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Quantifying the Extent and Nature of Risk in Alternative Cropping Patterns in Claveria, Philippines

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The study develops a formulation to decompose variability in profit into price and production effects. The production effect is further segregated into management and weather effects. The formulation is used to compare and decompose risk in the profit of three existing cropping patterns (corn-corn, corn-fallow, and rice-fallow) in the rainfed areas of Claveria, northern Mindanao, Philippines. High variability and low profitability of the crops in a more risky season (dry in our case) can limit cropping intensities in rainfed areas. However, intensification of the crops during the less risky season (wet in our case) can provide the necessary stake to invest in the risky season crops. Although weather is the dominant factor in explaining total variability, this should not be interpreted as a general rule for all agricultural environments. In an environment where input intensity is high, and input-output markets are inefficient, management and price effects can dominate the weather effect.

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1. INTRODUCTION

The discussion on the importance of risk in agricultural production oscillates between opposite viewpoints. Many authors in the 1980s and 1990s argued that poor farmers are risk-averse—i.e., they are willing to accept low income but with less risk than being excited to attain higher income attached with higher risk [Binswanger (1980); Antle (1988) and Anderson and Dillon (1992)]. Lately, however, Chambers and Quiggin (2004) had shown that regardless of the producer's preference towards risks, agricultural producers never forego any opportunity to lower costs without lowering returns. Apart from the discussions on the role of risk in production, however, studies focusing more sharply on various risk sources are scanty. For example, a substantial amount of literature provide frameworks to estimate changes in optimum input and output levels when farmers face price and production risk [Rosegrant and Roumasset (1985); Smith and Umalli (1985); Batlin (1983); Grant (1985)]. Some studies did focus on individual risk sources such as market risk arise from unforeseen changes in supply and demand forces [Coyle (1992); Nieuwoudt, *et al.* (1988)], or production risk caused by random factors such as pest infestation and weather [Jarvis and Richard (2001); Rosenzweig and Binswanger (1993)]. These studies treated these risk

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sources separately, but these were never dealt simultaneously to compare their relative importance in the production system. The principal contributions of this paper are, (i) it deals with price as well as production risk—all to often, one or the other is ignored for convenience in the existing literature (ii) the total risk in profit is decomposed into production and price risk and the variation in production is further segregated into weather and management effects (the later is caused by variation in managerial skill across farmers) by employing Griffiths and Anderson (1982) framework. The framework developed in this study is applied to compare the impact of total risk in the selection of various cropping patterns and to segregate various risk sources in these patterns of Claveria, northern Mindanao, Philippines—the site characterised by its relatively low income and high risky production environment.

Section 2 discusses the specification of production function under risky situation, describes an approach to compare the alternative cropping patterns under certain and uncertain situations, and outlines the methodology to segregate total risk in profit into its components. This section delineates the empirical model. Section 3 describes about the data and the study area. Section 4 summarises the results and discussion. The final section concludes the findings together with policy implications.

2. THEORETICAL AND EMPIRICAL FRAMEWORK

Specification of Production Function

Just and Pope (1979) show that the conventional formulation of the stochastic production function with multiplicative random error may be inappropriate because it imposes as *a priori* restriction on the variability of output—i.e., if marginal contribution of an input to the mean output is positive, then its positive marginal effect on the variance of output is also imposed [Just and Pope (1978)].[1] Chambers and Quiggin (2002) generalised the concepts of additive and multiplicative uncertainty discussed by Just and Pope (1979). However, contrary to the conventional production function characteristic, all inputs are not risk-increasing: inputs such as irrigation, pesticides, and equipment are likely to reduce risk in production [Rola and Pingali (1993); Pingali and Roger (1995)]. To segregate the effect of inputs on mean and variance of output, a heteroscedastic production function featuring flexible risk effects is suggested; where the variance of the stochastic error term is allowed to vary with levels of managed inputs [Just and Pope (1978, 1979); Anderson and Griffiths (1981)]. The production function specified in this way would have two components: (i) the deterministic component, and (ii) the stochastic component. By considering the Cobb-Douglas specification the production function for a cropping pattern with flexible risk effect can be written as:

$$\mathrm{Y}_{rijt} = \theta \prod_{k=1}^{n} \mathrm{X}_{krijt}^{\alpha_k} + u_{rijt} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

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[1] They also added that the other functional forms like transcendental, translog, CES (constant elasticity of substitution), and generalised power function will have the same limitation if they are used with additive log-linear disturbances.

where i (i = 1, 2,..., f) stands for the ith cropping pattern, r (r = 1, 2,..., o) for the rth crop in a cropping pattern, j (j = 1, 2, 3, . . ., m) for parcel of land, t (t = 1, 2, 3…., s) for time, and k (k = 1, 2, 3, . . ., n) represents the kth input. By excluding the subscript for crop and cropping pattern the properties of the error term in Equation (1) can be defined in mathematical form as follow,

$$E(u_{jt})=0, \quad E(u_j^2)=\sigma^2 h_{jt}^2, \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (2)$$

$$E(u_{jt}u_{js}) = \sigma_\gamma^2 h_{jt} h_{js}, \quad t \neq s, \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (3)$$

$$E(u_{jt}u_{mt}) = h_{jt} h_{mt}, \quad j \neq m, \text{ and} \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (4)$$

$$E(u_{jt}u_{ms}) = 0, \quad j \neq m \quad and \quad t \neq s, \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (5)$$

Equations (2) to (5) corresponds to variance and covariance properties of dependent variable (yield). Equation (3) allow for the existence of nonzero correlation between outputs from the same parcel in different time periods because fertiliser used for one crop also affect the output of the following crops. The Equation (4) represents the existence of correlation between outputs from different parcels in the same time period because different parcels are competing for the limited resources available to the farmer. Outputs from different parcels in different time periods are assumed to be uncorrelated (Equation 5). In an error decomposition model set up, the stochastic component of the production function where error term is assumed to be a function of inputs is presented as below,

$$u_{rijt} = (\gamma_j + \lambda_t + \eta_{jt}) h_{rijt}, \text{ and } h_{rijt} = \beta_0^{1/2} \prod_{k=1}^{n} \left(X_{kr\,ijt}^{\beta_k} \right)^{1/2} \qquad \dots \quad \dots \quad \dots \qquad (5a)$$

It is further assumed that γ_j, λ_t, and η_{jt} are mutually uncorrelated for all j and t. All three-error components $\gamma_j h_{rijt}$, $\lambda_t h_{rijt}$, and $\eta_{jt} h_{rijt}$, are heteroscedastic in the sense that their variances depend on the measured input levels. This suggests that the likely magnitude of firm specific effects that are not included as inputs, such as managerial ability and quality of land, as well as the likely magnitude of time-specific effects such as drought and diseases, will both be influenced by the measured inputs [Griffiths and Anderson (1982)]. Therefore, it is appropriate to assume that managerial ability (firm effect) and weather (time effect) will have some affect on inputs such as labour and cash inputs (i.e. seed, fertiliser, and pesticide).

Equation (1) is estimated by employing the error decomposition approach that requires a six-step procedure as suggested by Griffiths and Anderson (1982) and allows segregating the management and weather effect in production. The variability in production across parcels (named as management effect, after appropriately controlling the difference in parcel quality) over time (named as weather effect), and due to the joint effect of parcels and overtime is captured through different specification of random error as follows in Equations (6–8)..

Following Griffiths and Anderson (1982) specification, when only weather or time effect is considered, the random error in production function is specified as follows:

$$\dot{Y}_{rijt} = \theta \prod_{k=1}^{n} X_{krijt}^{\alpha_k} + \left(\lambda_t + \eta_{jt}\right) h_{rijt} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

When only parcel or management effect is considered, the random error in the production function is defined as follows:

$$\ddot{Y}_{rijt} = \theta \prod_{k=1}^{n} X_{krijt}^{\alpha_k} + \left(\gamma_j + \eta_{jt}\right) h_{rijt} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

When no effect (or nil effect) is considered, then random error in the production function is designated as below

$$\hat{\dot{Y}}_{rijt} = \theta \prod_{k=1}^{n} X_{krijt}^{\alpha_k} + \left(\eta_{jt}\right) h_{rijt} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

The predicted values of yield estimated in Equations (6)-(8) are employed to estimate the variability in output due to management, weather, and production effect (joint effect of management and weather), respectively.

2.1. Comparison of Cropping Patterns under Risk

The profit obtained from a cropping pattern under risky situation has less value to risk-averse farmers because it is less certain to occur—i.e., it has a probability less than one. The utility from profit is discounted by the factor called risk-averse parameter, which is directly related to farmers' odium of risky environment. The steps in evaluating the utility of profit under risky situation are incorporated in the expected utility approach. Before explaining this approach, a formulation is developed to estimate the variance in profit of a cropping pattern. For this, define the per-hectare profit on per parcel basis Π_{rij} of the *r*th crop in the *i*th cropping pattern for the *j*th farmer as:

$$\Pi_{rij} = P_{rij} Y_{rij} - \sum_{k=1}^{n} P_{krij} X_{krij} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8a)$$

where X and Y are respectively per hectare amounts of inputs and outputs; and P_s are the input and output prices depending upon the subscripts attached to these.

Under the assumption that input-output quantities depend upon their respective prices, the expected profit for the *i*th cropping pattern $\overline{\Pi}_i$ can be written as[2]

$$\overline{\Pi}_i = \sum_{r=1}^{o} \left[\overline{P}_{ri} \overline{Y}_{ri} + Cov\left(P_{rij}, Y_{rij}\right) - \sum_{k=1}^{n} \left(\overline{P}_{kri} \overline{X}_{kri} + Cov\left(P_{krij}, X_{krij}\right)\right)\right] \qquad \ldots \quad (9)$$

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[2] The expected value of the addition of two variables (dependent or independent) is equal to the sum of the expected values of each variable [Kmenta (1986)]. The expected value of the product of two independent variables is equal to the product of the expected value of each variable, while the expected value of the product of two dependent variables is equal to the product of the expected value of each variable plus the covariance of the variables [Mood, *et al.* (1974)].

where, $\overline{P}_{ri} = E\left(P_{rij}\right) = \left(\frac{1}{m}\right)\sum_{j=1}^{s} P_{rij}$ and $\overline{Y}_{ri} = E\left(Y_{rij}\right) = \left(\frac{1}{m}\right)\sum_{j=1}^{s} Y_{rij}$

"m" stands for number of parcels for each farmer. The cost spent on an input is correlated with the cost spent on other inputs (through cross-price input demand elasticities) as well as with the gross revenue (through output-price input demand and production function elasticities) total variance in the profit of the *i*th cropping pattern, $\sigma^2_{\Pi i}$, is estimated as:

$$\sigma^2_{\Pi i} = \sum_{r=1}^{0}\left[Var\left(P_{rij}Y_{rij}\right) + \sum_{k=1}^{n}\left\{Var\left(P_{krij}X_{krij}\right) - 2Cov\left(P_{rij}Y_{rij}, P_{krij}X_{krij}\right)\right\}\right]$$

$$+\sum_{r=1}^{o}\left[2\sum_{k<l}\sum Cov\left(P_{krij}X_{krij}, P_{lrij}X_{lrij}\right)\right] + 2Cov\left(\Pi_{1ij}, \Pi_{2ij}\right) \quad \ldots \quad \ldots \quad (10)$$

All terms together in Equation (10), except the last one, make a variance-covariance matrix between gross revenue and cost of each input. The last term shows covariance in the profit of different crops in a pattern (assumed to be only two crops in a pattern). The last term will be zero if there is only one crop in the *i*th cropping pattern.

The expected utility of profit of different cropping patterns can be estimated by assuming a functional form for the utility function. Different utility functions are available for empirical studies [Anderson, *et al.* (1977)], following Binswanger (1978) and Siller (1980), the constant partial risk aversion (CPRA) utility function is assumed in this study and by applying the Taylor series expansion [Antle (1988)] and after a little manipulation, the following form of the expected utility function is obtained:

$$E[U(\Pi)] = (1-S)\left(\overline{\Pi}\right)^{(1-S)} + (1/2!)\sigma^2_{\Pi}\left[(-S)(1-S)^2\,\overline{\Pi}^{-(1+S)}\right] \quad \ldots \quad \ldots \quad (11)$$

Where, $\overline{\Pi}$ is the mean value of profit and S is the partial risk-averse parameter. The value of risk-averse parameter can vary between zero and any real number, depending on the risk-averse attitude of farmers. It should be noted that Equation (11) could also represent a certain situation when the value of risk-averse parameter becomes zero. A value near zero implies that farmers give no weight to risk or they are not risk-averse, while a higher value indicates that they are highly risk-averse. In this study, different values of risk-averse parameters are assumed.

Under uncertain situation, utility-maximising farmers will prefer the *p*th cropping pattern over the *q*th pattern if:

$$E\left[U\left(\overline{\Pi}_p\right)\right] > E\left[U\left(\overline{\Pi}_q\right)\right], \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

In case of certainty, the expected utility of profit will be equal to the mean value of profit:

$$E\left[U\left(\overline{\Pi}_i\right)\right] = U\left(\overline{\Pi}_i\right) = \overline{\Pi}_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

and utility-maximising farmers will compare the mean profit of alternative patterns.

2.2. Segregation of Total Variability in Profit

The total variability in profit in Equation (10) can be decomposed into two factors: (i) variability in yield or production and (ii) variability in prices. The variability in yield can be purely due to weather if time-series experimental data with constant inputs including management are used. However, when cross-section, time-series farm survey data are employed, where individual parcels are studied over time, variation in yield can be due to management, or weather, or both. Therefore, the variability in profit due to yield was further segregated into (i) management effect, (ii) weather effect, and (iii) combined or production effect.

To segregate total variability in production into its components, the predicted values of means and variances for each crop in a cropping pattern were estimated by employing the error decomposition model under alternative specifications of the error term. The variability in output due to management effect is computed by using the predicted value of yield from the production function specified in a way that only time (or weather) effect is considered. The variance in profit due to only management $\hat{\hat{\sigma}}^2_{\Pi i}$ is estimated as:

$$\hat{\hat{\sigma}}^2_{\Pi i} = \sum_{r=1}^{o}\Big[\bar{P}^2_{ri} Var(\dot{Y}_{rijt}) + \sum_{k=1}^{n}\big\{\bar{P}^2_{krit} Var(X_{krij}) - 2\bar{P}_{ri}\bar{P}_{kri} Cov(\dot{Y}_{rijt}, X_{krit})\big\}$$

$$+ 2\sum_{l<}\sum_{k}\bar{P}_{krij}\bar{P}_{lrij} Cov(X_{krij}, X_{lrij})\Big] + 2Cov\left(\hat{\hat{\Pi}}_{1ij}, \hat{\hat{\Pi}}_{2ij}\right) \quad \ldots \quad \ldots \quad (14)$$

where $\dot{Y}_{rijt}$ is the predicted yield of the *r*th crop, estimated by employing Equation (6) and $\hat{\hat{\Pi}}_{1ij}, \hat{\hat{\Pi}}_{2ij}$ are the farm-specific profits for the first and second crop in the *i*th cropping pattern obtained by using the predicted yield from Equation (6) and mean prices in the profit equation.

The variability in output due to only the weather effect is computed by using the predicted value of yield when only the parcel effect is controlled as in Equation (7). The variance in profit due to only weather, $\ddot{\sigma}^2_{\Pi i}$, is estimated as:

$$\ddot{\sigma}^2_{\Pi i} = \sum_{r=1}^{o}\Big[\bar{P}^2_{ri} Var(\ddot{Y}_{rijt}) + \sum_{k=1}^{n}\big\{\bar{P}^2_{kri} Var(X_{krij}) - 2\bar{P}_{ri}\bar{P}_{kri} Cov(\ddot{Y}_{rijt}, X_{krij})\big\}$$

$$+ 2\sum_{l<}\sum_{k}\bar{P}_{krij}\bar{P}_{lrij} Cov(X_{krij}, X_{lrij})\Big] + 2Cov(\ddot{\Pi}_{1ij}, \ddot{\Pi}_{2ij}) \quad \ldots \quad \ldots \quad (15)$$

where $\ddot{Y}_{rijt}$ is as defined in Equation (7), and $\ddot{\Pi}_{1ij}, \ddot{\Pi}_{2ij}$ are the farm-specific profits for the first and second crops in the *i*th cropping pattern obtained by using the predicted yield from Equation (7) and mean prices in the profit equation.

The variability in output due to management and weather effects combined is called the production effect and is estimated by using the predicted value of yield when nil or no effect is considered in the production function specification in Equation (8). The variability in profit due to production effect, $\hat{\dot{\sigma}}^2_{\Pi i}$, is estimated as:

$$\hat{\dot{\sigma}}^2_{\Pi i} = \sum_{r=1}^{o}\left[\overline{P}^2_{ri} Var\left(\hat{\dot{Y}}_{rijt}\right) + \sum_{k=1}^{n}\left\{\overline{P}^2_{kri} Var\left(X_{krij}\right) - 2\overline{P}_{ri}\overline{P}_{kri} Cov\left(\hat{\dot{Y}}_{rijt}, X_{krij}\right)\right\}\right.$$
$$\left. + 2\sum_{l<}\sum_{k}\overline{P}_{krij}\overline{P}_{lrij} Cov\left(X_{krij}, X_{lrij}\right)\right] + 2Cov\left(\hat{\dot{\Pi}}_{1ij}, \hat{\dot{\Pi}}_{2ij}\right) \quad \ldots \qquad \ldots \quad (16)$$

where $\hat{\dot{Y}}_{rijt}$ is as defined in Equation (8), and $\hat{\dot{\Pi}}_{1ij}, \hat{\dot{\Pi}}_{2ij}$ are the farm-specific profits for the first and second crops in the *i*th cropping pattern obtained by using the predicted yield from Equation (8). It should be noted that the production effect as estimated above is different from the simple addition of management and weather effects because of the covariance between input-output quantities.

The variability in profit due to only prices, $\hat{\sigma}^2_{\Pi i}$, controlling the input and output quantities at the mean level and assuming that prices are not correlated, is estimated as

$$\hat{\sigma}^2_{\Pi i} = \sum_{r=1}^{o}\left[\overline{Y}^2_{ri} Var\left(P_{rij}\right) + \sum_{k=1}^{n}\overline{X}^2_{kri} Var\left(P_{krij}\right)\right] + 2Cov\left(\hat{\Pi}_{1ij}, \hat{\Pi}_{2ij}\right) \quad \ldots \qquad \ldots \quad (17)$$

where $\hat{\Pi}_{1ij}, \hat{\Pi}_{2ij}$ are respectively the *j*th farm profits for the first and second crops in the *i*th pattern (again only two crops in a pattern are assumed) with input-output quantities at the mean level in the profit equation. The combined effect of price and production on profit variability is called the joint effect. The variability in profit due to joint effect, $\vec{\sigma}^2_{\Pi i}$, is estimated as:

$$\vec{\sigma}^2_{\Pi i} = \sum_{r=1}^{o}\left[Var\left(P_{rij}\hat{\dot{Y}}_{rij}\right) + \sum_{k=1}^{n}\left\{Var\left(P_{krij}X_{krij}\right) - 2Cov\left(P_{rij}\hat{\dot{Y}}_{rij}, P_{krij}X_{krij}\right)\right\}\right.$$
$$\left. + 2\sum_{l<}\sum_{k} Cov\left(P_{krij}X_{krij}, P_{lrij}X_{lrij}\right)\right] + 2Cov\left(\vec{\Pi}_{1ij}, \vec{\Pi}_{2ij}\right) \quad \ldots \qquad \ldots \quad (18)$$

where $\hat{\dot{Y}}_{rij}$ is as defined earlier and $\vec{\Pi}_{1ij}, \vec{\Pi}_{2ij}$ are the farm-specific profits for the first and second crops in the *i*th cropping pattern obtained by employing $\hat{\dot{Y}}_{rij}$ and letting prices vary at the farm-specific level. Again, it should be noted that the joint effect, as estimated above, is different from the simple addition of production (Equation 16) and price (Equation 17) effects, because of the covariance between input-output quantities and the respective prices. The unexplained variability in profit termed as residual effect,

$\overleftrightarrow{\sigma}^2_{\Pi i}$, is estimated by subtracting the joint effect (effect of production and prices, Equation 18) from the total effect (Equation 10):

$$\overleftrightarrow{\sigma}^2_{\Pi i} = \hat{\sigma}^2_{\Pi i} - \vec{\sigma}^2_{\Pi i} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

2.3. Empirical Models

The explanation of variables and specification of Cobb-Douglas production function fitted to each crop in a cropping pattern for a survey data is as follow:

$$Y = A\, X_1^{\alpha_1} X_2^{\alpha_2} q^{\alpha_3} e^{(V * \alpha_4)} + u \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (20)$$

where Y is the yield in t ha^{-1} for each crop in a cropping pattern; X_1 is total labour ha^{-1} (family and hired) in hours; X_2 is the value of purchased inputs including fertiliser, and seed (₱/ha),[3] "q" is a proxy variable for the difference in land quality measured as the slope of the parcel in cm m^{-1}; V is a dummy variable for a variety having a value of 1 if modern variety of the crop is used, and 0 otherwise; and μ is the stochastic error term as defined in Equation (1). Pesticide use is extremely low in the study area but due to its risk-reducing role in production we included it as a separate variable in the first run but we did not find its significant impact either on yield or variance even at 20 percent level and therefore, we decided to exclude pesticide in the final run. The profit from a crop in a cropping pattern is defined as (the subscripts are deleted for simplicity)

$$\Pi = P\, Y - P_1 X_1 - P_3 X_3 - X_4 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (21)$$

where X_1 is as defined before, and X_3 and X_4 are respectively seed in kg ha^{-1} and real cost of pesticide and fertiliser estimated as nominal cost divided by the consumer price index (CPI), and P_k are input prices in real terms estimated by dividing the nominal prices with the CPI. For example, P_1 is the real wage rate in ₱ h^{-1} (family labour is evaluated at the farm-specific hired labour cost), P_3 is the real price of seed in ₱ kg^{-1} (the home-produced seed is evaluated at the farm-specific market output price), and P is the real price of output in ₱ kg^{-1}.

3. DATA AND THE STUDY AREA

The data used in this study were collected by the International Rice Research Institute (IRRI) in collaboration with the Ministry of Agriculture and Food (MAF). Six upland barangays of Claveria, municipality of Misamis Oriental, were randomly selected to record data on farm operations by parcel. The data were gathered during

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[3] The upland ecosystem is characterised by low level of input use and low cropping intensity. Many farmers did not use fertiliser and pesticide, especially during the dry season. It was therefore, decided to incorporate the value of cash inputs (seed, and fertiliser, and pesticide) as one variable in production function.

repeated farm visits from 1988 to 1990. All farms were completely rainfed and had no supplementary source of irrigation.

The corn-corn, rice-fallow, corn-fallow, and rice-corn were the major cropping patterns in the study area. During the wet season, corn and rice are grown in June and harvested respectively at the end of October and November. Dry-season corn is grown in early December and harvested at the end of April.

Due to lack of input-output data on perennial crops and the insignificant proportion of farm area under other patterns, only parcels under the corn-corn, rice-fallow, and corn-fallow patterns were included in the analysis. Number of observations for the whole survey period under these patterns was 162, 120, and 102, respectively.

4. RESULTS AND DISCUSSION

4.1. Rainfall Pattern

Some judgement on the overall risk involved in crop cultivation can be made by looking at the cumulative distribution functions (CDF) of rainfall for each 10-day interval. This is estimated for Claveria separately for the wet and dry seasons (Figure 1). As rice and corn are the major crops grown in the area, the distribution functions are divided into rice and corn growing regions based on the assumption that 15-40 mm of rainfall in each 10-d-interval is required for corn, while 40-150 mm of rainfall in each 10-d-interval is required for rice.[4] No crop can be grown in a region having rainfall less than 15 mm in the 10-d-interval. The rice has water stress in the upland crop zone and no-crop zone; corn crop can be grown in the rice zone, but rice has more optimal conditions; and rice and corn will get flooded if the rain is higher than 150 mm in 10-d-interval.

Fig. 1. Ten-day Interval Cumulative Distribution Function of Rainfall at Claveria, 1984-92

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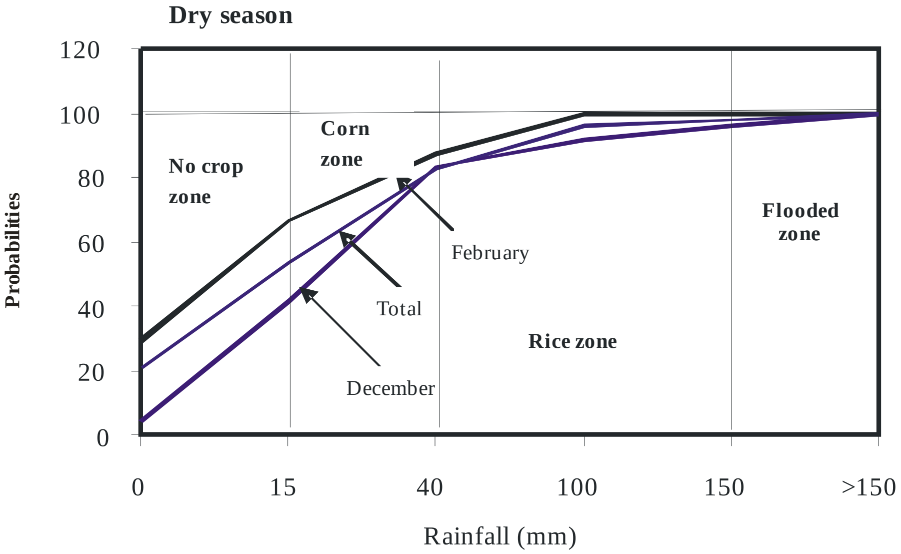
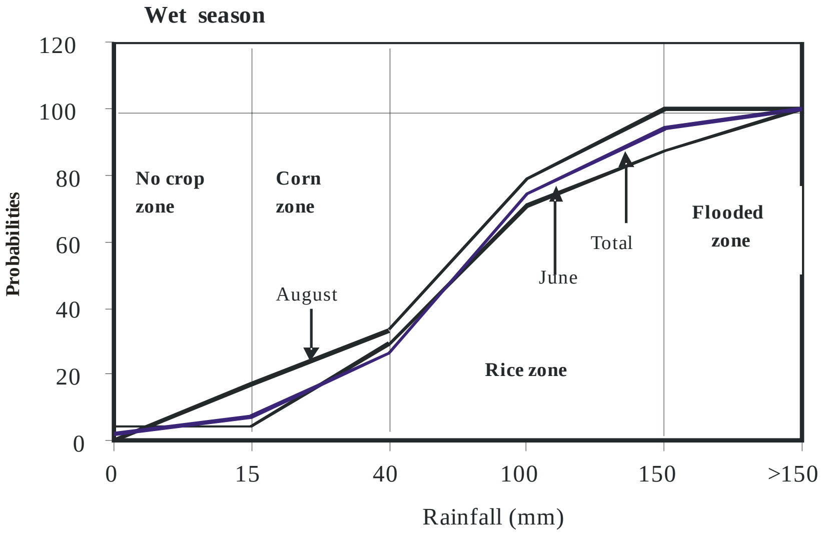
[4] The optimum water requirement for rice is about 200 mm mo^{-1}. When rainfall is less than 100 mm mo^{-1}, crop growth is seriously retarded, especially if the deficit happened during the flowering and grain-filling stages [Syamisiah, *et al.* (1993)].





The 10-d-interval cumulative distribution functions are drawn for December and June when area allocations are decided, for February and August which are the crop's critical periods in the dry and wet season, respectively, and for the whole wet and dry season (total in the graph). Based on rainfall probabilities, there are good chances of successful crops both in the wet and dry seasons. However, the pattern is more favourable for rice cultivation in the wet-season, and corn during the dry-season. If rice is cultivated in June, there is only a 5 percent chance of the crop being delayed due to water shortage. There is about a 20 percent chance of water stress occurring (less than 15 mm per 10-d) during the critical rice-growing period in August. During the dry-season, on the other hand, there is 80 percent or more chance that rice will get insufficient water;

about 40 percent chance that all crops will have insufficient water to cultivate, and 60 percent probability to get water stress during the critical period of the upland crop growth. Thus the rainfall pattern caries a high risk in dry-season crop production. This explains why at least one-third of the farmers leave their land fallow in the dry-season, and rice cultivation is confined to the wet-season.

4.2. Cost and Return Analysis

Before presenting the quantitative results on risk and the sources of risk under alternative cropping patterns, it will be useful to see how these patterns compare with respect to cash and noncash input requirements, and gross and net returns. For this, Equation (9) is employed for the individual crop as well as for the three cropping patterns. Results are reported in Table 1. The cash cost includes hired labour and pesticide and fertiliser cost, while the noncash cost includes family labour and costs of planting material, evaluated at shadow market prices.[5]

Table 1

Costs and Returns (P ha^{-1}) by Crops and Cropping Pattern in Claveria, Northern Mindanao, Philippines

	Corn-corn				
Parameter	Wet	Dry	Total	Corn-fallow	Rice-fallow
Hired Labour Cost	412	317	729^a	388^b	279^c
	(22)	(29)	(25)	(23)	(15)
Family Labour Cost	575	359	934^a	909^a	1264^b
	(31)	(33)	(32)	(53)	(71)
Total Labour Cost	987	676	1663^a	1197^b	1543^c
	(53)	(62)	(57)	(70)	(86)
Seed Cost	221	134	355^a	175^b	190^b
	(12)	(12)	(12)	(10)	(11)
Pesticide Cost	121	35	156^a	41^b	16^b
	(7)	(3)	(5)	(2)	(1)
Fertilizer Cost	511	254	765^a	190^b	41^c
	(28)	(23)	(26)	(11)	(2)
Cash Input Cost	1044	606	1650^a	619^b	336^c
	(57)	(55)	(56)	(36)	(18)
Non-cash Input	796	493	1289^a	1084^b	1454^c
	(43)	(45)	(44)	(64)	(82)
Total Cost	1840	1099	2939^a	1603^b	1790^c
	(100)	(100)	(100)	(100)	(100)
Average Output Price	2.90	2.80	2.85^a	2.83^a	3.80^b
Gross Benefits	3961	2561	6522^a	2887^b	2594^c
Net Benefit	2121	1462	3583^a	1184^b	804^c
Net Benefit per Unit of Cash Input	2.03	2.68	2.17^a	1.91^b	2.39^a

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[5] All prices (i.e., fertiliser nutrient price, wage rate, seeding material price, and pesticide cost) were deflated by the consumer price index with 1988 as a base year.

Figures in parentheses represent the percentage of total cost incurred in each cropping pattern. Different superscripts represent significance at 5 percent level, and 'similar' represents that they are not significantly different from each other.

The significantly low use of fertiliser by corn-fallow farmers probably could be due to two reasons, (i) keeping the land fellow for six months may have enhanced the soil fertility of land, and (ii) corn-fallow farmers may have higher cash constraints. However, wet season corn of corn-fallow farmers used more total labour compared to wet season corn of corn-corn pattern, although the difference was not significant. More importantly, the former group substituted hired labour with family labour to overcome possible cash liquidity constraint, although we did not have data to support our argument. However, lower average annual income of corn-fellow farmers, P1184, compared to P3583 of corn-corn farmers does provide some support to this argument.

The farmers invested highest cash in the more intensive cropping pattern corn-corn. The wet-season corn crop of the corn-corn pattern required the highest cash flow, while the rice crop of the rice-fallow involved the lowest liquidity. The noncash input is also high for the corn-corn pattern, but the corn crop of the corn-fallow used the highest noncash inputs among all wet- and dry-season crops, again showing substitution of noncash with cash cost in attempt to overcome cash liquidity constraint on corn-fellow farms.

Looking at the input-use scenario, it is not surprising that the corn-corn pattern gave a significantly higher net benefit than did the corn-fallow and rice-fallow patterns. Comparing the wet-season crops, corn (of corn-corn) gave the highest net benefits. The dry-season corn (of corn-corn) produced higher net benefits than did wet season corn (of corn-fallow) and rice (of rice-fallow), entailing significantly lower costs.

Among the wet-season crops, the rate of return per unit of cash investment is highest for rice in the rice-fallow pattern, while the rate of return is almost equal for the wet-season corn grown in corn-fallow or in corn-corn. This implies that farmers who face cash constraints in the wet season would prefer rice over corn in corn-fallow and corn-corn, while the wet-season corn of corn-fallow would be preferred over the wet-season corn of corn-corn because of lower cash requirement with similar rate of return.

The profit of dry-season corn is positively correlated to profit of the wet-season corn in the corn-corn pattern, because of the ability that the wet season profit gives to finance inputs in the dry-season crop. Such an ability to finance cash inputs in the dry-season corn of the corn-fallow and rice-fallow is limited. Thus, the rice- fallow and corn-fallow farmers would have achieved much lower income from dry-season corn had they tried to grow it.

4.3. Risk in Alternative Cropping Patterns

To see the extent of risk in the three cropping patterns, the variance (Equation 10), coefficient of variation (CV), and the expected utility of profit (Equation 12) of each cropping pattern are compared (Table 2). The expected utility of profit is estimated at four assumed values of risk-averse parameters—0.2, 0.5, 0.8, and 1.5.

Table 2

Estimated Values of Various Risk-related Parameters by Crops and

Cropping Pattern in Claveria, Northern Mindanao, Philippines[1]

Parameter	Corn-corn Wet	 Dry	 Total	Corn-fallow	Rice-fallow
Variance (Million)/Hectare	9.5	17.1	31.4	10.4	4.4
Coefficient of Variation (%)	146	283	156	273	260
Utility under Certainty[2]	2121	1462	3583	1183	804
Utility under Uncertainty[2] S = 0.2	304	97	449	93	76
Utility under Uncertainty[2] S = 0.5	44	1.8	58	4.4	6.1
Utility under Uncertainty[2] S = 0.8	17	–0.1	20	1.2	2.1

[1] All risk-related parameters are estimated under the assumption that risk is only due to the weather effect.

[2] The total expected utility of profit of the corn-corn pattern was higher than the simple addition of the expected utility from each crop. This was despite the fact that variance of the pattern was higher than total variance of the individual crops, perhaps because the higher mean profit of the pattern affected the expected utility more strongly than did the higher variance of the pattern.

Although the variance in profit of the corn-corn pattern is highest, but because of high average profit, the pattern produced the lowest CV. The opposite is true for the rice-fallow pattern. Comparing individual crops, the dry-season corn of corn-corn has the highest variance and CV. The wet season corn when grown in the corn-corn pattern is much less risky than the wet season corn grown in the corn-fallow pattern, both in term of variance and CV. It is worth noting that cash investment is also highest in the wet-season corn of the corn-corn pattern. This suggested that intensification both in terms of cash input use as well as cropping intensity reduces risk.

The expected utility of profit is highest from the corn-corn pattern for all the assumed values of risk-averse parameters. Comparing the wet-season crops, corn of the corn-corn pattern still has the highest expected utility of profit, again at all assumed values of risk-averse parameters.

The ranking with respect to net benefit between wet-season corn of corn-fallow and rice of rice-fallow changed when risk is included in the analysis. Both crops have relatively low input use, but rice is less risky than corn of the corn-fallow pattern. Therefore, the expected utility of profit of rice-fallow is higher than that of the corn-fallow pattern at risk-averse parameter values equal to or more than 0.5. It means that farmers with cash constraints and a risk-averse parameter value of more than 0.5 will choose rice; those with a value less than 0.5 and face less liquidity constraints will grow corn in the wet-season.

The expected utility of profit from dry-season corn of the corn-corn pattern became negative at a high value of risk-averse parameter of 0.8. The farmers' decision to grow dry-season crop would depend on the relative expected utility of profit that they would expect to earn by engaging their resources in off-farm activities, an estimate of which is beyond the scope of the study. However, the relatively low expected utility from dry-season corn compared with that from any other crop would prohibit high risk-averse farmers to cultivate dry season-corn. The high variability in the dry-season corn of the corn - corn pattern gave a relatively low expected utility of profit and contributed little to expected utility of profit of the pattern at high values of risk-averse parameters. Because of the positive correlation between wet and dry season incomes, this contribution would be even lower and could possibly be negative under a low-income situation from the wet-season crop. This also explains why at least one third of the farmers leave their fields fallow in the dry season.

4.4. Sources of Risk

The analysis in the previous section clearly highlights the importance of risk in the selection of a cropping pattern. However, it does not explain the sources of risk. To segregate the variance in profit, estimates of production function and the corresponding variance functions with various specifications of the error term are required. The estimates of the production function coefficients are reported in Table 3; and the coefficients of the corresponding variance functions are given in Table 4.

The coefficients of mean output as well as those of variance function are as expected. In the mean output function, labour, value of cash inputs, and variety dummy have a positive effect, while slope of land has a negative effect on output. Labour, value of

Table 3

Parameters of Mean Output Function (Yield in Kg ha^{-1} is a Dependent Variable) by Crop in Different Cropping Patterns with Error Decomposition Model in Claveria, Philippines

Type of Error Controlled	Constant	Labour	Cash Input^{a}	Land Slope	Variety	R^2
Wet-season Corn in Corn-corn						
η_{it}	1.64^{ns}	0.21^{**}	0.34^{***}	-0.17^{***}	0.12^{**}	56.9
	(1.48)	(0.10)	(0.12)	(0.06)	(0.06)	
$(\gamma_i + \eta_{it})h_{it}$	1.53^{ns}	0.19^{**}	0.30^{***}	-0.13^{***}	0.11^{***}	63.7
	(1.34)	(0.09)	(0.10)	(0.04)	(0.04)	
$(\gamma_t + \eta_{it})h_{it}$	1.50^{ns}	0.17^{*}	0.28^{*}	-0.11^{**}	0.09^{**}	42.4
	(1.31)	(0.09)	(0.15)	(0.05)	(0.04)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	1.43^{ns}	0.16^{**}	0.27^{***}	-0.09^{***}	0.07^{***}	61.5
	(1.29)	(0.08)	(0.11)	(0.03)	(0.02)	
Dry-season Corn in Corn-corn						
η_{it}	1.18^{ns}	0.85^{*}	0.41^{***}	-0.14^{*}	0.23^{*}	40.0
	(1.37)	(0.45)	(0.14)	(0.08)	(0.13)	
$(\gamma_i + \eta_{it})h_{it}$	1.06^{ns}	0.73^{***}	0.39^{***}	-0.11^{ns}	0.19^{*}	38.6
	(1.15)	(0.25)	(0.16)	(0.09)	(0.11)	
$(\gamma_t + \eta_{it})h_{it}$	1.05^{ns}	0.69^{**}	0.33^{***}	-0.09^{ns}	0.16^{*}	34.8
	(1.13)	(0.34)	(0.13)	(0.07)	(0.90)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	1.04^{ns}	0.65^{***}	0.30^{***}	-0.06^{ns}	0.14^{*}	39.3
	(1.12)	(0.21)	(0.10)	(0.05)	(0.80)	
Corn in Corn-fallow						
η_{it}	1.93^{ns}	0.12^{***}	0.29^{**}	-0.12^{*}	0.26^{**}	49.2
	(2.15)	(0.05)	(0.16)	(0.07)	(0.14)	

$(\gamma_i + \eta_{it})h_{it}$	1.65^{ns}	0.09^{**}	0.22^{**}	-0.09^{*}	0.21^{**}	46.8
	(2.04)	(0.05)	(0.12)	(0.06)	(0.11)	
$(\gamma_t + \eta_{it})h_{it}$	1.32^{ns}	0.07^{***}	0.19^{***}	-0.08^{*}	0.14^{**}	52.5
	(1.98)	(0.03)	(0.07)	(0.05)	(0.08)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	1.21^{ns}	0.06^{***}	0.14^{***}	-0.05^{**}	0.11^{*}	51.4
	(1.63)	(0.02)	(0.05)	(0.03)	(0.07)	
Rice in Rice-fallow						
η_{it}	0.08^{ns}	0.65^{**}	0.56^{**}	-0.24^{**}	0.96^{*}	47.7
	(0.07)	(0.34)	(0.29)	(0.14)	(0.51)	
$(\gamma_i + \eta_{it})h_{it}$	0.06^{ns}	0.57^{**}	0.49^{**}	-0.18^{***}	0.85^{**}	50.6
	(0.05)	(0.30)	(0.26)	(0.07)	(0.43)	
$(\gamma_t + \eta_{it})h_{it}$	0.05^{ns}	0.52^{***}	0.41^{***}	-0.16^{**}	0.77^{**}	54.2
	(0.03)	(0.21)	(0.16)	(0.09)	(0.40)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	0.04^{ns}	0.46^{***}	0.36^{***}	-0.13^{***}	0.72^{***}	59.9
	(0.04)	(0.18)	(0.13)	(0.05)	(0.32)	

[a] Value of cash input includes cost of fertilizer, and seed. ***, **, * Implies that the coefficients are significant at the 1 percent, 5 percent, and 10 percent level, respectively, and ^{ns} implies that the coefficient is not significant at least at the 10 percent level. Figures in parentheses are asymptotic standard errors.

Table 4

Parameters of Variance Function with Error Decomposition Model by Crop in Different Cropping Patterns in Claveria, Philippines

Type of Error Controlled	Constant	Labour	Cash Input^{a}	Land Slope	Variety	R^{2}
Wet-season Corn in Corn-corn						
η_{it}	9.24**	0.32*	0.26**	0.40**	–0.23*	38.4
	(4.35)	(0.18)	(0.14)	(0.21)	(0.14)	
$(\gamma_i + \eta_{it})h_{it}$	6.17^{ns}	0.40*	0.23**	0.29*	0.21^{ns}	22.5
	(4.65)	(0.24)	(0.12)	(0.17)	(0.18)	
$(\gamma_t + \eta_{it})h_{it}$	5.62**	0.24^{ns}	0.18**	0.26*	–0.19*	26.7
	(2.54)	(0.32)	(0.10)	(0.16)	(0.12)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	4.05*	0.44*	0.16*	0.21**	–.11*	29.2
	(2.40)	(0.25)	(0.11)	(0.12)	(0.08)	
Dry-season Corn in Corn-corn						
η_{it}	10.64^{ns}	0.36^{ns}	0.31*	0.08*	–0.12^{ns}	16.3
	(6.36)	(0.34)	(0.19)	(0.06)	(0.11)	
$(\gamma_i + \eta_{it})h_{it}$	7.16*	0.15^{ns}	0.26*	0.07**	–0.08*	25.0
	(3.98)	(0.17)	(0.16)	(0.04)	(0.06)	
$(\gamma_t + \eta_{it})h_{it}$	3.65**	0.21*	0.22^{ns}	0.06**	–0.05*	29.4
	(1.92)	(0.13)	(0.18)	(0.03)	(0.04)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	2.17**	0.27^{ns}	0.18^{ns}	0.05***	–0.03**	22.8
	(1.16)	(0.20)	(0.21)	(0.02)	(0.02)	
Wet Season Corn in Corn-fallow						
η_{it}	8.17*	0.24*	0.29*	0.30**	–0.20*	24.6
	(4.48)	(0.15)	(0.18)	(0.16)	(0.13)	
$(\gamma_i + \eta_{it})h_{it}$	6.09*	0.37^{ns}	0.25*	0.26*	0.18^{ns}	16.0
	(3.92)	(0.24)	(0.15)	(0.16)	(0.14)	
$(\gamma_t + \eta_{it})h_{it}$	6.04***	0.18*	0.27*	0.21*	–0.15*	25.2
	(2.67)	(0.12)	(0.16)	(0.13)	(0.10)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	5.53**	0.30*	0.23**	0.19**	0.12*	29.5
	(2.86)	(0.18)	(0.12)	(0.10)	(0.09)	
Rice in Rice-fallow						
η_{it}	7.38**	0.31*	0.36**	0.29**	–0.34**	36.8
	(3.76)	(0.12)	(0.19)	(0.16)	(0.18)	
$(\gamma_i + \eta_{it})h_{it}$	5.31*	0.12^{ns}	0.29*	0.22**	–0.26*	22.7
	(2.98)	(0.13)	(0.18)	(0.12)	(0.16)	
$(\gamma_t + \eta_{it})h_{it}$	4.18**	0.22*	0.25*	0.17*	–0.20*	24.1
	(2.15)	(0.14)	(0.15)	(0.11)	(0.13)	
$(\gamma_i + \lambda_t + \eta_{it})h_{it}$	1.03*	0.17*	0.16^{ns}	0.19**	–0.18*	20.3
	(0.69)	(0.11)	(0.17)	(0.11)	(0.12)	

[a] Value of cash input includes cost of fertiliser and seed. ***, **, * Implies that the coefficients are significant at the 1 percent, 5 percent, and 10 percent level, respectively, and

^{ns}implies that the coefficient is not significant at least at the 10 percent level. Figures in parentheses are asymptotic standard errors.

cash input, and slope of land have positive effect on the variance of output, while the variety dummy in most cases has a negative and significant effect. The level of significance for each variable in the first and second moment of output varies with the specification of the error term.

The contribution of management, weather, prices, and residual effects to total variability in profit of alternative cropping patterns are segregated using Equations (14), (15), (17), and (19), respectively. The production effect is estimated by employing Equation (16), and the joint effect by Equation (18). The percentage contribution of each source is reported in Table 5.

Table 5

Decomposition (in Percentage) of Variability in Profit by Crop and Cropping Pattern, Claveria, Northern Mindanao, Philippines

Source	Corn-corn			Corn-fallow	Rice-fallow
	Wet	Dry	Total		
Management	23	9	11	19	21
Weather	49	67	58	47	41
Combined Effect of Weather and Management (Production Effect)[a]	76	85	79	72	69
Prices	6	2	5	5	11
Effect of Production and Prices (Joint-effect)[a]	79	82	78	74	88
Residual Effect	21	18	22	26	12
Total	100	100	100	100	100

[a] The production effect differs from the simple addition of management and weather effect due to covariance between input-output quantities. Similarly, joint-effect of production and prices differs from the simple addition of production and prices due to covariance in input-output quantities and prices.

Weather explained the highest proportion of variability in all crops. This conclusion agrees with the perception that weather is a dominant factor in determining variability in profit in the semi-arid environment [Binswanger, *et al*. (1979)]. However, the contribution of weather varied from crop to crop. It explained 67 percent of the variation in dry-season corn of corn-corn but only 41 percent in rice-fallow.[6]

Management explained about one-fifth of total variability in profit in the wet-season crops, while in the dry-season corn, it explained only 9 percent of the variability. Among the wet-season crops, the share of management is highest in wet-season corn of the corn-corn pattern, and lowest in the dry-season corn of the corn-corn pattern. The production effect varied from 69 percent in rice-fallow to 85 percent in dry-season corn of the corn-corn pattern. The dry-season corn of corn-corn has the highest production effect because of the dominant weather effects.

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[6] The data on rainfall for the study area were collected only for the period 1988 through 1990 under the auspices of a project. Therefore, we cannot compare rainfall distribution in the sample area during the study period with its long-run distribution, the deviation of which could have influenced the results. However, comparison of long-run data from a closer city suggests that the rainfall distribution during 1988-1990 was closer to the normal.

The effect of input-output prices on profit variability is relatively small. In dry-season corn, prices explained only 2 percent of total variation. In the wet-season crops, price variation explained 5–11 percent of total variation in profit. Among the wet-season crops, the proportion of variation explained by prices is highest in rice mainly due to non-established output market for the rice crop in the study area. This is indicated by the high proportion of rice output sold in the undefined local market (77 percent), while most of the corn is sold in city market and to farm traders [Mandac, *et al*. (1987)]. The lowest variability explained by prices in the wet-season corn of the corn-fallow and dry-season corn of corn-corn is not only due to stable output market but also to low input use in these crops.

The low impact of price variation on profit variability is despite the fact that the variance in input-output prices was much lower at the village than at the national level during the study period. Therefore, the importance of prices variability will be even lower at the national level. Moreover variability across farmers was much higher than the variability across time suggesting that different individual farmers access to market plays more important role in defining the profit variability in a region rather than random variation in prices over the year.

The joint effect of production and prices is highest in rice of rice-fallow, and more than simple addition of production and price effects because of the high and positive covariance between input-output quantities and input-output prices. The joint effect of production and prices is less than the simple addition of production and prices for corn-corn and corn-fallow patterns because of negative covariance between input-output quantities and respective prices.

5. CONCLUSIONS

This study concludes that high input and cropping intensity can reduce crop production risk under the rainfed situation when analysis is conducted at the farm level. Although, this contradicts earlier findings of Mehra (1981), Rao (1975), and Barker, *et al.* (1981), but their results are not comparable with ours because; (i) the study in hand was conducted in rainfed situation while earlier studies were for irrigated areas; (ii) the earlier conclusion was based on aggregate district-level data while this study was based on micro-level farm data. The higher variance in production in earlier studies might be due to higher variance in input availability rather than to higher variability in yield caused by modern inputs.

Weather turned out to be the major risk factor in crop production in our study while prices played relatively minor role. However, it cannot to be construed as a general rule and may be valid under the particular situation of rainfed farming. There may be a situation when market interaction is strong, with high variability in prices and input use. Under such circumstances, the role of price and management effects will increase, and the contribution of weather will correspondingly reduce. This situation may arise when farming is characterised by high input intensity especially of chemicals, irrigation, and information, and the market fails to regularly supply these inputs and collect agricultural outputs. Under this situation, individual farmers access to market rather than random walk in prices seems to be more important in stabilising profit from agricultural production at the regional level. Thus integration with input-output markets can help to stabilise farmers' income at the regional level in the intensified agricultural production regions. Stress tolerant varieties may be another mean to reduce variability in profit in the risky environment.

The major caveat of the study is lack of detail data on resource quality and farmers socio-economic conditions, such as cash liquidity constraints. While these data could have shed more light on the factors responsible for the selection of certain cropping pattern with alternative risk and may even have improve the production function fit. This however, does not affect the main results of the study and reduce the validity and usefulness of risk comparison and decomposition methodology specified in this paper.

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