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AN ECONOMIC ANALYSIS OF WATER MANAGEMENT SYSTEMS IN SOUTHERN TAMIL NADU—PRODUCTION FUNCTION AND PROGRAMMING APPROACH*

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One of the major goals for Indian agriculture is to increase food production substantially in order to cope with the population growth. Of the various methods of intensive agriculture, application of timely and adequate quantities of fertilizer and irrigation plays an important role in increasing production. Farmers[1] in southern parts of Tamil Nadu (Udangudi block in Tirunelveli district) have devised two methods to increase the water holding capacity of light textured soil and have succeeded in raising three crops of paddy a year in place of a single crop of banana or groundnut. The two improved water management systems involved are (1) a concrete system, and (2) a silt system. The concrete system involves laying a concrete layer 2′ beneath top soil and raising a 4′ high, 5″ thick masonry wall around the field. The approximate cost of construction is Rs. 32,000-36,000 per hectare (in 1978 rupees). The silt system involves raising a 4′ high, 5″ thick masonry wall around the field followed by addition and mixing of fine silt to the existing sandy soil. The approximate cost of construction is Rs. 16,000-18,000 per hectare. These two systems are primarily aimed at increasing water holding capacity of sandy soils.

The major objectives of the study are (1) to investigate the economic feasibility of the concrete and silt systems compared to the existing field situation,[2] (2) to investigate the nature of production function relationships for paddy and banana crops under different water management systems and to compare the productivity of resources such as fertilizer, irrigation, and labour among systems, (3) to investigate if there is any technological break-through in production function relationships, if so, whether it is factor-neutral or biased, (4) to obtain the profit maximizing combination of systems for small, medium or large farms under existing resource-production constraints and also for alternative expected resource scenarios.

METHODOLOGY

The economic feasibility of a system is determined by comparing annual amortized cost (cost of system construction + foregone returns during system construction) and annual returns from that field (returns calculated from the most profitable crop rotation).

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1. Having open well and electricity pump for irrigation purpose.
2. Existing field situation is considered as traditional system.

$$C = \frac{cr}{1-(1+r)^{-t}}$$

C = annual amortized cost in rupees;
c = total cost of system construction;
r = market interest rate (15 per cent); and
t = expected life of systems in years (45 years).

The returns are additional returns obtained from a concrete or a silt system field over the traditional system. If the ratio between annual additional returns and annual amortized cost is greater than or equal to one, then the particular system is considered to be economically feasible.

PRODUCTION FUNCTION APPROACH

In this study, production functions are estimated directly using farm level data. Use of a profit function approach may be more appropriate in the case of farm level data.[3] But data limitations do not permit us to use the profit function approach.

The variables of interest for the production function analysis for paddy and banana are as follows:

Dependent variables:
y_1 = yield of paddy in kg./hectare,
y_2 = returns per hectare of banana in Rs./hectare,

Independent variables:
x_1 = labour in man-hours/hectare,
x_2 = nitrogen in kg./hectare,
x_3 = phosphorus in kg./hectare,
x_4 = plant protection in Rs./hectare, and
x_5 = irrigation in hectare-metres.

Various production function forms (Cobb-Douglas, Quadratic, Spillman, square root, modified Cobb-Douglas) are fitted using stepwise ordinary least square procedure. The functional form with appropriate sign for variables of interest are selected for further productivity analysis. Using the selected production function, the estimates of marginal products, and marginal rates of substitution are compared between systems.

In order to determine if there is any break-through in production function relationship between systems or between varieties of high yielding and low yielding paddy, the following statistical tests are performed.[4] Systems' effects are determined by comparing production function of the same crop (variety) grown in each system during a given season. Varietal and seasonal effects are determined by comparing production functions of different varieties grown in the same system. The same production functions selected for productivity analysis are used in this analysis also.

3. Surjit S. Sidhu and Carlos A. Baanante, "Estimation of Farm Level Input Demand and Wheat Supply in the Indian Punjab Using a Translog Profit Function", *American Journal of Agricultural Economics*, Vol. 63, No. 2, May 1981, pp. 237-246.

4. For details of these tests, see J. Johnston: Econometric Methods, McGraw-Hill, Kogakusha Ltd., Tokyo, 1972.

Test I: Test for Technological Change

Step I: A separate production function is fitted for each system—crop variety combination.[5] Let the error sum of squares for the estimated production functions be $s_1 \ldots s_k$ for k combinations with n_1, n_2, and n_k degree of freedom, respectively.

Step II: A common production function is fitted for the pooled data. Let us say the error sum of square is e_1 with degrees of freedom k_1.

Step III: An F-test is performed to determine whether the production function relationships are the same or different for any two cases.

$$F = \frac{[e_1 - s_1 - s_2]/[k_1 - n_1 - n_2]}{(s_1 + s_2)/(n_1 + n_2)}$$

If the calculated F is greater than tabulated F value at the 5 per cent significance level, then the production relationships are considered to be different between systems or varieties.[6]

Test II: Test for Difference in Intercepts

The following tests are performed to determine if the production relationships are different.

Step I: A common production function is fitted for the pooled data, where we assume the fitted function has error sum of square e_1 with k_1 degree of freedom.

Step II: A production function is fitted again to the pooled data with dummy variables with values '0' for a system or variety and 1 for another system or variety. Let us assume the error sum of square is z_1 with degrees of freedom m_1.

Step III: An F-test is performed to determine the significance of difference in intercepts.

$$F = \frac{(e_1 - z_1)/(k_1 - m_1)}{z_1/m_1}$$

If the calculated F is greater than tabulated F at the 5 per cent significance level, the intercepts are assumed to be different between systems or varieties. This test is conditional on a common slope, so the test for differences in slope is performed first before we decide to test for differences in intercepts.

Test III: Test for Homogeneity of Slope

Based on the estimated error sum of squares for the above two tests, a test for homogeneity of slope is performed using an F-test.

$$F = \frac{[z_1 - s_1 - s_2]/[m_1 - n_1 - n_2]}{(s_1 + s_2)/(n_1 + n_2)}$$

5. System-Crop-Variety combination: systems are three (concrete, silt, traditional); crops are paddy and banana. Paddy is grown in concrete and silt system in three seasons. During the first two seasons (June-January) farmers grow a high yielding variety paddy (IR-8, IR-20, etc.) In the summer season farmers grow local low yielding paddy. Banana is grown year long in silt and traditional systems.

6. S. Bisaliah: Effects of Technological Change on Output, Employment and Functional Income Distribution in Indian Agriculture: A Case Study of the Punjab Wheat Economy, Ph.D. Thesis, University of Minnesota, St. Paul, U.S.A., 1975.

If the calculated F is greater than tabulated F at the 5 per cent significance level, then there is a significant difference in slope of production functions between systems or varieties.

PROGRAMMING APPROACH

A simple linear programming model is used to analyse the effects of alternative output and input price situations on the choice of output and input levels including the water management systems. The essential parts of the linear programming model used in this study are briefly described here.

Objective Function

The model simulates maximization of net returns per year from crop production subject to a set of linear constraints. The net returns are defined as the difference between revenue from crop sales, and sum of variable costs of producing all crops (pesticides, fertilizer, labour and water) and the amortized cost of constructing the water management systems if the crop activity is grown under concrete or silt system.

Constraints

(1) Total land supplies available for crops are restricted to be less than the specified number of hectares in each cropping season. A set of constraints is defined to allow inter-season transfer of land where feasible. For example, three crops of paddy can be grown in a year on the same acre of land; but only one crop of banana is grown in a year. The inter-season transfer of land is also restricted such that if concrete or silt water management system is adopted in a season, then this system is retained in subsequent periods. If a concrete or silt system is adopted in any season, then the amortized cost of construction is charged for the full year to the given amount of land.

(2) Water balance constraints restrict the use of water in each season to the level available in that season. The quantity of water available in the first, second and third seasons is assumed to be 8, 9, and 6 hectare-metres, respectively.

(3) Yield constraints are the output balance constraints. Crop production is restricted to be at least equal to the crop sales. In the case of the low yielding variety of paddy, the quantity produced plus the quantity purchased is restricted to be at least equal to the quantity sold plus home consumption requirement for paddy. Yield constraints are defined for high yielding paddy, low yielding paddy, groundnut, sesame, and banana.

Activities

(1) Crop production activities are defined in units of hectares of land under a given crop, for a given season (season I, II or III) with a particular water management system (concrete, silt or traditional). The crops considered in this study are banana, groundnut, low and high yielding (IR-8, IR-20) varieties of paddy, and sesame.

(2) Selling activities are defined for all crops produced with prices selected at current levels. Selling activities for paddy, sesame and groundnut are defined in units of kilograms for paddy, in quintals for sesame and groundnut, and hectares for banana. Prices are accordingly defined as (Rs./kg. or quintals) and (Rs./hectare).

(3) Other activities such as hiring labour, buying water for irrigation, buying traditional variety rice for home consumption and transfer columns also are defined in the model.

The linear programming model is run under alternative price and resource base scenarios. The alternative price scenarios are summarised in Table I. The alternative resource bases are characterized by three different levels of water and land availability restrictions. The water availability levels are given in Table I. The land availability restrictions are: small farm (1.75 hectare), medium farm (3.5 hectares) and large farm (4.5 hectares).

TABLE I—ALTERNATIVE OUTPUT AND INPUT SCENARIOS

Resource bases	High price	Medium price	Low price
Water price			
(Rs. / hectare-metre)	1,100·0	760·0	529·0
Water availability			
Season I (hectare-metre)*	8·0	8·0	6·0
Season II (hectare-metre)	9·0	8·0	7·0
Season III (hectare-metre)	8·0	6·0	5·0
Fertilizer cost			
N (Rs./kg.)	5·0	4·5	3·9
P (Rs./kg.)	5·4	4·8	4·5
K (Rs./kg.)	1·8	1·6	1·4
Paddy price			
High yielding (Rs./kg.)	1·7	1·35	1·15
Low yielding (Rs./kg.)	1·8	1·45	1·25
Home consumption requirement for low yielding paddy (kg.)	3,600·0	1,800·0	0·0
Gross returns from banana			
Silt banana (Rs./hectare)	28,000·0	25,000·0	18,000·0
Traditional banana (Rs./hectare)	17,000·0	16,000·0	12,000·0
Plant protection (Rs./hectare)			
High yielding paddy	245·0	210·0	175·0
Low yielding paddy	140·0	120·0	100·0
Silt system banana	210·0	180·0	150·0
Traditional system banana	70·0	60·0	50·0

* 1 hectare-metre = 39·37 acre-inches/acre or 97·28 acre-inches/hectare (see Appendix 1).

To determine the break-even point between concrete and silt systems (*i.e.*, the cost level at which a farmer can either go for concrete or silt system), the fixed cost of constructing alternative water management systems is parameterized.

Data

The required input-output, cost-price information for this study was collected from 45 randomly selected farms in Udangudi block having a concrete system or a silt system or both during the year 1978.

RESULTS AND DISCUSSION

The computational results of benefit-cost ratios to determine the economic viability of concrete and silt systems are given in Table II.

TABLE II—MARGINAL BENEFIT AND MARGINAL COST RATIOS FOR CONCRETE AND SILT SYSTEM

System	Initial capital costs (Rs./hectare)	Economic life (Years)	Annual amortized cost at 15% (Rs./hectare)	Annual net return (Rs./hectare)	Additional net return over traditional system (Rs./hectare)	Additional costs over traditional system (Rs./hectare)	Marginal benefit-marginal costs ratios	Rank
Concrete ..	35,000	45	5259·76	11,247·3	7,534·4	5,259·76	1·4	2
Silt ..	16,000	45	2404·46	10,554·5	6,841·6	2,404·46	2·8	1
Traditional ..	0	—	—	3,712·9	—	—	—	—

The results show that the benefit-cost ratio is greater than one, implying a rupee investment in converting traditional land to a silt system or concrete system pays the farmer Rs. 2.8 or Rs. 1.4 respectively. Further, it is more profitable to convert a traditional land to a silt system than to a concrete system.

Production Function Approach

Of the various forms of production function fitted for the input-output data, a Cobb-Douglas and a modified Cobb-Douglas version turned out to be the best fit with important variables nitrogen and irrigation at significant levels. The results are presented in Table III. Uniformly in all functions, nitrogen and irrigation turn out to be the significant variables. The comparison of marginal rate of substitution between inputs (N and I_t) at mean level application to the price ratio 0.007 (3.91/529.1) reveals excess application of nitrogen compared to irrigation. Even though farmers are applying more or less the recommended level of nitrogen, irrigation application seems to be low enough to reduce the productivity of nitrogen. Probably, farmers are more cost conscious in irrigation application. Only the Cobb-Douglas version of production function is considered for further analysis. The significance level of estimated coefficients and R-square are presented in Appendix 2.

TABLE III—PRODUCTION FUNCTIONS

System	Season	Crop	Production function(s)	Marginal rate of substitution between inputs of mean level	Mean level of inputs
Concrete ..	.. *Kuruvai* and *Thaladi* (I and II)	HYV paddy	$y_1 = 977 \cdot 2\ N^{0 \cdot 372}\ I_t^{0 \cdot 229}$	0·0235	110 kg. of N 1·6 hectare-metres of I_t
Concrete ..	.. Summer (III)	Low yielding paddy	$y_1 = 886 \cdot 49\ N^{0 \cdot 234}\ I_t^{0 \cdot 578}$	0·0115	60 kg. of N 1·7 hectare-metres of I_t
Silt ..	.. *Kuruvai* and *Thaladi* (I and II)	HYV paddy	(*a*) $y_1 = 1001 \cdot 77\ N^{0 \cdot 347}\ I_t^{0 \cdot 219}$	0·026	110 kg. of N 1·8 hectare-metres of I_t
			(*b*) $y_1 = 297 \cdot 15\ N^{0 \cdot 598}\ e^{0 \cdot 226 I_t}\ e^{-0 \cdot 001\ NI_t}$	0·031	110 kg. of N 1·8 hectare-metres of I_t
Silt ..	.. Summer (III)	Low yielding paddy	(*a*) $y_1 = 1360 \cdot 8\ N^{0 \cdot 200}\ I_t^{0 \cdot 261}$	0·031	60 kg. of N 2·5 hectare-metres of I_t
			(*b*) $y_1 = 1377 \cdot 67\ N^{0 \cdot 198}\ e^{0 \cdot 092\ I_t}$	0·0359	60 kg. of N 2·5 hectare-metres of I_t
Silt ..	.. —	Banana	(*a*) $y_2 = 1129 \cdot 01\ N^{0 \cdot 363}\ I_t^{0 \cdot 569}$	0·018	190 kg. of N 5·4 hectare-metres of I_t
			(*b*) $y_2 = -70136 + 12947 \cdot 9\ L_n N + 16910 \cdot 18\ L_n I_t - 5 \cdot 9268\ NI_t$	0·0218	190 kg. of N 5·4 hectare-metres of I_t
Traditional	.. —	Banana	(*a*) $y_2 = 2291 \cdot 93\ N^{0 \cdot 216}\ I_t^{0 \cdot 391}$	0·026	150 kg. of N 7·1 hectare-metres of I_t
Traditional	.. —	Banana	(*b*) $y_2 = -19580 \cdot 4 + 3886 \cdot 39\ L_n N + 8492 \cdot 54\ L_n I_t - 1 \cdot 5\ NI_t$	0·0155	150 kg. of N 7·1 hectare-metres of I_t

Note:— HYV=High yielding variety.
Y_1 = Yield of paddy in kg.
N = Nitrogen in kg.
I_t = Quantum of irrigation in hectare-metre measured at the point of pump discharge and not at field level.
Y_2 = Returns of bananas in rupees.

Testing for Technological Change

The results of testing the system effect, varietal effect, homogeneity of slope and homogeneity of intercepts are presented in Tables IV to VII.

TABLE IV—SYSTEM EFFECT

System	Variety	Error sum of square	Degrees of freedom	Calculated F	Tabulated F at $\alpha = 0{\cdot}05$
Concrete ..	.. HYV	0·07374	24		
Silt ..	.. HYV	0·36653	44	3·02	2·27
Pooled data	..	0·54919	71		
Concrete ..	.. Low yielding paddy	0·2318	12		
Silt ..	.. Low yielding paddy	0·3484	22	0·67	2·86
Pooled ..	..	0·6143	37		
Silt ..	.. Banana	0·0258	11		
Traditional	.. Banana	0·0546	10	42·0	2·84
Pooled ..	..	0·560	24		

The test for difference in effect of concrete and silt systems gives mixed results. For the high yielding variety of paddy, production functions are significantly different between concrete and silt system but the difference is not significant with low yielding paddy. But the differences between silt and traditional banana turn out to be highly significant. So there could be a system effect in production function relationship.

The differences in production function relationship between high yielding variety of paddy and low yielding paddy variety are significant (Table V). The high yielding variety has superior yields compared to the traditional variety.

TABLE V—VARIETAL EFFECT

System	Variety	Error sum of square	Degrees of freedom	Calculated F	Tabulated F at $\alpha = 0{\cdot}05$
Concrete ..	.. HYV paddy	0·07374	24		
Concrete ..	.. Low yielding paddy	0·2318	12	26·58	2·92
Pooled ..	..	0·9828	39		
Silt ..	.. HYV paddy	0·36653	44		
Silt ..	.. Low yielding paddy	0·3484	22	18·8	2·37
Pooled ..	..	1·2985	69		

The results indicate that these differences in slopes of production functions between systems or varieties are not significant in all comparisons. So the technological change may not have a significant effect on the shape of production function (Table VI).

TABLE VI—TEST FOR HOMOGENEITY OF SLOPE

System	Variety or crop	Error sum of square	Degrees of freedom	Calculated F	Tabulated F at $\alpha = 0 \cdot 05$
Concrete	HYV paddy	0·07374	24		
Silt	HYV paddy	0·36653	44	0·133	3·19
Pooled with intercept dummy variable		0·44174	70		
Concrete	Low yielding paddy	0·07374	24		
Silt	Low yielding paddy	0·2312	12	1·32	3·28
Pooled with intercept dummy variable		0.3281	38		
Silt	HYV	0·36653	44		
Silt	Low yielding paddy	0·3484	22	2·20	3·16
Pooled with intercept dummy variable		0·7625	68		
Silt	Banana	0·025809	11		
Traditional ..	Banana	0·054583	10	0·311	3·47
Pooled with intercept dummy variable		0·09492	23		

The difference in intercept among production relationships between the systems and varieties is significant (Table VII). Based on these above results, the technological change in production function between the concrete and silt systems or between the silt and traditional systems or between high yielding variety of paddy and low yielding paddy is a factor-neutral one and not a biased one. The main purpose of the concrete and silt systems is to increase the productivity of both nitrogen and irrigation, so the technological change could be factor-neutral, consistent with the results.

Programming Approach

Profit maximizing combinations of water management systems and crop rotations for a farm size of 4 hectares with relevant resource constraints are given in Table VIII.

TABLE VII—TEST FOR DIFFERENCES IN INTERCEPTS

System	Variety	Nature of analysis	Error sum of square	Degrees of freedom	Calculated F	Tabulated F at $\alpha = 0 \cdot 05$
Concrete-Silt ..	.. HYV	Pooled	0·5492	71	17·03	3·92
Concrete-Silt ..	.. HYV	Pooled with intercept dummy	0·44174	70		
Concrete-Silt ..	.. Low yielding paddy	Pooled	0·9828	39	75·86	4·15
Concrete-Silt ..	.. Low yielding paddy	Pooled with intercept dummy	0·3281	38		
Silt	.. HYV—low yielding variety	Pooled	1·2985	69	47·81	3·96
Silt	.. HYV—low yielding variety	Pooled with intercept dummy	0·7625	68		
Silt-Traditional ..	.. Banana	Pooled	0·5606	24	113·58	4·88
Silt-Traditional ..	.. Banana	Pooled with intercept dummy	0·094916	23		

TABLE VIII—OPTIMUM SYSTEM COMBINATION AND ACTIVITY LEVELS

Season	System	Activities	Levels (hectares)
I ..	Silt	(a) HYV paddy	1·07
	Silt	(b) Banana	2·93
II ..	Silt	(a) HYV paddy	1·07
	Silt	(b) Banana	2·93
III ..	Silt	(a) Sesame	1·07
	Silt	(b) Banana	2·93

The results indicate, given the existing cost and resource situation, a profit maximizing farmer should bring all his land under the silt system. High yielding variety of paddy in two seasons followed by sesame is the most profitable crop rotation. Banana, an export crop, occupies a major percentage of land area in a farm. Further, the farmer will be better off by buying the home needed local paddy from the market rather than producing on his farm. Shadow prices of land and third month irrigation at limiting level are Rs. 8,621.6 and Rs. 1,323.6 respectively. The high price for water is due to the season coincidence with hot summer when water becomes a scarce resource. Using range analysis, if we force the concrete system into the solution, a reduction in cost around Rs. 270 to Rs. 500 per hectare occurs. The income penalty for using the silt system paddy is Rs. 2,000-2,600/hectare and Rs. 4,600/hectare for banana. The high fixed cost associated with the concrete system could be one of the reasons for its not being a profitable system.

Table IX presents the combination of systems for the assumed scenarios. The low scenario depicts a low return for banana and low water availability compared to existing resource situation. This results in the adoption of the concrete system with the high yielding paddy crop rotation. An interesting thing is that the small farmer should bring all of his land into the concrete system. However, as the farm size increases, the silt system occupies a reasonable share in the farm. The appropriate interpretation for this result could be, with low banana return and low water availability, the greater profitability of paddy crop allows it to be grown in the concrete system despite the high fixed costs involved in such enterprise. These results are further substantiated in the medium price scenario where moderate increases in prices of inputs and outputs occur. But as the banana crop gives good return, it occupies a major share of land in the silt system. The high scenario, with a very high water price level, makes the concrete system to be profitable. So the availability and price level of water determine the adoption of an advanced water management system.

TABLE IX—SYSTEM COMBINATIONS UNDER ALTERNATIVE SCENARIOS

Farm size	Scenarios					
	Low		Medium		High	
	Activities	Levels	Activities	Levels	Activities	Levels
		(hectares)		(hectares)		(hectares)
Small						
1·75 hectare	Concrete: HYV-HYV-HYV (Paddy rotation)	1·75	Silt: Banana	1·75	Concrete: HYV-HYV-HYV	1·75
Medium						
3·5 hectares	(a) Concrete: HYV-HYV-HYV	2·57	(a) Silt: Banana	3·12	(a) Concrete: HYV-HYV HYV	3·50
	(b) Silt: Banana	0·93	(b) Concrete: HYV-HYV-Sesame	0·38		
Large						
4·5 hectares	(a) Concrete: HYV-HYV-HYV	3·80	(a) Concrete: HYV-HYV-Sesame	1·50	(a) Concrete: HYV-HYV-HYV	3·75
	(b) Silt: HYV-HYV-Sesame	0·60	(b) Silt: Banana	3·00	(b) Silt: HYV-HYV-HYV	0·75

The parameterization for the concrete system fixed costs, for a medium scenario solution with the concrete system in base, shows that an increase of Rs. 500-Rs. 600/hectare is needed to replace the concrete system by the silt system. So under a medium scenario, the concrete system construction cost could go up to Rs. 12,437/hectare to Rs. 14,925/hectare (Rs. 47,000-Rs. 49,000/hectare) over and above the silt system construction.

CONCLUSIONS

Based on the results of this study, one can say both concrete and silt systems are economically feasible in the agro-climatic situation analysed. However, the silt system is more profitable. The technological change in production relationships for paddy and banana is neutral. Under the existing resource constraints, a farmer should bring all his or her land into the silt system with banana as a major crop to maximize profits. If there is any significant and favourable change in water prices or availability of water, a concrete system will be a definite competitive alternative to the silt system.

APPENDIX 1

Irrigation Methods and Measurement of Irrigation

When a farmer applies one hectare-metre of water for a crop, our computation means an application of 39·37 acre-inches to an acre of land or 100 acre-inches to a hectare of land. So a water use level of 1·8 hectare-metre for HYV paddy means 70·8 acre-inches per acre and not 180 acre-inches. Further, our data regarding water application may have some measurement error because the water use level is determined at the point of discharge from electricity or gasoline operated pump and not at the field application level. Moreover, the pump's discharge was assumed to be constant over the operation time. But that is not true, because as the water level goes down in the well, the discharge of water per hour by the pump also goes down. Further, the discharge varies over the initial water level of the wells. Our water use estimate is equal to number of hours the pump operated per irrigation × average discharge capacity of the pump (obtained from the Agricultural Engineering Department) × number of irrigation per cropping period.

These errors are biased upwards. So our water use data may be slightly higher. Initially, we are planning to make correction for the measurement error, but we did not have a prior knowledge about the error term in the variables that have error.

(*e.g.*) $Y = \beta x_t + U_t$ $\qquad$ x_t = true value

$X_t = x_t + V_t$ $\qquad$ X_t = observed value

Knowledge about $\overset{R}{\underset{V}{<}}$ is needed for making corrections. So we dropped that idea and assumed that water use of a crop is equal to the pump discharge of water for that crop.

APPENDIX 2

Significance Level of Variables in Production Functions and R-Square

Functions in Table III		Significance criteria of the estimated coefficient	Independent variables: Nitrogen	Irrigation	Intercept	Log of nitrogen	Log of irrigation	Log of scale factor	Nitrogen × irrigation	R-square
Concrete: I and II		Standard error	—	—	—	0·030	0·068	0·133	—	0·90
		Prob > |T|	—	—	—	0·0001	0·0026	0·0001	—	
Concrete: Season III		Standard error	—	—	—	0·132	0·313	0·444	—	0·57
		Prob > |T|	—	—	—	0·1000	0·0899	0·0001	—	
Silt: Season I and II	A	Standard error	—	—	—	0·041	0·064	0·194	—	0·67
		Prob > |T|	—	—	—	0·0001	0·0014	0·0001	—	
	B	Standard error	—	0·078	—	0·142	—	0·671	0·0006	0·69
		Prob > |T|	—	0·0056		0·0001	—	0·0001	0·0742	
Silt: Season IV	A	Standard error	—	—	—	0·065	0·150	0·252	—	0·45
		Prob > |T|	—	—	—	0·0055	0·0950	0·0001	—	
	B	Standard error	—	0·053	—	0·065	—	0·251	—	0·45
		Prob > |T|	—	0·095	—	0·0060	—	0·0001	—	
Banana: Silt	A	Standard error	—	—	—	0·087	0·088	0·415	—	0·90
		Prob > |T|	—	—	—	0·0015	0·0001	0·0001	—	
	B	Standard error	—	—	33624·02	5792·592	5826·770	—	5·467	0·91
		Prob > |T|	—	—	0·0636	0·0494	0·0158	—	0·3038	
Banana: Traditional	A	Standard error	—	—	—	0·034	0·164	0·337	—	0·84
		Prob > |T|	—	—	—	0·0001	0·0385	0·0001	—	
	B	Standard error	—	—	8686·31	1063·275	2967·55	—	1·291	0·87
		Prob > |T|	—	—	0·0507	0·0053	0·0187	—	0·2608	