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Input-Output Relationships of Philippine Milkfish Aquaculture

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The existing gap between experimental yield and potential yield under field conditions and actual yield is highlighted. The determinants of actual yield are investigated by estimating a Cobb-Douglas production function relating yield to 11 explanatory variables. The inputs found to have a significant impact on output were stocking of fry and fingerlings, age of pond, farm size, fertilizers, and miscellaneous operating costs. Estimates of the marginal physical productivity of the inputs are used to study the optimization of input allocation, e.g., the optimum stocking rate at the given input prices. It is concluded that, at current prices, a profit-maximizing milkfish farmer in the Philippines should raise the stocking rate in deeper ponds and increase the use of supplementary inputs.

In a country where fish is one of the main sources of protein and aquaculture has a long tradition, fish culture can be expected to play an important role in supplying the fish needs of the country, especially in view of steadily rising fish prices. Moreover, the catch from capture fisheries is leveling off or even declining as limits to stock exploitation are reached. In the Philippines, however, aquaculture, which is predominantly milkfish culture (*Chanos chanos*), provides less than 10% of the total fish supply.

There are at present about 176 000 ha of brackish water ponds devoted to milkfish culture in the Philippines. The 1973–77 average milkfish production per year was about 110 000 t: an average yield of about 600 kg/ha/year. This low national average yield has been a perennial problem and a major concern for the Philippine government.

Past and present research on improved techniques of milkfish production have shown that the yields of Philippine milkfish ponds can be increased by at least threefold. In fact, such threefold increases in yields have been reported for a limited number of farms. Annual per hectare yields in excess of 2000 kg are attainable with the use of more inputs. As with all intensive production employing more inputs, its adoption is a question of economics.

Information on the technology and costs and returns of milkfish culture is already available. In fact, milkfish production has been the subject of numerous surveys to gather data on production practices in terms of input use. Their conclusions point to the importance of greater intensification of operations and management to increase milkfish production in the Philippines (Rabanal 1961; Tang 1967; Shang 1976; Librero et al. 1977; Chong 1980). Shang (1976) observed that rapid increases in the cost of fry and fertilizers are likely to discourage producers in the Philippines from adopting intensive farming techniques. However, the use of expensive inputs can be profitable if properly carried out as Shang demonstrated for Taiwan.

Why then has milkfish culture not played a bigger role in the Philippines? Why have milkfish yields been perennially low in spite of the availability of improved technology? This study attempts to answer these questions by assessing the responses of milkfish production to supplementary inputs and by quantifying a few input-output relationships of milkfish production in the Philippines.

Although supplemental inputs have to be used to improve the productivity of milkfish ponds (intensification of operations), the uncertainty of output response due to inputs affects a producer's decision on the use and rates of use of such inputs. As a result, the producer is naturally interested in knowing the costs and benefits (and

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risks) involved in increasing inputs. The present study addresses this concern and shows the responses of milkfish production to various inputs.

Inputs are not applied uniformly throughout the country. There is, therefore considerable geographical variation in output. Some of this could, however, be due to differences in environmental conditions such as soil type, climate, or pH. This study concentrates on output variability related to inputs.

Soil type, climate, and pH, although important factors in determining output initially, cannot explain all the yield differences observed in the country. Like all production activities under human control and management, the limitations on production in milkfish culture are related to the use of inputs.

Objectives

(1) To estimate the input-output relationships (production function) for milkfish production in each of seven selected provinces in the Philippines, and for the whole country.

(2) To determine the marginal productivities and returns of inputs used in different quantities and proportions.

(3) To derive the optimum rates of application of the various inputs used in producing milkfish by using the estimated functions and 1978 prices.

(4) To show which inputs are the most important determinants of total output.

(5) To analyze variations in Philippine milkfish production by province.

(6) To use the estimated production function (or model) to predict production levels from given levels of input application.

Methods

Data Collection

A working knowledge is necessary of the production operations for which functional input-output relationships are to be empirically estimated to correctly specify the production function and collect the appropriate data. Data were obtained through a cross-section survey of producers in seven provinces of the Philippines covering the production period January-December 1978.

The most common and widely practiced method of production is the use of a farm layout comprising nursery, transition, and rearing (grow-out) ponds. The sample for this study consists of milkfish producers whose farms are of this design. The average size of such a farm is about 16 ha. The provinces covered in the survey are, from north to south, Cagayan, Pangasinan, Bulacan, Masbate, Iloilo, Bohol, and Zamboanga del Sur. A minimum of 30 respondents per province was taken as a sample. The largest number of respondents, 81, was from Pangasinan. Purposive sampling was used to obtain as homogeneous a group of milkfish operators as possible to eliminate differences in production techniques and to obtain data from a range of farm sizes and rates of input use. Only milkfish operators who use supplementary inputs are included in the sample.

It was not possible, however, to restrict the sample to farms that monoculture milkfish. Some farms that culture milkfish and penaeid shrimp were also retained in the sample, but the output and the corresponding value of penaeid shrimp were not considered in the analysis.

Because 1978 was used as the reference period for the information collected, the 1978 price structure of inputs and output was adhered to. Also, information collected is based on quantities of inputs actually used and not those available for use.

The data were collected by a core group of 8-10 closely supervised enumerators, assisted by two additional enumerators in each province. The same group was also involved in preparing the data for processing to avoid errors in interpretation, coding, computation, and analysis.

It is not always easy to obtain the data required for production function estimation. Two types of data are frequently used: field survey and experimental data. One thing common to both types of data is that there are variables that may be difficult to measure. While it is true that data from controlled experiments are relatively homogeneous, that is, there are no differences in the quality of inputs, results from analysis using experimental data have limited applications. This is because experiments are of necessity conducted on a small scale and they seldom capture and replicate actual variations in field conditions. Consequently, their usefulness in national policy formulation is correspondingly limited. On the other hand, because a survey can be conducted over a wide geographical area, the results of survey data have broader applications. Our survey, which has this wide coverage, thus reflects a variety of actual farm conditions.

Milkfish Production Function Model

Three algebraic forms of the production function model were initially estimated to determine their appropriateness and explanatory/predictive power. These were the linear, quadratic, and Cobb-Douglas forms although a wider range could be considered. The functional form of the milkfish production model chosen based on its explanatory power is that of an unconstrained Cobb-Douglas production function model. The specified function is an acceptable representation of the underlying mechanics of the production process.

Milkfish production results from combining various fixed and variable inputs in a body of water. Eleven inputs or explanatory variables were hypothesized to explain milkfish production. To evaluate the relative influence of each of the 11 inputs or explanatory variables on the output of milkfish, the model is estimated by using multiple regression techniques.

The basic Cobb-Douglas model specified is:

$$Y = \alpha_o X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} X_8^{\beta_8} X_9^{\beta_9} X_{10}^{\beta_{10}} X_{11}^{\beta_{11}} \epsilon$$

$$\log Y = \log \alpha_o + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6 + \beta_7 \log X_7 + \beta_8 \log X_8 + \beta_9 \log X_9 + \beta_{10} \log X_{10} + \beta_{11} \log X_{11} + \epsilon$$

where Y = output of milkfish (kg); X_1 = age of pond (years); X_2 = milkfish fry (pieces); X_3 = milkfish fingerling (pieces); X_4 = acclimatization (hours); X_5 = hired labour (man-hours excluding caretaker's time); X_6 = miscellaneous operating costs (peso); X_7 = milkfish culture experience (years); X_8 = pesticides (peso); X_9 = organic fertilizers (kg); X_{10} = inorganic fertilizers (kg); X_{11} = land (ha); α_o, β_i = regression coefficients (parameters) to be estimated; and ϵ = random error or disturbance term.

The explanatory variables (X_i) or inputs are sometimes known as target variables because they are subject to influence by the decision-maker (producer or policymaker). Of the 11 explanatory variables specified in the model, all but age of pond are within the control of producers. The production coefficients (β_i) or exponents in the Cobb-Douglas form are the elasticities of production. The β_i terms are actually transformation ratios of the various inputs used in milkfish production at different quantities. Depending on the need of the study, the basic model can be modified, as reported in the section on results.

So far no mention of the expected signs of the parameters has been made. The Cobb-Douglas form does not allow signs to be attached, unlike the quadratic form where a parameter can be expressed as $-\beta_i X_i^2$, for example. However, the marginal products as distinct from the parameters are expected to have either positive or negative signs.

Two basic functions were estimated: one on a per farm basis and one on a per hectare basis. Estimating a production function calls for accurately measured data on output and inputs. Faulty data have often been the source of poor fit and insignificant estimates. Recognizing the importance of accurate data, brief discussions of the variables used in estimating the production function and the problems of measurement are provided.

This is of necessity only an approximate modeling of the true production process because there exist several variables such as pond depth and water salinity that may be important in explaining variation in milkfish production but that have not been included.

Total Output

Total output refers to the quantity of milkfish harvested (in kilograms) during the 1978 production year. Other species such as shrimp, tilapia, and mullet have been excluded from the total. This figure includes the milkfish that are consumed at home, given away as gifts, and the harvester's and caretaker's shares. The total output, therefore, reflects all milkfish harvested from the pond — marketed as well as non-marketed. Whenever possible, losses due to typhoon and floods were estimated and included in total output. Milkfish harvested before final harvest are also reflected in total output, because one characteristic of Philippine milkfish production is that some fish are harvested well before the final harvest; to entertain guests who drop in at the farm, for subsistence, and for festivals. It was not possible to determine the extent of such practices and the magnitude of output that went unrecorded. This and other data collection problems such as accuracy in counting stocking material (fry) are dealt with below.

Types of Inputs

Following De Wit (1979), inputs can be classified as material inputs, management inputs, and input of field work (labour). Material inputs can be further categorized as either yield-increasing inputs such as fertilizers, or yield-protecting inputs such as pesticides.

Besides these material inputs, management inputs and input of field work, other inherent characteristics of the pond environment, and/or factors affecting its environment such as age of the pond and weather can be employed to explain milkfish output. Again, a working knowledge of these other factors can be invaluable to the milkfish producer.

Results and Discussion

The Estimated Production Function

The main results of the estimation of the milkfish production function for the whole country are summarized in Tables 1 and 2. The estimates of the production coefficients, their standard error, and the coefficient of determination are also reported. The usefulness of the estimates of the various production coefficients of milkfish culture is discussed to provide the reader with a more thorough understanding of the underlying input-output relationships. In general, the levels of statistical significance of the estimated production coefficients are encouraging.

One can interpret the positive production coefficients and marginal physical products of the respective inputs as implying that an increase in output of milkfish can be accomplished by

Table 1. Estimated production function (Cobb-Douglas), sample means, and estimated output for Philippines on a per-farm basis (Equation 1).

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Intercept = 10.91											
Production coefficients	0.28	0.14	0.10	0.04	-0.01	0.16	0.04	0.03	0.03	0.09	0.57
T-value	4.70	5.37	4.25	1.00	-0.29	3.21	0.65	1.09	1.96	3.42	9.26
Standard error	0.05	0.02	0.02	0.04	0.02	0.05	0.06	0.02	0.01	0.02	0.06
Significance level	0.0001	0.0001	0.0001	0.32	0.77	0.001	0.51	0.27	0.05	0.0007	0.0001
R^2	77										
Input mean ($\overline{X}$)											
GM	12.84	3543	2346	3.74	123.26	639.56	10.28	27.79	630.44	74.77	6.16
AM	21.57	5940	5892	14.09	228.71	1033.06	15.72	62.46	2178.83	172.33	16.20
Estimated output at $\overline{X}$ = 2577											
Marginal product	57.25	0.11	0.11	28.10	-0.22	0.60	10.24	2.85	0.13	3.21	243.40
Average price of input	—	0.09	0.18	—	—	—	—	—	0.29	1.66	—

Note: GM is the geometric mean, AM is the arithmetic mean, and the F-value = 95.3.

Table 2. Estimated production function (Cobb-Douglas), sample means, and estimated output for Philippines on a per-hectare basis (Equation 2).

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Intercept = 7.01											
Production coefficients	0.27	0.18	0.14	0.05	-0.01	0.17	0.04	0.02	0.04	0.12	-0.02
T-value	4.56	6.22	4.88	1.22	-0.35	3.36	0.55	0.46	2.24	3.43	-0.57
Standard error	0.05	0.02	0.02	0.04	0.02	0.05	0.06	0.03	0.01	0.03	0.04
Significance level	0.0001	0.0001	0.0001	0.22	0.72	0.0009	0.58	0.64	0.02	0.0007	0.57
R^2	39										
Input mean ($\overline{X}$)											
GM	12.84	3543	2346	3.74	123.26	639.56	10.28	27.79	630.44	74.77	6.16
AM	21.57	5940	5892	14.09	228.71	1033.1	15.72	62.46	2178.8	172.3	16.20
Estimated output at $\overline{X}$ = 1351.44											
Marginal product	28.40	0.06	0.06	18.12	-0.11	0.38	5.26	0.96	0.08	2.13	-4.40
Average price of input	—	0.09	0.18	—	—	—	—	—	0.29	1.66	—

Note: GM is the geometric mean, AM is the arithmetic mean, and the F-value = 18.3.

increasing the intensity of input use. On the other hand, negative coefficients and marginal products suggest that use of that particular input should be reduced.

Selected production functions were used to derive some technical and economic relationships. In addition, values of the respective inputs at their geometric means were substituted into the selected production functions to obtain the predicted average milkfish yield. Economic optima were calculated to show whether, on average, input combinations are efficient. From this, it can be shown whether input use can be increased or decreased to maximize profits.

Fit of the Model

In general, the Cobb-Douglas equation fitted the data well as indicated by the F-values and R^2. With the exception of Cagayan, the F-values were highly significant in all cases. All the R^2 values are also statistically significant, ranging from 0.39 to 0.89. Their occasional modest values are not unusual in multiple regression analysis using cross-sectional data. Lastly, there appear to be no problems with dominant variables or multicollinearity.

Nature of Input-Output Responses

A revealing result of this study is that for the most part, inputs applied at the reported levels do influence milkfish output. The 11 variables hypothesized to explain milkfish yield explain 39 to 89% of the variation in milkfish output.

Because a large interest of this study was to examine the nature of the input-output relationship and to test the significance of each of the estimates of the production coefficients, all the coefficients will be reported even though some of them are not significant as shown by their low t-values. In all cases there are sufficient degrees of freedom for statistical tests. More than 50% of the regression or production coefficients are significant at small probability levels. Errors due to memory recall may have contributed to the presence of some insignificant coefficients.

In general, an examination of the magnitudes of the coefficients estimated for the per farm and per hectare production functions by province, showed slight variations between the two coefficients estimated for the same explanatory variable. Signs of the estimated coefficients were found to be consistent with theory and technical knowledge of the production process. Selected production functions were used to derive broad economic and technical conclusions. Wherever appropriate, attempts were made to relate the results of the study to the current problems of the industry.

Economic Optima Defined

To realize maximum net returns, producers must find out the rates at which to apply the inputs. To do this, they will need to have information on the productivities of the inputs they use. Given the prices of inputs and the output prevailing in the factor and product markets, and with the help of the estimated production functions, optimum input combinations can be calculated. At the point of optimum input combination, the ratio of input-output prices should equal the marginal product for each of the inputs used. In other words, the value of the marginal product must be equated to the input price. If the marginal product is greater than the input-output price ratio, $MP_i > P_i/P_o$, then the use of that input should be increased. If the marginal product is less than the price ratio, the use of that input should be decreased. Similarly, if the marginal product and price ratio are equal, it means that producers are economically efficient.

From the Cobb-Douglas production function, marginal products of input application can be computed from the production coefficients and average products, or by differentiating the production function. In this study, marginal products were derived by differentiating the production function with respect to the particular input of interest, with other variable inputs calculated at their geometric means (as opposed to arithmetic mean). Using arithmetic means gives biased marginal products. An actual example will be provided to show how the economic optima were calculated for a few selected inputs for which price data were available.

Philippine Milkfish Production Functions

In this section, two production functions are discussed in detail to provide an appreciation of how production function analysis can be a useful tool to aid decision-making on the farm. The first production function represents a whole farm production relationship; the second uses data standardized on a per hectare basis. The first of these two estimated input-output relationships will be used in the following discussion to show how powerful production function analysis can be.

Farm Basis: (Equation 1)

$$Y_F = 10.9 X_1^{0.28} X_2^{0.14} X_3^{0.10} X_4^{0.04} X_5^{-0.01} X_6^{0.16} X_7^{0.04} X_8^{0.03} X_9^{0.03} X_{10}^{0.09} X_{11}^{0.57}$$

Hectare Basis: (Equation 2)

$$Y_H = 7.0 X_1^{0.27} X_2^{0.18} X_3^{0.14} X_4^{0.05} X_5^{-0.01} X_6^{0.17} X_7^{0.04} X_8^{0.02} X_9^{0.04} X_{10}^{0.12} X_{11}^{-0.02}$$

Of the 11 explanatory variables in the model, 6 variables in the case of Equation 2 and 7 variables of Equation 1 are significant (see Tables 1 and 2). These variables are: age of pond (X_1); milkfish fry (X_2); milkfish fingerling (X_3); miscellaneous operating costs (X_6); organic fertilizers (X_9); inorganic fertilizers (X_{10}); and farm size (X_{11}). The other variables are not significant in explaining milkfish output.

The summation of all the production coefficients ($\Sigma\beta_i$) for Equation 1 is equal to 1.47. This means that the production function exhibits increasing returns to scale; that is, if all the inputs specified in the function are increased by a certain percentage, milkfish output will increase by a larger proportion. In the example above, if all inputs are increased by 1.0% output will increase by 1.5%.

Further, an examination of Equation 1 shows that a 1% increase or change in the number of pieces of milkfish fry, X_2, will result in a 0.14% increase or change in milkfish output, other inputs held constant.

Miscellaneous operating costs (X_6), which include depreciation, repair and maintenance, taxes and other fees, interest expenses, food for labourers, etc., account for about one-sixth of the final output. Similarly, yield-increasing inputs (organic and inorganic fertilizers) contribute about one-thirtieth and one-eleventh of milkfish output. The minimal response of output to these inputs can be attributed to the current rates of application of these three inputs in shallow ponds. If farm size (X_{11}) is increased by 1%, output will increase by almost 0.6% as indicated by the coefficient of farm size, X_{11} of 0.57. The signs of the production coefficients are consistent with theory and the logic of the production process. Further, the R^2 or coefficient of determination is about 77% and the F-test of the overall regression is significant at the 0.0001% level (F-value, 95.3). Tables 1 and 2 spell out the other details regarding the farm and hectare basis production functions. Just like the farm basis production function, the hectare basis function can be interpreted in a similar fashion.

Theoretically, no output is forthcoming if no inputs are used. Equation 1 also shows an intercept or constant value of 10.9 (antilog of the intercept). This result arises from the nature of the mathematical form of the equation: the intercept term enters the equation multiplicatively. Although the value of the intercept is low, it is important from the technical point of view. It indicates the level of efficiency of the milkfish production process in transforming inputs into milkfish output. A value of 10.9 implies that milkfish production in the Philippines as a whole is inefficient, because the intercept values for the more productive provinces of Iloilo and Bulacan were respectively, 82.0 and 290.0.

Value of Marginal Product

As discussed previously, at the point of optimum input combination, the ratio of the input-output prices to marginal product must be the same for each of the inputs used. This is written algebraically as follows: $MP_i = P_i/P_o$; or $MP_i \times P_o = P_i$; or $VMP_i = P_i$; where MP_i = marginal product of input i; P_i = price of input i; P_o = price of output or milkfish; and VMP_i = value of marginal product.

Optimum Stocking Rate

The optimum stocking rate of milkfish fry (X_2) is calculated using the production function (Equation 1) estimated for the Philippines, the geometric means of all other inputs, the price of milkfish fry in 1978, and the farmgate price of market size milkfish in 1978.

$$Y = 10.9 X_1^{0.28} X_2^{0.14} X_3^{0.10} X_4^{0.04} X_5^{-0.01} X_6^{0.16} X_7^{0.04} X_8^{0.03} X_9^{0.03} X_{10}^{0.09} X_{11}^{0.57}$$

Taking the partial derivatives of Y with respect to X_2 gives the marginal product of X_2:

$$\frac{\partial Y}{\partial X_2} = 1.5 X_1^{0.28} X_2^{-0.86} X_3^{0.10} X_4^{0.04} X_5^{-0.01} X_6^{0.16} X_7^{0.04} X_8^{0.03} X_9^{0.03} X_{10}^{0.09} X_{11}^{0.57}$$

Having obtained $\partial Y/\partial X_2$ or the MP of the milkfish fry stocked, the price ratio of input to output is then determined.[3] $P_{X_2}/P_Y = 0.36/6.29 = 0.057$. That is,

$$1.5 X_1^{0.28} X_2^{-0.86} X_3^{0.10} X_4^{0.04} X_5^{-0.01} X_6^{0.16} X_7^{0.04} X_8^{0.03} X_9^{0.03} X_{10}^{0.09} X_{11}^{0.57} = 0.057$$

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[3] Based on four pieces to 1 kg of market size milkfish. Each milkfish fry costs P0.09, thus, four pieces of fry equal P0.36. The average farmgate price of milkfish is estimated at P6.29/kg in 1978 (as of 1982, P8.29 = U.S.$1.00).

And solving for X_2:

$$X_2^{-0.86}(1.5)(2.04)(2.17)(1.05)(0.95)(2.81)(1.10)(1.10)(1.21)(1.47)(2.82) = 0.057$$

$$113\ X_2^{-0.86} = 0.057$$

$$X_2^{-0.86} = 0.057/113 = 0.0005$$

$$X_2 = 6790 \text{ pieces of milkfish fry per hectare.}$$

Therefore, the optimum stocking rate for the country as a whole is 6790 pieces of milkfish fry per hectare per year. The implicit assumption for this economically determined stocking rate is that the milkfish survival rate has already been taken into account in the input-output relationship through the raw data.

If this optimum stocking rate is now compared to the arithmetic and geometric means of Philippine milkfish fry stocking rate of 5940 and 3540, respectively, it is apparent that the average Philippine milkfish farmer can profitably increase present stocking rates. However, producers with shallow ponds probably will not benefit from increased stocking rates unless they deepen their ponds.

At this point, a word to elaborate on the conclusion will help clarify the implications of the study result. Although it is true that each milkfish farm has its own individual production function, the production function estimated and presented above is the industry function in so much as it portrays an average input-output relationship for all the farms in the industry. Therefore, the production function for any one particular farm may conceptually be obtained from this industry function in terms of the farm's ability to implement optimal values of the parameters in the industry (Aigner and Chu 1968). The two authors point out that possibly all farms do not operate anywhere near the industry (or frontier) production function; their output lying below this frontier.

Based on the same production function, the optimum stocking rate for milkfish fingerling is calculated to be 2154 pieces of fingerlings per hectare per year. This economically determined stocking rate is about 60% lower than the national average stocking rate of 5892 pieces (arithmetic mean) or about 10% lower than the geometric mean (2346) of the national milkfish fingerling stocking rate. Therefore, the stocking rate of milkfish fingerlings can be cut back at current levels of input application if maximum financial returns are the objective of production. The most important thing to bear in mind is that current levels of input application in shallow ponds cannot help to support higher fingerling stocking rate. As such, fingerling stocking rate can be reduced to save unnecessary expenditures.

The difference between the price of fry and fingerling partly explains the optimal values obtained for fry (to increase) and fingerlings (to decrease). Based on 1978 price data, milkfish fingerlings are twice as expensive as milkfish fry. The implication is that milkfish fry is a more economic stocking material. In fact, only 13% of the sampled milkfish farmers use fingerling as stocking materials.

Another way to demonstrate the economic gains from increased fry stocking rates is to show the inequality of the two sides of the relation between the value of marginal product and input price. This is: $MP_i \times P_0 = P_i$: $0.11 \times 6.29 = 0.09 \times 4$ pieces; $0.69 > 0.36$

Obviously, the left-hand side of the identity is greater than the right-hand side. Because the input-output price ratio is given or exogeneously determined,[4] nothing can be done to influence it. Only the left-hand side of the identity can be changed to affect its magnitude. This can be effected by increasing the stocking rate until the marginal product (and VMP) declines further due to diminishing returns. The milkfish fry stocking rate is deemed optimum when the equality is again restored (see section on optimum stocking rate).

For milkfish fingerlings, it can be shown that the left-hand side of the identity is smaller than the right-hand side. By reducing the fingerling stocking rate, the MP of fingerlings will become larger, until the equality is restored again.

The optimum stocking rate is calculated based on four pieces of fish to a kilogram. An additional market dimension that complicates this straightforward relationship is the market price in relation to size of fish. In some markets, the bigger the fish the higher the price per kilogram, whereas in other markets, the relationship is inverse, that is, the bigger the fish the lower the price per kilogram. Thus, it is clear that once the input-output relationship has been estimated, the rates at which inputs are applied are dictated by the average per kilogram of output as well as the prices of inputs.

Optimum Application Rates of Fertilizers

Organic fertilizers: If the milkfish farmer took into account the price of organic fertilizers and the price of milkfish he would apply only 1750 kg/ha/year. Thus, according to the production function (Equation 1), milkfish producers

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[4] In perfectly competitive markets, prices are taken as given.

can increase their organic fertilizer application and increase their output and returns. The optimum organic fertilizer application rate is about 175% higher than the geometric mean (630) of organic fertilizer applications in the country. This finding to increase fertilizer application is consistent with the conclusion suggesting an increase in the stocking rate of milkfish fry.

Inorganic fertilizers: Inorganic fertilizers should be applied at a rate of 1124 kg/ha/year if the price of milkfish is P6.29 and the price of inorganic fertilizers is P1.66/kg. The price of inorganic fertilizers in terms of a kilogram of the fertilizer including its fillers must be distinguished from the price of a kilogram of its nutrients (NPK). The type of inorganic fertilizers is crucial if these fertilizers are used in ponds suffering from acid sulfate soils. For example, 16-20-0, which is ammonium sulfate phosphate, is very acidic and using this type of fertilizer would further compound the problem of acid sulfate soils of existing ponds. The use of such "acidic" fertilizers would, therefore, necessitate periodic liming to correct/restore pond pH. This implies that additional production costs can be avoided if the proper fertilizers (less acid forming) are used.

The point to be stressed from this brief discussion is that input use recommendations in the absence of explicit price considerations (and relating these to the marginal products of the respective inputs) is not useful from the management point of view. This is the basic difference between profit maximization and output (biomass) maximization.

Explicit input subsidies or price support for milkfish is unheard of in the Philippines. There is, however, fertilizer subsidy for Priority I and II crops, and milkfish are a Priority II crop. Input subsidization or price support can make the added use of inputs profitable where before it was uneconomic. Research to determine optimum input combinations and optimum output level must, therefore, recognize the presence or absence of such government support.

Estimated Output

Equation 1 can also be used to predict or estimate the output of milkfish. The estimated output can be calculated at one of three points: at the point of maximum biomass production (physical measure) or total product; at the point of maximum profits (value measure); or at the input means (in this case, the geometric means) of application. For this study, only the third method of calculation is used.

A total of about 2500 kg/ha/year of milkfish output is predicted from the industry production function as represented by Equation 1 if the milkfish producer applies inputs at the means in ponds that are deeper and not in existing shallow ones. This 2500 kg/ha/year estimated output has been obtained using the industry function and is not based on individual farm production functions (Aigner and Chu 1968). However, because a large majority of milkfish producers do not apply as much inputs and their ponds are shallow, actual output of milkfish is thus correspondingly much lower.

Summary and Conclusions

In this study, the concept of the production function, describing a relation between 11 inputs or explanatory variables and milkfish output, has been employed. The optimal application of the different inputs in response to prevailing 1978 prices of inputs and output was calculated for a small number of inputs whose prices were readily available.

This study was undertaken in response to a need for information on the productivity of inputs used in Philippine milkfish production. Based on the empirical results of the study, Philippine milkfish ponds have available potential that is not yet realized. Higher output can be obtained through the use of more inputs in deeper ponds that is, intensifying production methods. The analyses of the input-output relationships of Philippine milkfish production have shown the economic benefits that are foregone from using too many inputs in existing shallow ponds and, second, from not using more inputs in deeper ponds.

The survey data have shown that the average milkfish production per hectare from existing ponds is 761 kg/year. To be sure, this estimated yield is higher than the reported national average of 600 kg/ha/year. This is because the survey data consist of production data from farms using inputs: milkfish farms that did not use any inputs were excluded from the survey. With proper husbandry, management, and deeper ponds, milkfish yield can be increased to at least 2 t, or about three times higher. If the increase in output comes from hectarage expansion with existing practices it will require at least 3 ha of land to produce 2 t of milkfish; it can be produced in 1 ha with proper management in deeper ponds. However, these two alternatives have to be evaluated for their costs and benefits to determine which of the two should be recommended.

for government-leased and privately owned ponds and that the latter are more efficient.

The inclusion of miscellaneous operating costs as an explanatory variable in the production function was questioned. This is a value aggregate of seven variables. Doubts were also expressed concerning measurement of scale economies in terms of the sum of the input elasticities when some of the latter parameters were not statistically significant. It was suggested that this problem could be handled by testing whether the sum of the input elasticities differed from unity.

What is the role of depth of ponds? Farms with shallow ponds would not benefit by raising the stocking rate. The estimated production function is only an average one involving both deep and shallow ponds.

Why was experience not a significant variable? Maybe the question asked in the survey: "How many years of milkfish culture experience do you have?" fails to distinguish between experience with the old method and experience with the improved method of production. It is the *latter* that counts.

How can one make the biological optimum and the economic optimum compatible? Can one suggest precise numerical changes in the amounts of inputs based on the economic optima? It was observed that the biological and economic optima were the outcome, respectively, of an output maximization and a profit maximization objective. It was also noted that only small numerical changes in the neighbourhood of the estimated production function could be suggested.

Next, only interfarm (cross-section) production functions have been estimated. This is because lack of data precluded the estimation of intrafarm (time-series) production functions. As such, these interfarm functions should be regarded as representing the average farm in the industry.

Although it is true that each milkfish farm has its own individual production function, the production functions estimated using the cross-section data are judged to be realistic approximations of the "real" industry function. The estimated overall production functions will nevertheless have applications to existing farms in the country. In fact, Aigner and Chu (1968) state that the production function for any particular farm may conceptually be obtained from the industry function in terms of the farm's ability to implement optimal values of the parameters in the industry. We would also argue that most farms do not operate near the industry production function: their output lies below the industry production function.

Several algebraic forms of production functions were fitted to the data. However, the algebraic form selected for interpretation and application in this study is the Cobb-Douglas production function. The Cobb-Douglas form was used to estimate input-output relationships by province. In general, the Cobb-Douglas form fits the data well as revealed by the highly significant F-values and relatively high R^2.

The low absolute values of the estimated production coefficients reflect the inadequacy of existing shallow ponds to make full use of present rates of input application. Milkfish yield is responding poorly to the present quantities of inputs applied in these shallow ponds. This implies that if the milkfish producers in the country switch to the use of deeper ponds with larger quantities of inputs, output will increase. Experiments with higher levels of input applications in deeper ponds have shown that milkfish yields can be increased significantly. In this case, there is thus a strong response to larger quantities of inputs in deep ponds as compared with the poor response of milkfish to present levels of input used in shallow ponds.

The authors believe that the reluctance of producers to use more inputs and also to pay more attention to management of their milkfish farms may be attributed to the prices of both inputs and output. Perhaps, if there is a government subsidy for inputs and price support for milkfish, producers may be encouraged to intensify their production.

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Discussion

Why were the coefficients for fry and fingerling different? Is it due to different mortalities of fry and fingerlings? The different mortalities have already been taken into account through the raw data. The difference, therefore, may be due to the fact that while fry are acclimatized in the same pond before being released, the fingerlings purchased from other pond operators enter the pond as a new environment. To capture such differences one suggestion was to use a dummy variable for the fry-fingerling classification.

It was observed that, besides the biological and economic dimensions, one should also bring in the social dimension to explain yield. Factors like ownership pattern, indebtedness of the farmers, and marketing arrangements can influence output significantly. The authors reported that they had estimated the production function separately