice acreage in East Pakistan see (31) Tables 24 and 26. The above jute percentages are lower than those presented in Table II because they are based on all the districts in East Pakistan.

surplus labor so that the cost differential, C, would be lower and hence encourage peasants to grow more jute.

d. Policy Implications

The analysis presented in the paper sheds some light on the effect of population growth on crop growing decisions. In East Pakistan this is a particularly pressing problem as the population has increased by almost 50% in the past 20 years.[1] Specifically a decrease in an individual farmer's land holdings requires him to increase his required minimum return per acre by a proportionate amount. Hence he will want to grow more of the low variance crop, sacrificing some expected return for greater security.

Some form of guaranteed government support when there is a bad year may enable the farmer to increase the expected return from his land. Suppose he has A acres available for jute or aus rice and is willing to plant mA with jute and (1-m)A with rice. If the government provides him with a guarantee of H maunds of rice whenever the per acre jute return is below a critical level, then he will plant m^*A acres of jute where $m \leq m^* \leq 1$. If the farmer wants to receive <u>at least</u> the same net expected return from his land as before, he will be prepared to pay an annual insurance premium of up to $(m^* - m)(\mu_x - \mu_y)P_rA$ rupees for this government guarantee.

To illustrate the implications of such a crop insurance program, suppose that under the current system a farmer from Faridpur with A acres requires a minimum return of s = 6.0 at a risk level α = .05. Figure 8 indicates that if C = 93 and P_r = 37.5 he will plant

[1]The Pakistan Central Statistical Office estimates that the population of East Pakistan has increased from 42 million in 1951 to 61 million in 1970. See (30), p. 2.

twenty percent of his land with jute. Suppose the government offers a guarantee of 11 maunds of rice per family whenever there is a bad jute year. The farmer may then revise his required minimum return to $s = 5.5$ and increase his risk level to $\alpha = .10$. Looking at Figure 8 we see that the proportion of jute he grows will increase to $m^* = .65$ and the farmer will be prepared to pay up to $(.65 - .20)(8.7 - 8.1)\ 37.5A = 101.25A$ rupees per year for this guarantee.

Such a crop insurance system would not only make a great deal of sense to the individual farmer but also to the nation if jute has a comparative advantage over rice. Specifically if the foreign exchange received from an acre of jute more than offsets the cost of importing an acre's worth of aus rice then Pakistan should provide incentives for farmers to grow more jute. Such a trade comparison is made in Table III. The figures for the aus rice and jute crops are based on the average yield for East Pakistan during the 1969-70 season. Coarse rice of a somewhat higher quality than that grown in East Pakistan is currently selling f.o.b. Bangkok at about $3.65 per maund so we have used a figure of $4.00 per maund as an estimate of the delivered price in East Pakistan. During the 1969-70 season the average price of raw jute f.o.b. at Dacca was $9.40. With the higher yields of jute over rice and its comparative price advantage the benefits of devoting more land to jute are obvious. For each acre of rice land transferred to jute Table III shows that the net foreign exchange earnings will be more than $95.

Several qualifying remarks are in order. We have implicitly assumed that the increase in the supply of jute or the demand for rice would not affect the world market price of either commodity.

Table III

Foreign Exchange Advantage of Growing Jute Rather than Aus Rice in East Pakistan (1969-70)

	Jute	Aus Rice
Yield per Acre (in Maunds)[a]	14.15	9.40
World Price (per maund)	$ 9.40[b]	$ 4.00[c]
Dollars per acre	$ 133.00	$37.60
Net Foreign Exchange Earnings per Acre of Jute	$ 95.40	

Sources:

(a) Bureau of Agricultural Statistics (26)

(b) Monthly Foreign Trade Statistics of Pakistan (28)

(c) Efferson (3)

It is hard to quibble with this assumption for rice since East Pakistan in 1970 purchased much less than one per cent of the supply of the crop on the world market[1] so that even doubling their demand would have an insignificant effect on the world price. For jute we are on somewhat shakier grounds since East Pakistan produces about 30% of the total world supply of this fiber.[2] Hence a significant increase in jute acreage may have some effect on the world price for the commodity but not enough to tip the foreign exchange scales in the other direction. Our comparison has also not incorporated the costs of imported inputs for growing aus rice and jute. Now that Pakistan produces its own fertilizer this assumption appears reasonable since the only input which has to be imported is pesticides. Khan (9) found that only 8% of all land growing traditional aus was sprayed with pesticides in the Phulpur area and has estimated that even a smaller percentage of jute land was protected by these sprays.

Why doesn't the farmer plant more of his land with jute given the impressive foreign exchange advantage of this crop over rice? The most important reason is the substantial difference between the world price and grower's price of jute and the very small difference with respect to the relevant price of rice. If we utilize the conservative rate of 10 rupees to the dollar then in 1969-70 jute was selling

---

[1]In 1970 East Pakistan purchased 517,000 tons of rice of which 380,000 were shipped from West Pakistan and the remaining portion came from other countries. Between 6.5 to 7.5 million tons of rice moved on the world market during 1970.

[2]In 1968-69 Pakistan produced 57.54 lakh bales which was 29% of total world production. [See (32) p. 6].

at an average world price of 94 rupees per maund.[1] At the same 10:1 conversion rate the world market price of rice was 40 rupees per maund, only slightly higher than the price which farmers paid for rice at village markets during 1969-70. Another factor relates to the cost differential between growing jute and rice. The comparison in Table III is based solely on the revenue side of the equation. If jute is a more expensive crop to plant and harvest the farmer may limit the amount of land devoted to it. This factor will be particularly significant if he is forced to hire workers to harvest jute and has only limited sources of funds and/or credit which can be used to pay them.

The conflict between individual security and national welfare is illustrated most dramatically by the crop growing decisions for the current 1971-72 season. The disturbances in East Pakistan which coincided with the months of planting has increased not only the uncertainty of the harvest prices of jute and rice but also the possibility of trading goods in an organized market due to the disruption of transportation facilities. Farmers understandably feel that it is far better for them to plant almost their entire acreage with rice and vegetables so that they can feed their family without having to market a cash crop.[2] Since the price of rice has been

---

[1]The official exchange rate is 4.76 rupees to the U.S. dollar. Winston (24) suggests that one dollar may command as much as 15 rupees in which case the difference between the grower's receipt and the world market price becomes even more extreme.

[2]Now that relatives from urban areas are residing in the country, there are even more mouths to feed in the coming months and the subsistence constraint becomes even more critical to the farmer. See (34).

estimated to have increased by 50% during April, [See (36)], this would then reinforce his decision in favor of rice. In more formal terms, if the farmer perceives an increase in σ_x due to structural changes in his external environment then it is optimal for him to set m very close to zero.

Few hard facts are currently available on actual farmers' decisions this spring. A recent report in The Economist (34) makes the point that Sheikh Mujibur Rahman has urged farmers to plant only aus rice this season, but the article does not speculate on what has actually been done. A report in one of the Calcutta newspapers (33) claims that jute sowings in East Pakistan are only 30% of normal and that there is great doubt as to whether the crop will eventually be harvested.

The long-run economic consequences for East Pakistan of farmers not growing much jute this season could be profound. In recent years synthetic materials such as polypropylene have become increasingly popular as substitutes for burlap (jute) as a packaging material.[1] Although polypropylene is more durable, attractive and cheaper to produce than jute, it does require a substantial changeover cost in capital equipment on the part of firms who decide to switch over to it. Many companies have been reluctant to incur these very high fixed costs and hence have continued to purchase jute for their needs. Uncertainty as to the future of jute due to the recent conflict in East Pakistan may lead a number of these firms to reconsider this decision. If they install the new equipment, it will be unlikely

---

[1]For a more detailed discussion of the competition between jute and the synthetics as a packaging material in the U.S. see (35).

for them to return to jute again even if its price and supply stabilizes. Thus we see that a short-run crisis facing individual farmers may produce an even more serious long-run crisis for the jute industry and the nation.[1]

4. Extensions of the Analysis

The mean-variance model sheds light on why farmers have planted only a small amount of acreage with new varieties of seeds when they first come on the market. Even if the farmers believe that these seeds will yield a high expected return, their estimate of its variance may also be very large. It thus makes very good sense for them to plant only a few acres of their land with this new variety at first. If the yields are high and relatively stable from one season to the next then farmers will reduce their estimate of the variance and hence increase the acreage devoted to the new seed.[2] Some form of crop insurance similar to the one described above should lead to more rapid adoption rates since variance will no longer be so critical to the farmer.

Conceptually it is relatively straightforward to extend the model to more than two crops. As before, diversification becomes a meaningful policy if there is a negative or low correlation between competing crops and their means and variances do not differ significantly. When the farmer is concerned with a minimum return from his crop then model (5) can be

---

[1]There is an interesting parallel between the jute situation in East Pakistan and the cotton situation in the southern United States. After the freedom rides and labor disturbances during the summer of 1964, landholders decided to use herbicides rather than relying on uncertain labor. For a more detailed discussion see Gotsch (6a).

[2]Similarly capital investment in irrigation projects can be pushed by detailing the benefits of a reduction in yield variance through a guaranteed source of water.

generalized to n crops as

$$\max \sum_{i=1}^{n} m_i \mu_i \tag{8}$$

subject to

$$\sum_{i=1}^{n} m_i \mu_i - t \left[\sum_{i=1}^{n} \sum_{j=1}^{n} m_i m_j \rho_{ij} \sigma_i \sigma_j \right]^{1/2} \leq s \tag{9}$$

$$\sum_{i=1}^{n} m_i = 1 \tag{10}$$

where ρ_{ij} represents the correlation between crops i and j.

Other constraints could also be incorporated into the model. If there was a maximum amount of labour hours, L, the farmer had available for use on his A acres of land during any month of the season and each crop i required ℓ_i^k units of man hours in month k then for this specific month k the constraint would take the form

$$\sum_{i=1}^{n} m_i \ell_i^k \leq L/A \tag{11}$$

Equation (11) would be particularly important for farmers who had to rely almost entirely on family labor for planting and harvesting crops.

If the uncertainty constraints are in a form similar to (9), this more general model can be solved by using non-linear programming techniques. It is then theoretically possible although perhaps computationally difficult to determine the imputed value of increasing the risk level α and increasing the available labor in month k. In the context of a certainty model Gotsch (6) has used a linear programming format

to examine agricultural problems in West Pakistan. Given land and labor constraints he has shown that the shadow price of labor is positive during planting and harvesting times and zero during other months of the year. One reason for multiple cropping within the same season may be due to this labor constraint at certain critical times.

Other complicating factors may effect a farmer's planting decisions. There may be economies of scale associated with growing a particular crop both from the purchase side (e.g. quantity discounts on seed) as well as from the planting and harvesting side (e.g. decreasing labor cost per acre). The farmer will then either want to plant a large number of acres of that crop or none at all. Similarly if there are fixed costs associated with growing each crop then the farmer must plant a minimum number of acres before the crop becomes profitable to him We have also not considered problems associated with switching from crop i in year t-1 to crop j in year t. If these adjustment costs are relatively high then stable cropping patterns over time may be optimal despite changes in expected returns and variances. Finally we have assumed that all land is homogeneous. Variations in the quality of land between farmers and/or regions would result in different cropping patterns.

More empirical research is therefore needed to determine the accuracy and limitations of the simple mean-variance model in analyzing farms' crop-growing decisions.

References

(1) K. Borch, " A Note on Uncertainty and Indifference Curves", The Review of Economic Studies, XXXVI, No. 67, January, 1969, pp. 1-5

(2) W. Davenport, "Jamaican Fishing: A Game Theory Analysis", Yale University Publications in Anthropology No. 59 (New Haven: Yale University, 1960)

(3) J. N. Efferson, "The Emerging Rice Marketing Problems in East Pakistan", (mimeograph) Dacca, February 10, 1971

(4) W. Falcon, "Farmers Response to Price in an Underdeveloped Area: A Case Study of West Pakistan", American Economic Review, LIV, No. 3 (May, 1964), pp. 580-91

(5) M. S. Feldstein, "Mean-Variance Analysis in the Theory of Liquidity Preference and Portfolio Selection", The Review of Economic Studies, XXXVI, No. 105, January, 1969, pp. 6-12

(6) C. Gotsch, "A Programming Approach to Some Agricultural Policy Problems in West Pakistan", Pakistan Development Review, VIII, No. 2, Summer, 1968, pp. 192-225

(6a) C. Gotsch, "Human Resource Utilization in the Mississippi Delta" (Unpublished paper), 1966

(7) S. M. Hussain, "A Note on Farmer Response to Price in East Pakistan", Pakistan Development Review, IV, No. 1, Spring, 1964, pp. 93-106

(8) S. M. Hussain, "The Effect of the Growing Constraint of Subsistence Farming on Farmer Response to Price: A Case Study of Jute in Pakistan", Pakistan Development Review, IX, No. 3, Autumn, 1969, pp. 235-74

(9) M. I Kahn, "Modernization of Small Farms in East Pakistan: A Study in Allocative and Structural Efficiency", (Unpublished Research Report), Pakistan Institute of Development Economics, June, 1970

(10) M. Lipton, "Strategy for Agriculture: Urban Bias and Rural Planning", in The Crisis of Indian Planning (ed., P. Streeten and M. Lipton) (London: Oxford University Press, 1968)

(11) M. Lipton, "The Theory of the Optimizing Peasant", The Journal of Development Studies, IV, No. 3, April, 1968, pp. 327-51

(12) H. Markowitz, "Portfolio Selection", The Journal of Finance, VII, No. 1, March, 1952, pp. 77-91

(13) H. Markowitz, Portfolio Selection: Efficient Diversification of Investments, (New York: John Wiley and Sons, 1959)

(14) J. Mellor. The Economics of Agricultural Development (Ithaca: Cornell University Press, 1966)

(15) A. Mood and F. Graybill, Introduction to the Theory of Statistics, (New York: McGraw-Hill Book Co., 1963)

(15a) V. F. Nowshirvani, "Land Allocation Under Uncertainty", Oxford Economic Papers (forthcoming)

(16) R. Porter, "Risk Incentive and the Technique of the Low-Income Farmer", The Indian Economic Journal, VII, No. 1, July, 1959

(17) G. Rabbani, "Economic Determinants of Jute Production in India and Pakistan", Pakistan Development Review, V, No. 2, Summer, 1965, pp. 189-228

(18) R. Ratna, "A Game Theoretic Approach to Agricultural Land Use Patterns: An Indian Example", (Unpublished Ph.D. Dissertation), University of Pittsburgh, 1969

(19) P. A. Samuelson, "The Fundamental Approximation Theorem of Portfolio Analysis in Terms of Means, Variances and Higher Moments", The Review of Economic Studies, XXXVI, No. 105, January, 1969, pp. 6-12

(20) J. Tobin, "Liquidity Preference as Behavior towards Risk", The Review of Economic Studies, XXV, No. 67, February, 1958, pp. 65-86

(21) J. Tobin, "Comment on Borch and Feldstein", The Review of Economic Studies, XXXVI, No. 105, January, 1969, pp. 13-14

(22) C. Wharton (ed.), Subsistence Agriculture and Economic Development (Chicago: Aldine Publishing Company, 1969)

(23) C. Wharton, "Risk, Uncertainty and the Subsistence Farmer", (Paper presented at the Joint Session of the American Economic Association and the Association for Comparative Economics, Chicago, December, 1968)

(24) G. Winston, "Overinvoicing, Underutilization and Distorted Industrial Growth", Pakistan Development Review, X, No. 4, Winter, 1970, pp. 405-21

Government Related Publications

(25) "Agriculture of East Pakistan"(Selected Tables) (mimeograph) (Islamabad: Ford Foundation, January, 1970)

(26) Bureau of Agricultural Statistics, Agricultural Production Levels in East Pakistan (1947-1970) (Directorate of Agriculture, Dacca, East Pakistan)

(27) Economy of Jute, (Dacca: State Bank of Pakistan, June, 1966)

(28) Foreign Trade Statistics of Pakistan (Karachi: Central Statistical Office)

(29) Markets and Prices (Karachi: Agricultural Marketing & Statistical Adviser, Government of Pakistan)

(30) Pakistan Statistical Yearbook 1968 (Karachi: Central Statistical Office, 1970)

(31) Pakistan Census of Agriculture (1960), Vol. I, East Pakistan, (Karachi Ministry of Food and Agriculture, 1960)

(32) The Jute Season 1968-69: Annual Review (Dacca Jute Board, Ministry of Commerce)

Recent Jute and Rice Developments in Pakistan

(33) "Remarkable Upward Swing in Jute Goods Export", Hindustan Statesman, May 17, 1971, p. 10

(34) "Riding a Starving Tiger", The Economist, May 15, 1971, pp. 72-73

(35) "U.S.A.: Downtrend in Burlap Usage Accelerates", Jute Chronicle, Vol. 6, No. 1, January/February, 1971, pp. 7-8

(36) "Dacca, City of the Dead", Time, May 3, 1971, p. 28