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GROUNDWATER IRRIGATION AND PRODUCTION RISKS IN RICE FARMING IN SOUTHERN PHILIPPINES

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Abstract

A stochastic production function specification is used to value the variability in agricultural productivity of groundwater use in rainfed lowland rice areas by farmers using shallow tube wells (STWs). The study was done in Southern Philippines Province of Cotabato. Using survey data, this study first estimated the mean rice yield function with the cost of pumping, which represents well depth and water availability, used as water supply proxy variable input into the stochastic production function. The results of the estimated mean yield function showed that machineries cost, cost of pesticides, and cost of pumping are the most important determinants of yield levels of rice grown during wet season cropping. The mean yield function revealed a diminishing marginal productivity for the cost of pumping. Nitrogen fertilizer was found to be positively related to yield in the dry season cropping in the sample study area.

The variance function of the stochastic production function provided empirical evidence that the cost of pumping reduces rice yield variability in the wet season cropping. This implies that risk-averse rainfed lowland rice farmers concerned with reducing production risk, hence income variability could use groundwater as source of irrigation. The study proposes, though

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subject to further verification, that the use of shallow tube well stabilizes rice yield in rainfed lowland irrigation agriculture.

The significant higher difference in gross margin (P7,323 ha^{-1}) attained by farmers in high recharge areas in dry season cropping is probably due to higher water levels in turn more water availability than in low recharge areas. The welfare loss associated with increased pumping cost could shed some light on the lower bound estimate valuation of raw water fees for irrigation agriculture that use groundwater. This lower bound estimate only considers the extraction cost but consideration on the in-situ value of the groundwater resource is highly important though it is not included in this study.

Key words: Production risk, shallow tube well, rice farmers, groundwater recharge, cost of pumping, Philippines

1. Introduction

Water scarcity is increasingly recognized as a global concern and, within that broad concern, more attention is focused on emerging patterns of groundwater overexploitation and their implications on human and environmental needs, food production and food security among the more important ones. Reliable water supply is the lead input to increased yields, reduce agricultural risk and stabilize farm incomes highlighting the importance of access to groundwater in food security, as well as for human water supplies in developed and developing nations alike (Foster, 2000). The use of groundwater is a vital source of water supply especially in areas where dry season or extended drought causes streamflow to stop. Its use is a key factor in promoting more efficient irrigation water use.

In any production endeavors, farmers face different kinds of risk. They face production risks from natural phenomena and economic risks from market fluctuations and related economic phenomena. Production risk comes from unpredictable nature of the weather and uncertainty about the performance of crops (Hardaker et al, 2004). The effect of risk and uncertainty is more significant in developing countries due to market imperfections, asymmetric information and poor communication networks. In addition, the stochastic nature of agricultural production is in most cases a major source of risk (Pandey, 1989). Especially in agriculture, variability in yield is not only explained by factors outside the control of the farmers such as input and output prices but also by controllable factors such as varying the levels of inputs (Just and Pope, 1978; Pope and Kramer, 1979; Antle 1983).

The extent to which crop yield is affected by changes in water application depends on several factors including the stage of crop development affected by reduced or non-availability of irrigation water; crop sensitivity to fluctuations in water availability; climatic factors such as evaporation rates; soil factors, soil type, soil moisture and the length of the growing period (Archarya et al, 2000). But the water requirements of crops are nearly satisfied, an increase in the variability of water supply is likely to have a smaller effect on yield variability, due to the relative "flatness" of the yield response function at high levels of water application (Pandey, 1986).

Empirical studies (Tsur, 1990) reveal substantial stabilization value of groundwater. Masahiko and Tsur (2007) pointed out that the variability reducing role of groundwater is ignored, although it carries an economic value, which is designated as the stabilization value (or buffer in the dynamic context) of groundwater. Groundwater use leads to stabilized water supply especially in situations where there is a conjunctive groundwater and surface water use system. Groundwater sources are also relatively more stable and can be used to stabilize the supply of irrigation water.

This implies that risk-averse rainfed lowland rice farmers concerned with reducing income variability can use groundwater as source of irrigation to reduce production risk.

In the case of groundwater abstraction for irrigated agriculture, over-abstraction of groundwater would lead to fluctuation of groundwater levels. This would mean critical changes in the patterns of groundwater flow. It can likewise lead to a wide array of social, economic, and environmental consequences (FAO, 2003). The impacts of overabstraction and water level declines have been reported widely (FAO, 2003)

Past empirical analyses of production risk have been applied to fertilization (de Janvry, 1972; and Rosegrant and Roumasset, 1985), pesticides (Rola and Pingali, 1993), and cotton production under risk (Farnsworth and Moffitt, 1981). The study of Chen et al (no date) presents maximum likelihood panel data estimates of the impacts of climate on yield variability for the major U.S. agricultural crops. Panel data time-series techniques are used to specify and estimate a stochastic production function of the form suggested by Just and Pope. This study would like to investigate the production risk of rice farmers with groundwater as source of irrigation. It would shed light on the link between groundwater resource base to agricultural productivity. By applying the stochastic production function approach, this study would look into the effect on farmers' yields and corresponding changes in net benefits, if groundwater levels change. It analyzes the mean and variability of yield and net benefits of rice production, focusing on the contribution of groundwater irrigation.

2. Description of Study Area

The PRB is one of the three major basin groups in the Central Mindanao Water Resources Region. The total drainage areas of these basins is 16,306 km^2. The PRB lies between $6^0 17'$ and $8^0 20'$ north latitude, and $124^0 65'$ and $125^0 10'$ east longitude. The study covered four selected municipalities in the middle downstream portion of the PRB. These are contiguous areas which are traversed by the PRB from the northwest to the southeast direction, and with the greatest number of STWs.

The geologic formation in the sample study area which is in middle portion of the basin is underlain by Recent (R) Unconsolidated Coastal, river outwash, valley fill-irrigular deposits of clay, silt, sand, gravel, coral and other organic remains. This occupies 3,864 km^2 or 23.7% of the total basin area. The climate in the study area belongs to the 4^{th} climatic type. Wet season falls during May to September while the dry season falls from October to March. Majority of the sample municipalities posted a mean annual rainfall of 1,397.79 mm.

The topography is generally flat with slope ranging from 0-3%. The soil texture types in the study area are of sandy clay loam and clay loam. Over 60% of the total land areas in the four sample municipalities are devoted to agriculture. Rice and corn are the dominant crops. Of the 11 sample barangays in the four municipalities of Cotabato, 7 are semi-confined aquifers and 4 are confined aquifers. The least and maximum aquifer thickness in the study area is 30 ft bgs and 70 ft bgs, respectively, and the shallowest and deepest static water table levels, 1.52 ft bgs and 60 ft bgs, respectively. A little over half (54%) of the respondents' well depth are at fine sand porous material yielding an average specific yield of 0.33.

3. Methodology

3.1 Sampling Methodology and Data Collection. The study used both primary and secondary data. Primary data were collected through interviews with farmer-respondents, using pre-tested questionnaires. The respondents were those with shallow tube wells (STWs) and underground water pump.

The study used four-stage stratified sampling, with the first stage on the groundwater formation categorization, second stage by region, the third stage by provincial boundary, and the fourth, by municipality. From the administrative boundaries covered by the Pulangui River Basin (PRB), the province of Cotabato, Philippines was chosen. The municipalities which extensively use STWs or which have the most number of STWs used for irrigating crops and at the same time use the aquifer area served by the PRB were chosen.

The sampling unit of the study consists of owners and/or operators of STWs as well as users of STW for irrigation purposes. The initial list of farmers owning STWs in the study area and who had availed of financing from the Department of Agriculture (DA) was obtained. It was verified that most of those in the list were not using their STW during the cropping period covered in the study. There was difficulty in establishing the population of STW farmers in the study area, and under this limitation, the researcher used purposive sampling. Through memory recall (of barangay officials and referrals from STW farmer-respondents interviewed) the names of farmers owning STWs at the barangay level were added to the list. Criteria used by the researcher were: areas with great number of STWs, STWs were situated in contiguous area; and availability of well log data. Only the cropping season of rice cultivation for the cropping period 2005-2006 by the respondents which made use of STWs was considered by the researcher.

Eleven barangays in four municipalities were surveyed and 125 STW farmer-respondents were interviewed. Initial encoding of the data and from the scatter diagram made on yield vis-à-vis cost of pumping, and yield vis-à-vis volume of groundwater extraction necessitated the removal of the outliers from the initial sample size in the wet and dry season croppings. Four outliers in the wet season cropping pool data and five in the dry season pool data were removed, narrowing the sample size to 113 respondents in wet season and 117 respondents in dry season cropping (overall sample of 63 respondents in high recharge areas[1] and 55 respondents in low recharge areas. Specifically, in terms of per cropping and by recharge area, there were 56 and 57 respondents in high and low recharge areas, respectively in wet season cropping. In dry season cropping, there were [2]61 and 56 respondents from high and low recharge areas, respectively.

3.2 The Yield Distribution Function. Estimating for risks due to groundwater level fluctuations, a stochastic specification under risk following from Just and Pope (1979) was used. Where if all relevant variables were known with certainty, farmers would face the classical maximization problem: maximizing profits. However, after decisions are made, natural and economic conditions change, and with this new setup, previously optimal decisions become sub-optimal. Just and Pope (1979) pointed out that risk considerations are increasingly necessary in the analysis of agricultural sector. Just and Pope also showed that the usual multiplicative-error economic production function specifications may be inappropriate because they restrict the effect inputs can have on output variance.

The yield distribution function reflects the stochastic effects of groundwater level fluctuations damage on production and hence indirectly on yields. The Just and Pope Stochastic Production Function Model (1979) specifies the following relationship:

$$y = f(x) + h(x)^{1/2} e^{u} \qquad (1)$$

where:

y = yield

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[1]Using Water Table Fluctuation Method of groundwater recharge estimation, the sample study area was arbitrarily zonified into high and low recharge areas. High recharge areas are those with recharge estimates greater than the overall average of 1.295 ft/2.3 months (Gomez, 2007). While areas with groundwater recharge estimates of less than 1.296 ft/2.3 months are arbitrarily classified as low recharge areas.

f(x) = deterministic component of the production function and

e^u = error term, where u ~N(0, σ^2)

h(X) is the variance of the output: E(y) = f(x) and Var(y) = h(X). Note that $e^u h(X)^{1/2}$ behaves like an error term with mean zero and variance h(X). Thus, the Just-Pope specification corresponds to a regression model with heteroscedastic error term.

Where both f and h follow a popular log-linear form the Cobb-Douglas, the function f(x) could be estimated using the non-linear regression estimation and h(x) is estimated using the Ordinary Least Squares.

The second moment or variance of the distribution was computed via a weighted regression of the inputs of production by the square of the error term in Equation (1). Given $\partial Var(y)/\partial x = \partial h/\partial x$, it follows that $\partial h/\partial x \rangle 0$ identifies inputs x that are risk-increasing, while $\partial h/\partial x \langle 0$ identifies inputs that are risk-decreasing.

3.3 Empirical Model

3.3.1. Mean Yield Function. The empirical model for the stochastic production function is in Cobb-Douglas form. It assumes constant input elasticities and variable marginal products. The coefficients estimated by using this form represent output elasticities of individual variables and the sum of these elasticities indicates the nature of returns to scale. It can be estimated in log-linear form as follows:

$\ln Y = \alpha + \beta_1 {}_{+} \ln labor + \beta_2 \ln fertN + \beta_3 \ln fertP + \beta_4 \ln fertK +$

+ β_5 lnCost of Pesticides ha^{-1} + β_6 ln Machineries Cost + β_7 lnPumping cost + β_8 lnWell spacing

+ β_9 Dummy for Recharge (where 1 – High Recharge; 0 – Low Recharge) + ε_i

(2)

and ε_i is the random disturbance associated with the production function

Where:

Y - yield in tons per hectare

ln labor – labor in man-days; ln fertN – nitrogen fertilizer (in kgs);

ln fertP – fertilizer phosphorus (in kgs); ln fertK – fertilizer potassium (in kgs);

ln cost of pesticides ha^{-1} (in pesos); ln machineries cost ha^{-1} (in pesos); ln pumping cost ha^{-1} (in pesos) Pumping cost is used as water supply proxy variable in the model. It signifies well depth and water availability, and is derived from the linear relationship between energy and volume of diesel used. Energy is the product of power requirement and duration of pumping.;

ln well spacing (in meters); ln dummy for recharge (where 1 – high recharge; 0 – low recharge)

3.3.2. Second Moment Yield Function. The second moment of the distribution was computed via a weighted regression of the inputs of production by the square of the error term in Equation (1).

The empirical model for the second moment yield function is in log-linear model. It can be estimated in log-linear form where groundwater recharge is represented by a dummy variable as follows:

$$\ln Y = f(\ln L, \ln N, \ln P, \ln K, \ln CP, \ln MC, \ln PC, \ln WS, \ln R) \qquad (3)$$

Where:

Y - yield in tons per hectare

ln L – labor in man-days; ln N – nitrogen fertilizer (in kgs);

ln P – fertilizer phosphorus (in kgs); ln K – fertilizer potassium (in kgs);

ln CP- cost of pesticides ha^{-1} (in pesos); ln MC - machineries cost ha^{-1} (in pesos);

ln PC - pumping cost ha^{-1} (in pesos) Pumping cost is used as water supply proxy variable in the model; ln WS- well spacing (in meters);

ln R - dummy for recharge (where 1 – high recharge; 0 – low recharge)

3.3.3. Net Benefit Estimation. We also estimated for Gross Value of Product, Cost of Production, and Net Benefit as follows:

Gross Value Product (GVP) = predicted yield/ha x price of palay (4)

Cost of Production (COP) = is variable cost of production (includes all cash and non-cash expenses) incurred on producing inputs activities, including cost of hired labor and imputed value of family labor. Fixed costs and equipment depreciation are not included. (5)

Cost of Production component = cost of family labor + cost of hired labor + cost of machineries used/hired+ cost of seeds + cost of fertilizers N + cost of fertilizer Phosphorus + cost of fertilizer potassium + cost of pesticides + cost of fuel used in STW operation + cost on engine oil + cost of hauling (6)

Gross Margin/Gross Benefit = GVP – Variable Cost of Production (7)

4. Results and Discussion

4.1 Descriptive Statistics of Farmer and Farm Characteristics. Majority of the respondents use family labor during pumping and assign the responsibility of operating the pump to only one person. Direct seeded predominate (60%) in wet season cropping in high recharge area with a mean size of 2.38 hectares an average frequency of pumping of 4.61 times. About 56% of the rice fields in low recharge areas are transplanted and the average frequency of pumping is 5.7

times. The average frequency of pumping in direct seeded areas during the dry season cropping is 8 times and 9 times, respectively, in high and low recharge areas. The direct seeded areas in both recharge areas are relatively bigger in dry season cropping.

On a per hectare basis, the duration of pumping in the wet season cropping is 81.5 hrs and 129.60 hrs in high and low recharge areas, respectively. In the dry season cropping, the pumping duration per hectare is 175.91 in high recharge areas and 269.18 hrs in low recharge areas. In both wet and dry season cropping, the duration of pumping in low recharge areas is longer. The corresponding volume of groundwater extraction for irrigation, a hectare of rice in the study site making use of groundwater for irrigation in the wet season cropping extracts 2,324.57 m^3ha^{-1} and 2,816.98 m^3ha^{-1}, respectively in high and low recharge areas. In dry season cropping, the sample rice farmers extracts 5,004.9 m^3ha^{-1} and 6,451 m^3ha^{-1}, respectively in high and low recharge areas.

4.2 Descriptive Statistics of Yields and Inputs. Mean gross yield ha^{-1} in high recharge areas in the wet season cropping is 4.47 tons, with average inputs as follows: labor use, 25.05 man-days, and average fertilizer used based on its Nitrogen, Phosphorus, and Potassium content are 45.42 kgs, 11.52 kgs, and 7.11 kgs, respectively. Average cost of pesticides ha^{-1}, machineries cost, and cost of pumping amount to P2,008, P4,048, and P1,927, respectively (Table 1).

Farmers in low recharge area reported a mean gross yield of 4.27 tons in the wet season cropping, with average inputs used as follows: labor 32.59 man-days, Nitrogen, Phosphorus, and Potassium content 35.96 kgs, 11.15 kgs, and 6.14 kgs, respectively. Average cost of pesticides, machineries cost, and cost of pumping are P1,956, P4,048, and P2,230, respectively, ha^{-1}. Gross yield ha^{-1} in the dry season cropping is 3.86 tons

and 3.58 tons in high and low recharge areas, respectively. The cost of pumping ha^{-1} is P7,745 and P7,942, in high and low recharge areas, respectively (Table 2).

The scatter diagram plot of yield and pumping cost of the STW sample farmers in both wet and dry seasons indicates a decreasing trend in yield as pumping cost increases (Fig. 1-2). Likewise the scatter diagram plot of yield and volume of groundwater extraction shows that the yield is declining at a higher volume of groundwater extraction (Fig. 3-4). This negative coefficient of pumping cost suggests the possibility of a decrease in groundwater levels. About 32% of the respondents in high recharge areas reported decreased water flow discharge from wells during simultaneous pumping.

Table 1. Descriptive statistics of yield and inputs on per hectare basis in the high and low recharge area in wet season cropping, 2005-2006

HIGH RECHARGE AREA (WET SEASON CROPPING)	*MEAN*	*STANDARD DEVIATION*	*MIN*	*MAX*
Gross Yield (tons)	4.47	1.05	1.5	7.09
Input Use:				
Labor (man-days)	25.05	8.67	15.25	48
Fertilizer (kgs)				
Nitrogen	45.42	30.92	0	134
Phosphorus	11.52	10.72	0	42
Potassium	7.11	8.86	0	42
Pesticides (pesos)	2,008	1,204	0	6,620
Machineries Costs	4,048	1,519	1,620	7,822
Cost of Pumping[1/]	1,927	2,265	93	9,970
Well Spacing (meters)	182	154	10	750
LOW RECHARGE AREA (WET SEASON CROPPING)	MEAN	STANDARD DEVIATION	MIN	MAX
Gross Yield (tons)	4.27	1.18	1.76	7.44
Input Use:				
Labor (man-days)	32.59	13.20	15.2	95.7
Fertilizer (kgs)				
Nitrogen	35.96	20.53	0	83

Phosphorus	11.15	9.52	0	34
Potassium	6.14	8.10	0	37
Pesticides (pesos)	1,956	1,428	0	9,200
Machineries Costs (pesos)	4,048	1,479	930	7,575
Cost of Pumping (pesos)[1/]	2,230	1,981	155	8,386
Well Spacing (meters)	130	103	10	500

Note:[1/] Cost of pumping is derived from the linear regression of energy and volume of diesel used which established the relationship between the energy and volume of diesel used (Gomez, 2007)

$Y = 284.79 + 167.63X$

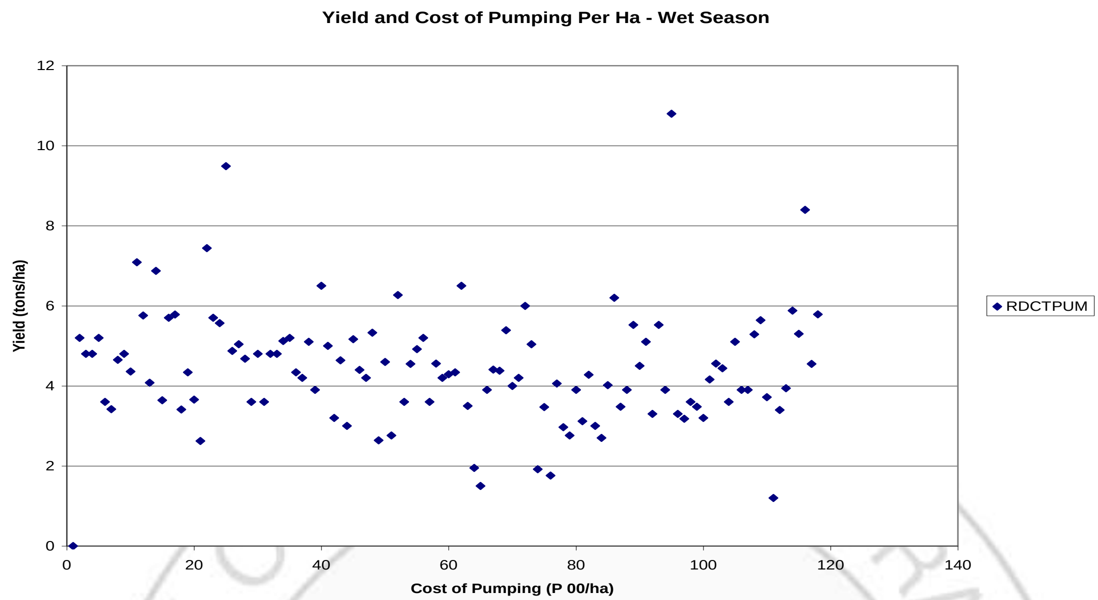

Fig. 1 Scatter diagram of yield and pumping cost in wet season cropping, 2005-2006

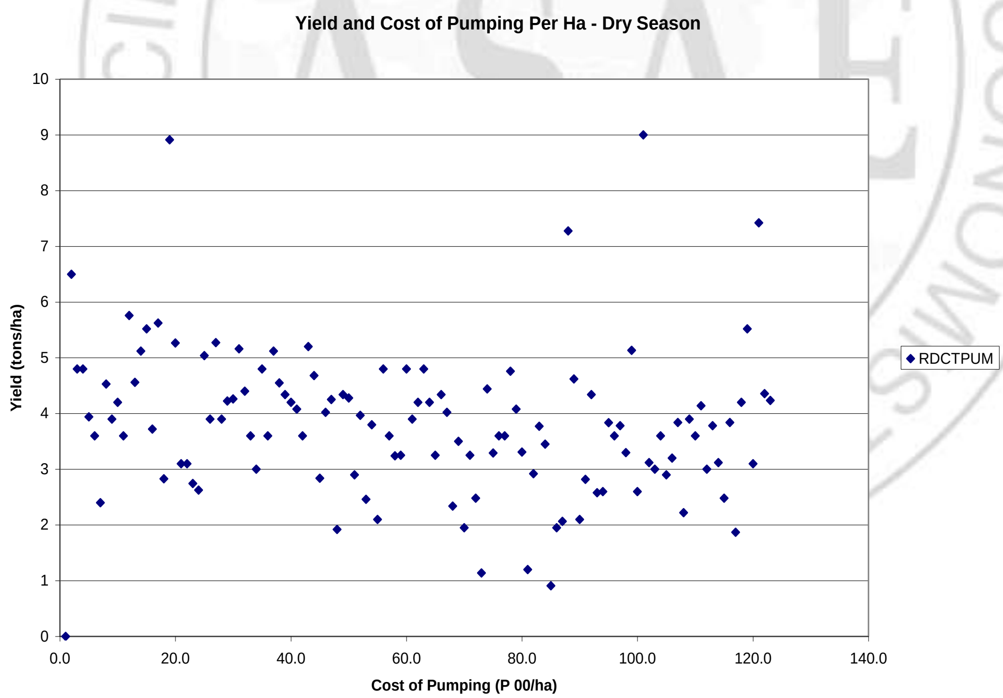

Fig. 2 Scatter diagram of yield and pumping cost in dry season cropping, 2005-2006.

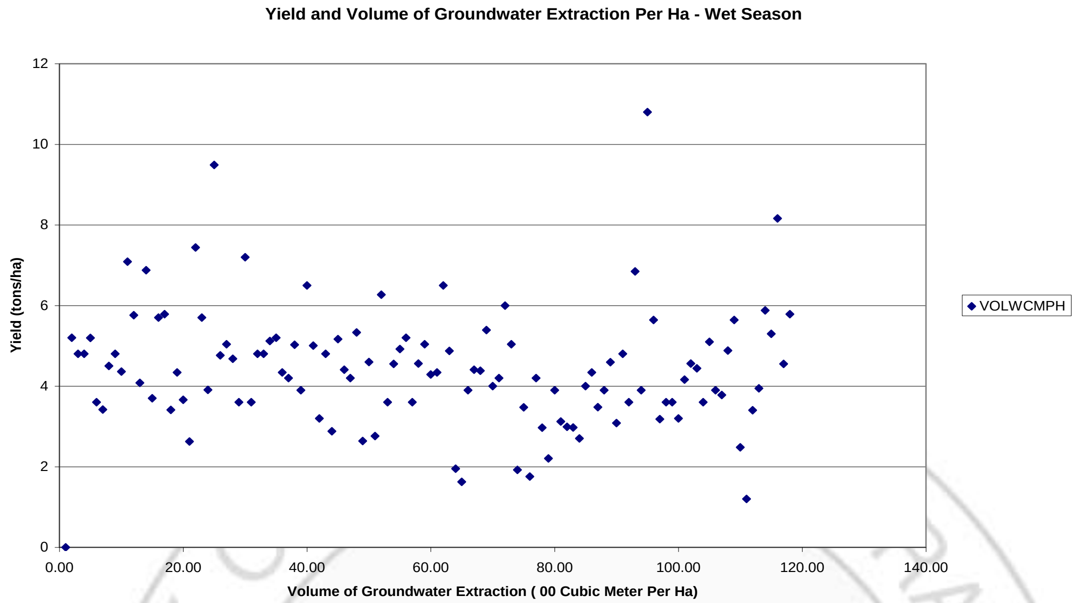

Fig. 3 Scatter diagram of yield and volume of groundwater extraction in wet season cropping, 2005-2006.

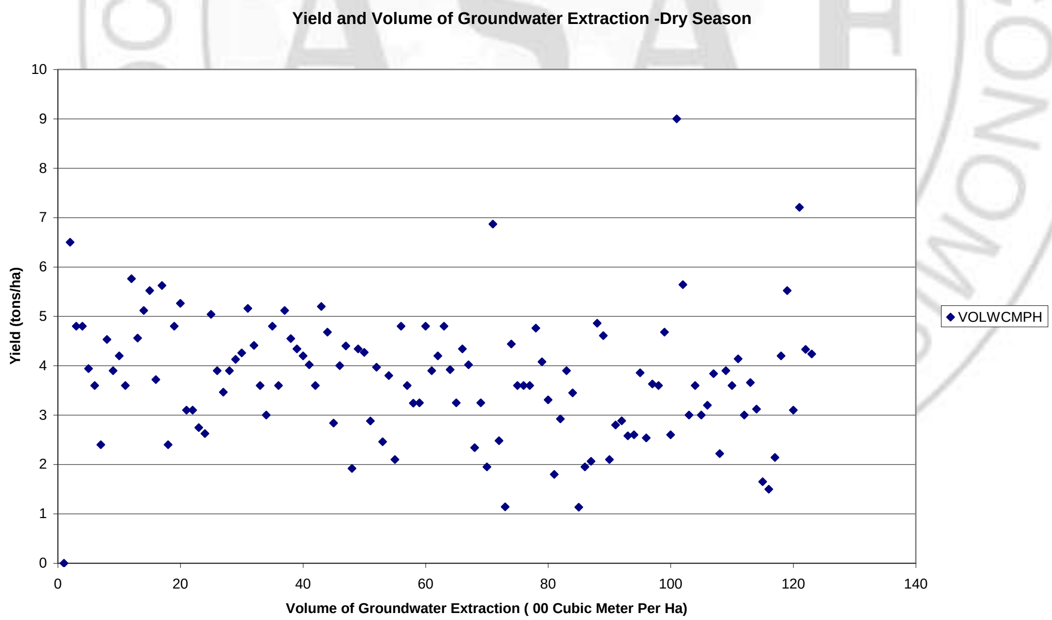

Fig. 4 Scatter diagram of yield and volume of groundwater extraction in dry season cropping, 2005-2006.

Increased pumping cost implies a possible decrease in groundwater level or there is greater depth of groundwater level. A decrease in groundwater levels would result in welfare loss, either due to increased pumping cost and/or change in productivity (Acharya et al, 2000). An increase in well depth (or the pressurization requirement) will reduce the water demand as well as reduce yield (Caswell et al, 1986). Furthermore, over-extraction on groundwater takes place in the high recharge areas in the wet season cropping, as reflected by a negative coefficient for pumping cost, which implies that farmers unnecessarily over-irrigate their rice crop as the yield response function at high levels of water application is relatively "flat". Hence additional pumping cost would only lead to diminishing marginal productivity.

At optimum yield, the optimal pumping cost is estimated at P2,511.45 in the wet season cropping, implying that a pumping cost above this point will be associated with yield loss and welfare loss. This would explain the non-responsiveness of nitrogen and phosphorus fertilizer on rice yield as reflected in the mean yield function. Excess water applied to irrigate rice would prevent the absorption of nutrients in the fertilizer applied, as these are wasted as run-off.

4.3 Econometric Results of Stochastic Production Function

4.3.1. Mean Yield Effects of Production Inputs – Wet season cropping. Table 3 presents the estimated parameter values of the mean yield function (first moment) in the wet and dry season croppings. The mean function in the wet season shows that statistically, pesticides and machineries cost (for hire for land preparation and threshing), are significant respectively at 5 and 1 percent level indicating their importance in

Table 2. Descriptive statistics of yield and inputs on per hectare basis in the high and low recharge area in dry season cropping, 2005-2006

HIGH RECHARGE AREA (DRY SEASON CROPPING)	*MEAN*	*STANDARD DEVIATION*	*MIN*	*MAX*
Gross Yield (tons)	3.86	0.94	1.12	5.76
Input Use:				
Labor (man-days)	25.91	9.72	15.25	52.75
Fertilizer (kgs)				
Nitrogen	47.48	33.82	0	162
Phosphorus	10.9	11.50	0	42
Potassium	7.19	10.03	0	42
Pesticides (pesos)	1,826	1,148	0	5,700
Machineries Costs	3,820	1,414	1,560	6,975
Cost of Pumping[2/]	7,745	12,151	852	89,467
Well Spacing (meters)	176	151	10	750

LOW RECHARGE AREA (DRY SEASON CROPPING)	MEAN	STANDARD DEVIATION	MIN	MAX
Gross Yield (tons)	3.58	1.06	1.2	6.5
Input Use:				
Labor (man-days)	31.49	9.62	15.2	52.5
Fertilizer (kgs)				
Nitrogen	35.99	20.54	0	83
Phosphorus	11.57	9.49	0	34
Potassium	5.98	8.13	0	37
Pesticides (pesos)	1,950	1,413	350	9,200
Machineries Costs (pesos)	4,046	1,580	1,321	8,180
Cost of Pumping (pesos)[2/]	7,942	7,227	1,678	40,260
Well Spacing (meters)	128	101	10	500

Note:
[2/] Cost of pumping is derived from the linear regression of energy and volume of diesel used which established the relationship between the energy and volume of diesel used (Gomez, 2007).
$Y = 8909 + 125.6X$

determining mean yield. Both inputs contribute positively in terms of marginal productivity.

The mean yield function reveals that pumping cost has a negative effect on yield; it is significant at 15% level. With water as input, the water response function is assumed increasing and strictly concave over the appropriate range of water input, reflecting diminishing marginal productivity (Carruthers and Clark, 1981; Masahiko and Tsur, 2007).

4.3.2. Mean Yield Effects of Production Inputs - *Dry season cropping*. The mean yield function in the dry season cropping in high recharge areas shows that the estimated coefficients associated with machineries cost is significant positively at 1 percent level. This is normally expected as hiring machineries services help carry out critical agricultural operations on time. Conversely, the estimated coefficient associated with pumping cost is negative but not significant. The mean yield function further reveals that nitrogen fertilizer is positively related to yield in the dry season cropping, indicating that a percentage increase in nitrogen fertilizer application will likewise increase rice yield.

4.4 Production Risk Effects

4.4.1 Yield Risk Effects of Production Inputs – Wet Season. Variability of rice yield is considered a measure of production risk. Thus, if variability of yield increases as the level of input is increased, the input is considered a "risk-increasing" input. Conversely, if variability of yield is decreased as input is increased, the input is

Table 3. Econometric results for mean yield function of wet and dry season croppings, 2005-2006

VARIABLES	*MEAN YIELD FUNCTION*			
	Wet Season		Dry Season	
	Beta coefficients	T-values	Beta Coefficients	T-values

Constant	-0.847	-1.430^{a}	-0.537	-0.779
Log Labor	-0.012	-0.102	0.027	0.288
Log Fertilizer Nitrogen	0.092	0.407	0.196	1.632*
Log Fertilizer Phosphorus	0.081	-0.728	0.003	0.028
Log Fertilizer Potassium	-0.139	-1.354^{b}	-0.131	-1.263^{b}
Log Cost of Pesticides Ha^{-1}	0.224	2.093**	-0.029	-0.255
Log Machineries Cost	0.378	4.084***	0.327	3.635***
Log Pumping cost	-0.139	-1.470^{a}	-0.067	-0.713
Log Wellspacing	0.073	0.794	-0.108	-1.204
Dummy for Recharge	0.115	1.208	0.163	1.699*
1 – High Recharge				
0 – Low Recharge				
Adjusted R^2	0.14		0.13	
F-value	2.955***		2.870***	

$\alpha = 20\%$ P < 0.05 - ** P < 0.10 - * P > 0.20 – n.s.
P < 0.01 - *** P < 0.15^{a} P < 0.20 - ^{b}

considered “risk-reducing”. The estimated results of the second moment function are shown in Table 4.

The estimated parameter values of the second moment stochastic production function in the wet season cropping shows that potassium fertilizer is a yield risk reducing input (e.g. higher levels of this fertilizer are associated with smaller yield variances). On the other hand, pesticide cost is considered a risk increasing input. The second moment function shows a negative coefficient value for pumping cost during the

wet season which implies reducing risk as this input increases. Coefficient of pumping cost is highly significant at 5%.

Table 4. Econometric results for second moment function of wet and dry season cropping, 2005-2006

VARIABLES	*SECOND MOMENT*			
	Wet Season		Dry Season	
	Beta coefficients	T-values	Beta Coefficients	T-values

Constant	-1.227	-0.755	-1.451	-0.486
Log Labor	-0.008	-0.097	-0.022	-0.254
Log Fertilizer Nitrogen	-0.056	-0.549	0.433	3.929***
Log Fertilizer Phosphorus	0.041	0.428	-0.022	-0.220
Log Fertilizer Potassium	-0.386	-4.263***	-0.377	-3.976***
Log Cost of Pesticides Ha^{-1}	0.530	5.643***	0.067	0.650
Log Machineries Cost	0.174	2.151**	0.058	0.700
Log Pumping cost	-0.192	-2.314**	0.092	1.067
Log Wellspacing	-0.036	-0.447	0.106	1.285[b]
Dummy for Recharge 1 – High Recharge 0 – Low Recharge	-0.049	-0.593	0.105	1.192
F-value	7.336***		5.684***	

$\alpha = 20\%$ P < 0.05 - ** P < 0.10 - * P > 0.20 – n.s.
P < 0.01 - *** P < 0.15[a] P < 0.20 - [b]

The risk-reducing nature of pumping cost (considered as water proxy variable) may be attributed to the nature of STWs, which operate by suction with a lifting range of about 7.5 mbgs. The groundwater extracted by STWs is usually replenished during the wet season. Hence, we can safely say that the drop in the natural water table level during the dry season for STWs is lower compared to that for deep wells. Furthermore, David (2004) pointed out that as long as the water level is within the suction lifting range throughout the dry season, partial crop failure due to water shortage as a result of temporary groundwater overdraft can be prevented. On the other hand, empirical evidence indicates that the relationship between irrigation and stability is not straightforward (Pandey, 1989).

4.4.2 Yield Risk Effects of Production Inputs - *Dry season*. The dry season second moment function reveals a positive coefficient value (0.433) for nitrogen fertilizer which implies increasing risk as this input increases. This supports the findings of most studies on risk due to nitrogen use on the rice crop (Rola and Pingali 1993; and Roumasset and Rosegrant 1985). It is noteworthy that the coefficient of pumping cost during the dry season (considered as water proxy variable) is not significant though positive. It is because groundwater as source of irrigation is considered as a necessity input during dry season cropping (Gomez, 2007).

This is in contrast with the negative coefficient value for pumping cost during the wet season which implies reducing risk as this input increases. This is due to the fact that where the water requirements of crops are nearly satisfied, an increase in the variability of water supply is likely to have a smaller effect in yield variability, due to the relative "flatness" of the yield response function at high levels of water application.

4.5 Estimation of Net Benefits

4.5.1 Based on Actual Data. Mean yield estimates from the raw data set show that actual yields of the respondents for high and low recharge areas are almost the same in the wet season cropping. Actual mean yield range is 4.47 tons ha^{-1} for high recharge areas and 4.27 tons ha^{-1} for low recharge areas. Gross margin in high recharge areas is P24,410.29 ha^{-1} and in low recharge areas, P23,566.39 ha^{-1} (Table 5).

The range of actual mean yield of both recharge areas in the dry season cropping is 3.86 tons ha^{-1} and 3.58 tons ha^{-1} for high and low recharge areas, respectively. This gives corresponding gross margins of P19,188.20 ha^{-1} and P15,820.96 ha^{-1}, respectively.

Table 5. Estimated mean benefit of rice production (P/ha) based on actual yield of the sample STW farmer-respondents, wet and dry season cropping, 2005-2006.

WET SEASON	*PRICE/KG*	*AVERAGE YIELD (TONS ha^{-1})*	*GROSS VALUE OF PRODUCT (GVP) in (P/ha)*	*COST OF PRODUCTION (COP) (P/ha)*	*GROSS MARGIN (P/ha)*
High Recharge Area	8.60	4.47	38,440.71	13,030.42	24,410.29
Low Recharge Area	8.60	4.27	36,690.47	13,124.08	23,566.39
DRY SEASON	PRICE/kg	AVERAGE	GROSS	COST OF	GROSS

		YIELD (tons ha^{-1})	VALUE OF PRODUCT (GVP) in (P/ha)	PRODUCTION (COP) (P/ha)	MARGIN (P/ha)
High Recharge Area	9.20	3.86	35,535.08	16,346.87	19,188.20
Low Recharge Area	9.20	3.58	32,904.29	17,083.33	15,820.96

Where:
GVP = Predicted yield x Price
COP is variable cost of production (include all cash and non-cash expenses) incurred on production inputs and activities, including cost of hired labor & imputed value of family labor. Fixed costs and equipment depreciation are not included
Gross Margin = GVP – Variable COP
Cost of Production Component = cost of machineries hired/used, cost of seed, cost of NPK, cost of pesticides, cost of labor, pumping cost, cost of harvesting and threshing, and cost of hauling.
Consumer Price Index (CPI) 2000 = 100%
All costs were deflated to 2000 CPI
Average CPI 2005 of Region XII = 127.025

4.5.2 Based on the Estimated Mean Yield Function. The estimated mean expected benefit from the mean yield function of wet season cropping reveals that high and low recharge areas do not reflect a great significant difference in terms of yield and gross margin per hectare. This is attributed to sufficient rainfall in both recharge areas during wet season cropping.

The difference in yield and expected benefit of STW rice farmers in the said two recharge areas is significantly evident in dry season cropping, when there is less precipitation and great dependence of STW rice farmers on groundwater as source of irrigation water. The gross margin ha^{-1} of farmers in high recharge areas is P26,824.03 and that in low recharge areas, P19,501.30 ha^{-1}. The gross margin ha^{-1} of STW rice farmers in high recharge areas is higher by P7,322.73 than that of farmers in low recharge

areas (Table 6).

Higher gross margin attained by rice farmers in high recharge areas may be attributed to more availability of underground water brought about by higher water level in high recharge areas. The water table level in low recharge areas are relatively lower; hence less water availability.

4.6 Comparing Net Benefits and Pumping Costs in High and Low Recharge Areas

Drawing from the mean yield function of the high and low recharge areas in the dry season cropping, the dummy variable for recharge is significant at 10% level with a positive coefficient of (0.163). This implies that the positive shift in yield of farmers in high recharge areas during the dry season cropping is 1.18 tons ha^{-1} over those farmers in low recharge areas. This positive shift in yield of those farmers in high recharge areas gives them a gross margin ha^{-1} of P7,323 which is higher than that in low recharge areas, based on estimated mean yield function of Table 7. The estimated yield levels are 4.69 tons ha^{-1} in high and 3.98 tons ha^{-1} in low recharge areas. In terms of the estimated pumping cost, the difference between the two recharge areas, is minimal, estimated at P197 per hectare, with lower estimated pumping cost ha^{-1} incurred by farmers in high recharge areas.

Table 6. Estimated mean benefit of rice production (P/ha) based on mean yield function in wet and dry season cropping, 2005-2006.

WET SEASON	*PRICE/KG*	*AVERAGE YIELD (TONS ha^{-1})*	*GROSS VALUE OF PRODUCT (GVP) in (P/ha)*	*COST OF PRODUCTION (COP) (P/ha)*	*GROSS MARGIN (P/ha)*
High Recharge Area	8.60	8.05	69,227.42	13,030.42	56,197
Low Recharge Area	8.60	8.05	69,227.42	13,124.08	56,103.34
DRY SEASON	PRICE/kg	AVERAGE YIELD (tons ha^{-1})	GROSS VALUE OF PRODUCT (GVP) in (P/ha)	COST OF PRODUCTION (COP) (P/ha)	GROSS MARGIN (P/ha)
High Recharge Area	9.20	4.69	43,170.91	16,346.87	26,824.03
Low Recharge Area	9.20	3.98	36,584.63	17,083.33	19,501.30

Where:
GVP = Predicted yield x Price
COP is variable cost of production (include all cash and non-cash expenses) incurred on production inputs and activities, including cost of hired labor & imputed value of family labor. Fixed costs and equipment depreciation are not included
Gross Margin = GVP – Variable COP
Cost of Production Component = cost of machineries hired/used, cost of seed, cost of NPK, cost of pesticides, cost of labor, pumping cost, cost of harvesting and threshing, and cost of hauling.
Consumer Price Index (CPI) 2000 = 100%
All costs were deflated to 2000 CPI
Average CPI 2005 of Region XII = 127.025

Table 7. Summary of difference in estimated pumping cost and gross margin in high and low recharge areas during wet and dry season cropping, using actual data and estimated yields.

ITEM	*MODEL 1*	*MODEL 2*
Gross Margin (in pesos/ha)		
Dry Season		
High Recharge – Low Recharge	3,367	7,323
Wet Season		
High Recharge – Low Recharge	844	94
Cost of Estimated Pumping (in pesos/ha)		
Dry Season		
Low Recharge – High Recharge	2,227	197
Wet Season		
Low Recharge – High Recharge	491	303

Where:
Model 1 – Based on actual data
Model 2 – Based on estimated mean yield function

On the other hand, the minimal difference in estimated pumping cost and gross margin of the two said recharge areas during wet season cropping is only P94 per hectare. This is explained by the fact that there is more rainfall during wet season cropping in both recharge areas, be it in terms of event, quantity, and intensity. The mean yield function shows a negative coefficient for the pumping cost, meaning that an additional pumping cost will not significantly add to the yield. This shows that farmers in high recharge areas tend to over-extract groundwater for irrigation when it is not necessary, given that this particular cropping season has relatively more rainfall. Hence, additional pumping cost only leads to diminishing marginal productivity. The same trend could be observed in gross margin per hectare and pumping cost in the Model 1, which is based on actual data of the farmer-respondents.

5.0 Conclusions and Implications

From the estimated mean yield function, the machineries cost, cost of pesticides, and cost of pumping are the most important determinants of yield levels of rice grown in the wet season cropping. The negative effect of the cost of pumping on yield reflects a diminishing marginal productivity. Likewise, the negative coefficient of the cost of pumping in the wet season signifies that these farmers might have excessively irrigated their rice at a level which exceeds the requirement.

The estimated mean yield in wet season cropping shows that an increase in the cost of pumping will lead to welfare loss This is significant information which for the local government policy makers when they consider levying a resource management charges for irrigation agriculture in the sample study area which reflect resource scarcity and external impacts. This could be the lower bound estimate valuation of raw water fee for irrigation agriculture making use of groundwater as source of irrigation water. This is a lower bound estimate because we only consider the extraction cost incurred by the farmers taking into consider the well depth and water availability in the sample study area. This does not take into consideration the in-situ value of the groundwater resource.

The second moment functions of the stochastic production function provided empirical evidence that the cost of pumping (which is used as a water supply proxy variable) reduces yield variability or reduces exposure to risk during the wet season only. The study proposes subject to further verification, that the use of STW stabilizes rice yield in rainfed lowland irrigation agriculture. This confirms the empirical findings of Masahiko and Tsur (2007) on the substantial stabilization value of groundwater which is of important economic value especially in stabilizing the supply of irrigation water.

Risk-averse rainfed lowland rice farmers concerned with reducing income variability can use groundwater as source of irrigation as a means of reducing production risk. Risk-reducing effects of potassium fertilizer and the risk increasing effect of the cost of pesticides in the wet season cropping and the risk increasing effect of nitrogen fertilizer in dry season cropping is also found to be important. The risk increasing effect of nitrogen supports findings of most studies done on rice.

The significant difference in the gross margin per hectare of farmers in high and low recharge areas, estimated from the mean yield function, shows a difference of P7,322.73 in favor of farmers in high recharge areas. This can be attributed to more groundwater availability due to higher water levels in this part of the aquifer basin.

A glimpse on prioritization in the groundwater resource use allocation for irrigation agriculture and land use planning could possibly be drawn from the analysis of the results. Higher priority on allocation during dry season cropping should be given to high recharge areas.

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