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RISK ANALYSIS OF A RAINFED RICE PRODUCTION SYSTEM IN TARLAC, CENTRAL LUZON, PHILIPPINES

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SUMMARY

Under rainfed conditions in Tarlac, Central Luzon, Philippines, risk was characterized using field and household panel data for 46 rice farmers over the period 1990–93. Measures of risk at the field level were calculated using pooled time-series cross-sectional data. Field-level risk was found to be quite high, with the average coefficient of variation of yield being 45% and 30% for fields with low and moderate elevations respectively. Farmers applied less nitrogen in fields with higher yield variability, and adjusted the quantity of nitrogen in order to reduce losses in poor years and benefit from greater potential in good years. Farmers with higher levels of education had lower variability of rice income than farmers with a lower level of education. Non-crop income helped reduce total income variability, especially for farmers with high variability of crop income. Implications for technology design and policy improvements are derived from these results.

INTRODUCTION

Study of risk and farmers' risk management practices is important because risk considerations affect the adoption of improved technologies. Farmers in developing countries are mostly risk-averse as their capacity to absorb income deficits is limited (Binswanger, 1980). Risk-averse farmers tend not to use new technologies if they perceive that such technologies would increase their income risk by more than their threshold level of acceptance. It is essential to understand the nature and magnitude of risk in traditional farming systems and how these are affected by new technologies or policies. This paper describes the nature of risk faced by rice producers and their risk-coping mechanisms under rainfed conditions in Central Luzon, Philippines. The data collection procedure in the study area is presented, followed by a general characterization of the farming systems. Risk analysis is conducted both at the field level and at the farm-level, using panel data from 46 farmers for 1990–93. Finally, research implications of the findings are presented.

STUDY AREA AND SURVEY DESIGN

Socio-economic monitoring of the rice production practices of 46 farmers from the municipality of Victoria, Tarlac, Philippines was initiated in 1990. The farming

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system in the selected municipality is representative of rainfed rice systems in the country. Rice is grown in the rainy season and most of the land is left fallow in the dry season. Livestock is an integral component with buffaloes being used as draught power for land preparation. The area has good market access and is linked with the town economy of Tarlac. Farmers engage in various off-farm and non-farm activities during the dry season to supplement their incomes.

The sample was selected randomly from a population of 600 farm households from the four representative Barangays (villages) of the municipality. No prior stratification of the population was possible due to lack of data on household and field characteristics for the overall population. Structured interview schedules were used to obtain information from farmers on their resource bases, land-use patterns, rice production practices, labour allocation and non-farm incomes. The collection of panel data was continued using the same group of farmers from 1990 to 1993. For each year, crop production data for 552 fields operated by the sample farmers were obtained. Both farmer recall and direct observations were used to collect the information.

ENVIRONMENTAL CHARACTERIZATION

Soil type and rainfall

Farmer classification of soil has been found generally to correspond well with the scientific classification (Talawar, 1996), indicating that farmer classification is suitable as a rapid and cost-effective method of characterizing soils. The farmer classification method was used here to characterize the soil and the land. Upper fields, which generally do not get flooded, are *Bantog* whereas the flood-prone lower fields are *Lubog*. Farmers classified soils into three types, Panaratin, Kadagaan and Pila, which are sandy, clay and heavy clay soils respectively. Of the operational holdings of the surveyed farmers 73% were classified as *Bantog*. The most common soil type was Kadagaan which covered over 50% of the area monitored (Table 1). The rainfall pattern for Tarlac is shown in Fig. 1 and the average annual rainfall over 16 years (1977–93) was 1600 mm, with a coefficient of variation of 23%.

Farm size and tenure

The average farm size was 2.08 ha, comprising 0.55 ha *Lubog* and 1.53 ha *Bantog* fields (Table 1). Of the total area 56% was owner-operated, 24% was under fixed-rent leasehold and 20% was under share tenancy. Lorenz curves for area owned and area operated were used to judge the extent of inequity in the distribution of land. The Lorenz curve is obtained by plotting the cumulative percentage area (owned or operated) against the cumulative percentage of farmers. The closer the Lorenz curve is to the diagonal line, which signifies perfect equity, the more equitable is the distribution (Kakwani, 1980). The Lorenz curves indicated that the operated area was more equitably distributed than the area owned. The Gini Concentration Ratio (or simply Gini Ratio) is a

Table 1. Land and soil type, average farm size and average yield during 1990–93, Tarlac, Philippines.

	Soil type			
Land type	Panaratin	Kadagaan	Pila	Total
	Area (% of total area)			
Lubog	1	21	5	27
Bantog	34	30	9	73
Total	35	51	14	100
	Average farm size (ha)			
Lubog	0.01	0.44	0.10	0.55
Bantog	0.72	0.63	0.18	1.53
Total	0.73	1.07	0.28	2.08
	Average yield (t ha^{-1})			
Lubog	2.2	2.5	1.9	2.4
	(0.9)†	(1.5)	(1.1)	(1.4)
Bantog	3.1	3.3	3.8	3.3
	(1.2)	(1.2)	(1.4)	(1.2)
Total yield‡	3.1	3.0	3.1	3.0
	(1.2)	(1.4)	(1.6)	(1.3)

† Values in parentheses are s.d.; ‡ calculated from weighted averages.

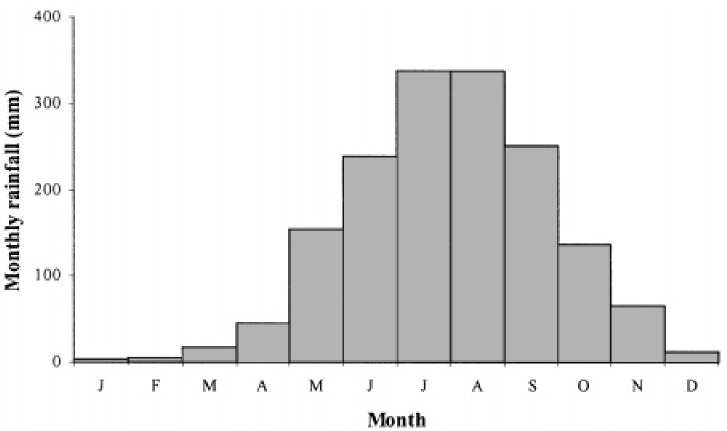

Fig. 1. Average monthly rainfall in 1977–93 at Tarlac, Philippines.

statistical measure of relative inequality. The higher Gini Ratio for owned farmland indicated a more unequal distribution of owned land than total area operated by the farmer (Fig. 2). The rental market for land thus appeared to have reduced the inequality in the ownership of land.

Cropping pattern

All land is planted to rice in the rainy season. As rainfall is inadequate for a second crop of rice, rainfed fields are left fallow after the wet season rice by most farmers. Rice–maize and rice–mungbean rotations are also practiced. Farmers who have access to irrigation grow vegetables in small areas. Overall, the rice–

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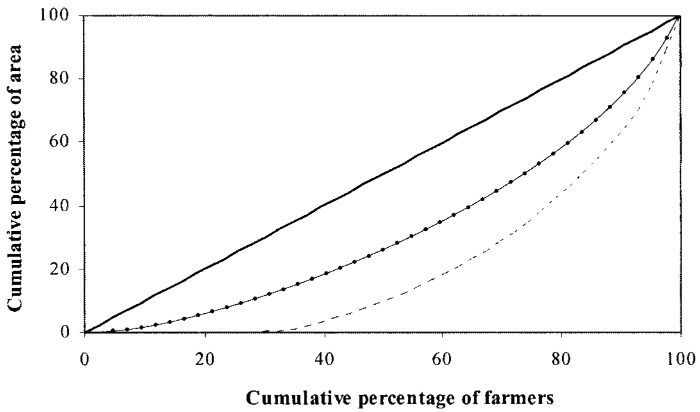

Fig. 2. Lorenz curve for land distribution at Tarlac, Philippines. Area owned (– – – –, Gini Ratio 0.5719); area operated (•-•-•-•-•, Gini Ratio 0.3539); perfect equity (———).

mungbean cropping pattern seems to be expanding at the expense of the rice–fallow pattern.

Rice yield and varieties

Average plot level yields estimated from the pooled cross-sectional and time-series data for all years and all farmers are presented in Table 1. The average rice yields for *Lubog* ($n = 126$) and *Bantog* ($n = 326$) fields were 2.4 and 3.3 t ha^{-1} respectively. The estimated standard deviations of yields appeared to be high compared with values generally reported for experimental data. Estimates of yield variability based on the survey data generally tended to be higher because, in addition to the effects of climatic variability, the survey data captured the effects of variations in management practices among farmers.

In *Bantog* fields, IR64 and IR60 together were the most popular varieties, grown in over 70% of the area. In *Lubog* fields, IR64 and IR68 together occupied over 70% of the area. Over time, these varieties have replaced traditional and other improved varieties. IR64 is better qualitatively (longer grain, intermediate amylose content, low gelatinization temperature) and is becoming increasingly popular.

Input usage, cost of production and returns

The average rate of nitrogen (N) fertilizer applied to rice in *Lubog* and *Bantog* fields were 52 and 74 kg ha^{-1} respectively. The total labour use varied from 48 person-d in *Lubog* to 54 person-d in *Bantog*. The use of phosphorus (P) and potassium (K) was low for both land types (Table 2).

The cost of rice production in *Bantog* fields was 31% higher than in *Lubog* fields (Table 3). The difference in production costs between *Bantog* and *Lubog* fields was statistically significant at the 1% level. The combined cost of harvesting and threshing labour was highest at 44% of the total cash cost, while the cost of fertilizer contributed about 27% of the total cash cost.

Table 2. Average chemical and labour inputs, 1990–93, Tarlac, Philippines.

Inputs	Land type: *Lubog*	Land type: *Bantog*
Nitrogen fertilizer (kg N ha^{-1})	52	74
	(3.65)	(1.87)
Phosphorus fertilizer (kg P ha^{-1})	4	8
	(0.65)	(0.56)
Potassium fertilizer (kg K ha^{-1})	7	8
	(1.66)	(0.78)
Insecticide (kg a.i. ha^{-1})†	0.16	0.12
	(0.02)	(0.01)
Herbicide (kg a.i. ha^{-1})†	0.08	0.12
	(0.01)	(0.01)
Labour‡ (person-d ha^{-1})	48	54
	(2.02)	(0.88)

†a.i. = active ingredient; ‡includes labour for harvesting and threshing; values in parentheses are standard errors.

Table 3. Average costs and returns (US$ ha^{-1} at constant 1990 prices), 1990–93, Tarlac, Philippines.

Category	Land type: *Lubog*	Land type: *Bantog*
Material inputs		
Seeds	5.54	4.54
Fertilizer	37.35	54.52
	(2.51)	(1.29)
Insecticide	6.37	6.34
	(0.77)	(0.48)
Herbicide	3.73	5.97
	(0.59)	(0.33)
Labour inputs		
Land preparation†	18.99	15.75
	(1.66)	(1.05)
Transplanting‡	19.15	25.34
	(1.08)	(1.14)
Harvesting‡	29.39	43.71
	(2.32)	(1.96)
Threshing‡	33.67	45.09
	(3.06)	(1.76)
Total cash cost	154.21	201.29
	(6.76)	(4.52)
Gross returns	491.69	689.16
	(26.92)	(14.73)
Net returns	337.49	487.87
	(22.71)	(12.34)

†Includes contract land preparation using tractors; ‡excludes the imputed value of family labour; values in parentheses are standard errors.

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Net returns from rice were calculated by subtracting all paid-out costs from gross returns, thus measuring returns to family-owned resources (land, labour and capital). To remove the effect of inflation, net returns were expressed at 1990 prices by using the consumer price index as the deflator. The average net returns based on pooled cross-sectional and time-series data were US\$337.5 ha^{-1} and US\$487.9 ha^{-1} for *Lubog* and *Bantog* fields respectively. The difference in net returns between *Lubog* and *Bantog* fields was statistically significant at the 1% level.

RISK ANALYSIS

Estimates of yield variability

Variability in yields generated by pooling time-series and cross-sectional data has two sources. Yield variability from plot to plot within a year is due mainly to differences in soil type and management practices. For a given plot, yields vary over time due to fluctuations in climatic events and changes in management practices. Pooled data capture both of these sources of variability. Variability over time is the main concern of farmers, as it influences their decisions regarding rice production. Thus, it is essential to separate out temporal variability from spatial variability. In this paper, a simple dummy variable model was used to achieve this. The model is specified as:

$$Y_{ijt} = a + b\,F_j + c\,S_i + e_{ijt} \qquad (1)$$

Where Y_{ijt} is the yield of the ith field for the jth farmer in year t, F_j is the dummy variable for the jth farmer, S_i is the dummy variable for the ith field, and e is the random error term. F_j and S_i capture the farmer-specific and the field-specific effects respectively. These effects are assumed to be constant over time. The variance of the random error term is a measure of the variance of yield after taking out deterministic farmer-specific and field-specific effects.

In order to conserve the degrees of freedom for statistical estimation, it was decided to classify fields by land type only. Thus, the variable S in Equation 1 was specified to be either *Bantog* or *Lubog*. The sample variance of rice yield for *Bantog* fields was statistically significantly different from the sample variance of the rice yield for the *Lubog* fields (Table 1) at the 5% level. The model specified in equation (1) was therefore estimated separately for *Lubog* and *Bantog* fields. The estimated summary measures of probability distribution of yields are presented in Table 4. The average coefficients of variation (CV) of yields for *Bantog* and *Lubog* fields were 30% and 45%, respectively. *Lubog* fields have a greater degree of variability than *Bantog* fields because they are flood-prone and some of them did suffer from different degrees of submergence during the survey period. The CVs of yields for both types of fields were nevertheless very high.

The skewness coefficient indicates approximate symmetry. The Shapiro–Wilk test did not reject the null hypothesis of normality of yield distribution at the 10% level of significance. The implication of this finding for risk analysis is that the

Table 4. Measures of probability distribution of plot-level yield, net returns, gross returns and nitrogen use, Tarlac, Philippines.

Category		Land type		
		Lubog	*Bantog*	Difference†
Yield	Mean (kg ha^{-1})	2364	3298	934**
	CV (%)	45	30	−15**
	Skewness	0.09	−0.02	
Gross returns‡	Mean (US$ ha^{-1})¶	492	689	197**
	CV (%)	46	30	−16**
	Skewness	0.14	−0.001	
Net returns§	Mean (US$ ha^{-1})	337	488	151**
	CV (%)	59	38	−21**
	Skewness	0.08	−0.14	
Nitrogen	Mean (kg ha^{-1})	52	74	22**
	CV (%)	57	30	−27**
	Skewness	0.74	0.67	

†Difference between CV was tested using a procedure (Anderson and Hazell 1989 p. 10) based on approximation to normality; ‡gross return = total rice production ha^{-1} × price of rice; § net returns = gross returns − total paid-out costs ha^{-1}; ¶$ values are at constant 1990 prices; **, significant at 1% level.

input choices made by risk-averse farmers could be evaluated adequately in terms of mean and variance of returns. The mean–variance criterion is a very special case of the expected utility-maximizing criterion for decisions under uncertainty (Anderson *et al.*, 1977).

To have a better appreciation of the magnitude of temporal variability faced by individual farmers, the CVs of plot-level yields over four years were calculated for individual plots. Since only three degrees of freedom were available for estimating plot-level CV using temporal data for four years, the estimates of individual plot-level CV may be somewhat less reliable. The information is, hence, presented as the frequency distribution of CV (Fig. 3). The median CVs of yield were 21% and 45% with the maximum values being 73% and 116% for *Bantog* and *Lubog* fields respectively. These estimates indicated that, at the individual plot level, farmers have to contend with quite large variations in crop yields.

Variability of net returns

The variability of net returns for individual plots was also calculated by using the procedure outlined in Equation 1. The average net returns per hectare for *Bantog* fields was 45% higher than for *Lubog* fields. The CVs of net returns were 38% and 59% for *Bantog* and *Lubog* fields respectively. The net returns were slightly skewed, with the coefficients of skewness being 0.14 for *Bantog* and 0.08 for *Lubog* fields. These skewness coefficients were not statistically significant at the 10% level and, again, the null hypothesis of normality was not rejected at the 10% level.

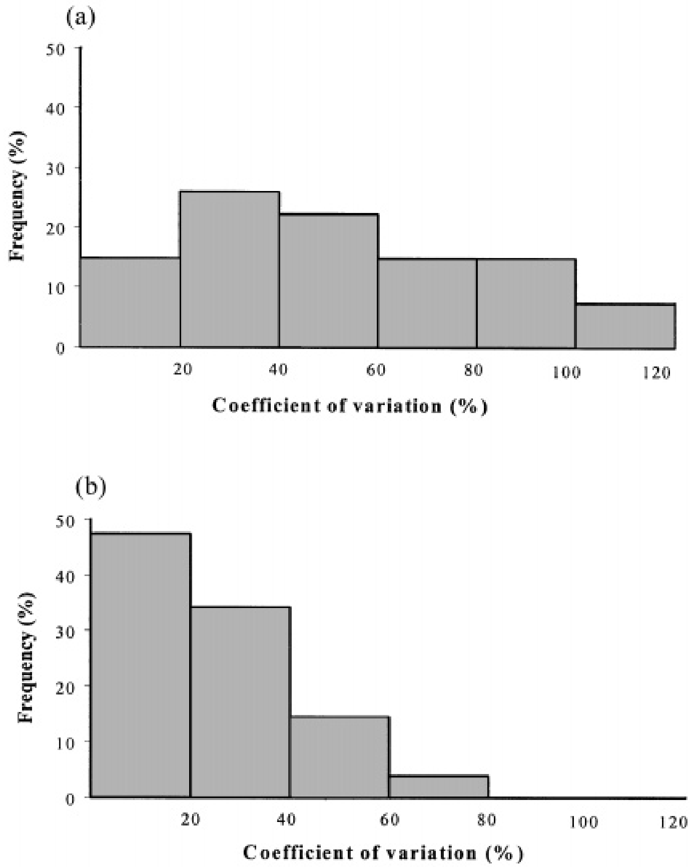

Fig. 3. Frequency distribution of CV of yields in (a) *Lubog* and (b) *Bantog* fields at Tarlac, Philippines.

Spatial diversification and risk

Spatial diversification generally results in a reduction in risk (Walker and Ryan, 1990). Scattering of operational holdings over different land types represents spatial diversification. If the moisture regime and management practices vary across plots, plot-level yields are likely to be less than perfectly correlated. Spatial diversification in such cases could lead to reduced variability of income estimated at the farm level. The average CV of net income from rice at the farm level (that is, the total income from rice grown in all fields operated by the farm household) was estimated to be 33%. This was lower than the CV of net income at the field level reported in Table 4, indicating that field diversification may have helped to reduce the variability of income from rice at the farm-household level.

Variability in input use

If farmers adjusted their input usage to the perceived yield risk in individual fields, the variability of yield and the variability of quantity of input applied would tend to be correlated. When the anticipated yield is high (due to favourable weather or field hydrology), a higher rate of yield-increasing inputs such as fertilizer is likely to be applied. In poor years, such inputs are adjusted downwards. The temporal variabilities of yield and quantity of fertilizer applied can, hence, be expected to be positively correlated. Farm interviews indicated that farmers did indeed alter fertilizer dosage depending upon the seasonal conditions.

Using the plot-level yield variability as a proxy for environmental variability, the CV of N application rate was regressed on the CV of yield for *Lubog* and *Bantog* fields separately. Regression equations are presented in Table 5. The coefficient associated with the CV of yield was positive and statistically significant in both cases (although the estimated value of R^2 for the *Bantog* fields was very low). A higher value of the coefficient of CV of yield in the *Lubog* fields was indicative of the greater sensitivity of N usage to environmental conditions in these fields compared with the *Bantog* fields. As the *Lubog* fields are more flood-prone, greater temporal adjustments to the rate of N application in these fields may be rational attempts by the farmer to reduce income risk. In addition, fluctuations in N use may be related to factors such as the level of risk aversion and the availability of cash or credit to buy fertilizers. Although the importance of these latter variables in determining fertilizer usage is generally well documented (Feder *et al.*, 1985), very little information is currently available on farmers' knowledge systems regarding fertilizer management. The implication is that, in addition to research directed towards developing technology for increasing N use efficiency, research that can help farmers improve their criteria for adjusting N application according to seasonal conditions seems warranted.

Variability of farm income

In an attempt to identify the factor determining the variability of net farm incomes from rice, a regression model with the CV of net farm incomes from rice as the dependent variable was estimated. Net farm income from rice was defined as the aggregate net rice income from all fields operated by the household. For each farm household, the CV of net farm incomes from rice was calculated using data for four years. The estimated parameters are presented in Table 6. The proportion of the *Lubog* area to total area, N application rate and farmer's educational level were the three variables having statistically significant effects on the CV of net

Table 5. Regression coefficients reflecting the effect of yield variability on variability in nitrogen use, Tarlac, Philippines.

Land type	Intercept	CV of yields	R^2	*n*
Lubog	14.06	1.24**	0.35	25
	(20.10)	(0.35)		
Bantog	17.73**	0.25*	0.07	76
	(3.14)	(0.10)		

** and *, significant at 1% level and 5% level; values in parentheses are standard errors.

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Table 6. Factors determining variability of net incomes from rice, Tarlac, Philippines.

Independent variables‡	CV of net farm incomes from rice†	Standard error
Intercept	77.12***	26.46
Income from other sources	1.25×10^{-6}	8.3×10^{-6}
Lubog area ratio	29.82**	0.11
Total cultivated area	−0.95	10.07
Nitrogen fertilizer	−0.13**	0.05
Education	−13.25*	6.95
Average size of parcel	−18.19	22.46
Number of parcels	−2.19	8.90
Access to credit	−1.29	8.98
R^2	0.3475	
Sample size	43	

†Dependent variable: CV of net incomes from rice over four years for each household; ‡independent variables: income from other sources = average non-crop income (average of four years) in US$; *Lubog* area ratio = average area under *Lubog*/average cultivated area; total cultivated area = average cultivated area; nitrogen fertilizer = average nitrogen use per ha; education = farmer's educational attainment, 1 = Elementary, 2 = High School, 3 = Technical School, 4 = College; average size of parcel = average cultivated area/average number of parcels; number of parcels = average number of parcels; access to credit = 1, if farmer borrowed money in 1993, 0, otherwise; ***, ** and *, significant at 1%, 5% and 10% levels respectively.

farm incomes from rice. As expected, farmers with a higher proportion of the *Lubog* area had a higher CV of net returns. Farmers who applied higher average rates of N had lower CVs of net returns. This was expected as farmers applied more N, on average, in fields with lower risk (Table 4). The expected yield would hence be higher, which in turn would help to reduce the CV of net returns. Educational status had a statistically significant negative effect, implying that farmers with a higher level of education were able to manage their farms better in the face of uncertainty in order to reduce risks associated with rice production. Education has been found to contribute to increased production efficiency generally (Welch, 1970; Pudasaini, 1983). The results here indicated that education may enhance farmers' capabilities to reduce risk through better management.

Variability of total household income

One common method used by farmers to reduce the variability of total household income is to earn income from off-farm and non-farm activities, especially during years when crop incomes are low. As long as income from crop production and income from other sources have a low or negative correlation, variability of total income will be reduced by such diversification of income sources. Here, we defined crop income as the sum of income from rice, mungbeans, mango, sugarcane and vegetables grown on the farm. Non-crop incomes were similarly defined as the total income from livestock and labour income, both off-farm and non-farm. All incomes were expressed at 1990 constant prices by using the relevant consumer price index as the deflator. Analysis of income was based on data from 35 farmers for whom complete data on all sources of incomes were recorded. The main characteristics of income data are presented in Table 7. The average household income was US$1350, which amounted to $255 per caput. The contribution of crops to the total income was 74% with non-farm sources contributing almost 22%. For some farmers, income from rice was as much as 97% of the total income. The overall median share of rice was 74%. This showed the importance of rice in the overall economy of the study villages.

The correlation coefficient between crop and non-crop incomes for each farm household was calculated using the income data for four years. Correlation coefficients between crop and non-crop incomes were not significantly different from zero for 33 of the 35 farmers. Two farmers had statistically significant negative correlation coefficients (at the 10% level). These low or negative estimates of correlation coefficients indicated that, in the face of variable crop income, farmers may have depended to a certain extent on non-crop incomes to reduce the instability in total income.

In order to investigate this further, the difference between the CV of total incomes (that is, the sum of crop and non-crop incomes) and the CV of crop incomes was plotted against the CV of crop incomes (Fig. 4). Of the 35 farm households, 17 had a negative difference between the CV of total incomes and the CV of crop incomes. For these households, non-crop income had a stabilizing effect on total income. The statistically significant negative relationship in Fig. 4 implies that farmers who had more unstable crop incomes benefitted from the

Table 7. Total farm household income and percentage share of various activities in total income, Tarlac, Philippines.

Attributes	Average	Median†	Minimum†	Maximum†
Total farm household income (US$)‡	1351	1013	281	3722
Activities				
All crops (% share)§	74	79	18	98
Rice (% share)§	68	74	14	97
Other crops (% share)§	6	1	0	39
Livestock (% share)§	4	1	0	18
Off-farm and non-farm income (% share)§	22	15	0	82

†Note that the percentage shares for columns other than for 'average' do not have to add up to 100. For the three columns 'median', 'minimum' and 'maximum', percentage shares refer to the whole sample, not to a specific individual farmer. For example, the maximum share of income (in the column 'maximum') from crops for the whole sample is 98%. Similarly, the maximum share of off-farm and non-farm incomes for the whole sample is 82%. A farmer who has the highest share crop income in the sample is not necessarily the farmer who has the highest share of off-farm income. Similar interpretations apply to the shares presented in the columns 'median' and 'minimum'; ‡total farm household income is defined as income from all sources (agricultural and non-agricultural); §percentage share in total farm household income.

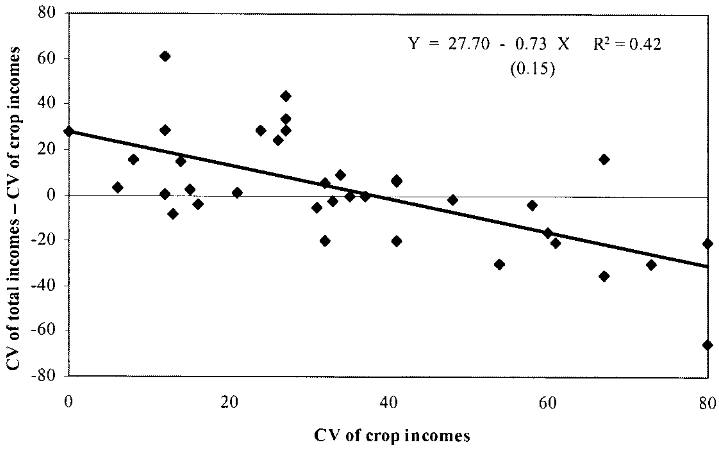

Fig. 4. Effect of CV of crop incomes on the difference between CV of total incomes and CV of crop incomes at Tarlac, Philippines.

strategy of income diversification. For farmers who had a more stable crop income, non-crop sources increased their total income variance by more than the proportionate increase in non-crop mean income, so that the CV of total incomes actually increased. These results indicate that, for farmers with higher levels of crop income variability, non-crop income can play an important role in reducing the variability of total income by supplementing income shortfalls. Government policies that facilitate income earning opportunities which encourage diversification into non-crop activities can thus help to reduce the level of income risk faced by farmers growing rainfed rice.

CONCLUSIONS AND IMPLICATIONS FOR RESEARCH

Land type was one of the major determinants of the magnitude of production risk in Tarlac. Yield was more unstable in flood-prone *Lubog* fields than in *Bantog* fields, which were generally flood-free. Farmers responded by applying fewer inputs to *Lubog* fields, resulting in a lower average yield and net income from these fields. Farmers who had a higher proportion of *Lubog* fields had a lower level of income; thus technologies which reduce risk in *Lubog* fields are also likely to have favourable equity effects.

A positive correlation between the CV of yields and the CV of N application rates indicated that farmers adjusted N application according to environmental conditions. The degree of adjustment is greater in the riskier *Lubog* fields. Research which can help farmers improve the adjustment of N application seems warranted. A first step would perhaps be to understand better farmers' practices and knowledge systems with respect to fertilizer management.

In addition to providing risk-reducing technologies, investment in education to build human capital may help farmers to manage rice production risks better.

Similarly, policies which promote off-farm and non-farm earnings, which are poorly or negatively correlated with crop income, can help dampen the effect of production risk on farmers' welfare. Such policies may also facilitate structural transformation by encouraging labour to move out of the farm sector.

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