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TITLE: ECONOMIC THEORY AND RESEACH FRAMEWORK FOR A MULTI-OUTPUT PRODUCTION SYSTEM: RICE-FISH CULTURE TECHNOLOGY IN THE PHILIPPINES

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Rice-fish culture technology is an example of a multi-output production system. It has potential for increasing the quantity and quality of Philippine food supplies, improving resource utilization and reducing risks associated with single-output production systems. Rice-fish culture technology, it's development potential and development policy are examined.

Theoretical and analytical rice-fish culture multi-output production models are developed. The theoretical model illustrates "symbiotic" and/or joint rice-fish production processes in the multi-output production system. The analytical model is a logarithmic form Cobb-Douglas Production function.

Survey data is well fitted to the logarithmic form Cobb-Douglas Production function model as

revealed by the significant F and high R^2 values. Eight pre-determined explanatory variables are included in the simultaneous rice-fish production function models.

Some rice specific inputs not only significantly influence the total rice production but also total fish production in the simultaneous culture system, and vice versa. Economies of scale in simultaneous rice-fish culture are revealed by the production elasticity results.

Structural input-output analyses gave intriguing "partial counter intuitive" results. The expected "symbiotic" rice-fish production relationship was not fully supported.

The following policy issues were addressed: 1) prospects for greater rice-fish production, 2) production management decisions, 3) technology transfer, and 4) technology improvement option. A truly comprehensive policy for rice-fish culture technology development could not be formulated from this study. However, a comprehensive technology assessment research framework is developed.

ECONOMIC THEORY AND RESEARCH FRAMEWORK FOR A MULTI-OUTPUT PRODUCTION SYSTEM: RICE-FISH CULTURE TECHNOLOGY IN THE PHILIPPINES

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To

Floria

Elmer, Alden and Junel

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Chapter I

INTRODUCTION

Intuitively, it would be worthwhile to begin with a quote from Jacques Chonchol (1979, "Feeding The World: The Failure of Productivist Solution"):

> "A successful food policy must recognize the complexity, particularity and endogeneity of food system; it must aim at satisfying food needs within specific local, or national situations, taking account of the ecological and cultural factors. It must be part of a strategy for increasing rural employment and income, and finally, supported by an international framework which prevents the rich industrialized countries from draining away a large part of world food production in wasteful over-consumption."

The need for appropriate agricultural technology in the Philippines is based on the demand for food, the inelastic supply of basic production resources, the risks and uncertainties associated with the widely used single-output agricultural production technology, and the people's nutritional requirements.

There is continuing increased demand for food as population grows. The Philippines is expected to have a relatively high population growth for the rest of the century, despite the reduced population growth rate from 3.0 percent in the late sixties, to 2.6 percent in the early eighties (National Economic and Development Authority (NEDA), 1981). It is estimated that the country will need to produce additional food, as well as other goods and services, for at least one million additional persons every year. Sufficient, reliable and affordable food supplies will be constrained by the inelastic supply of basic production resources - land and water in particular. The "frontier model" of agricultural development as described by V. Ruttan (1976), is no longer applicable to Philippine agriculture. The arable lands available for production represent only about one-third (1/3) of the country's total land area of 30 million hectares (NEDA, 1980). Most of these arable lands are already under cultivation. Thus, the possibilities for increasing food supply via increased land cultivation is limited.

There is growing awareness and concern about the changing nature of the agricultural environment. It has led to the recognition of some of the "ill effects" or "negative consequences" of the widely used agricultural production technology -the single-output oriented or monocultural production system. For instance, the continuous monoculture of high yielding variety (HYV) rice as complemented with intensified application of inorganic fertilizer and pesticides will in the long run generate a situation that is hazardous to health and agriculture (International Rice Research Institute (IRRI), 1968). A substantial portion, if not all, of the agricultural chemical pesticides and fertilizer supply in the country is not domestically produced. Thus, food production through continuous reliance on agricultural technology, that is too dependent on these inputs, may become economically and biologically unstable. In addition to food stability, the agricultural technology in question can also increase the country's trade-deficits. Furthermore, the continued use of single-output agricultural technology could have negative environmental effects since it requires the intensive use of inorganic technical inputs -the pesticides and fertilizer. The repeated and intensified application of agricultural chemicals in rice production has caused the decline, or even total loss, of the important aquatic resources, such as fish, shellfish, frogs, etc., in the paddy fields. Traditionally, these aquatic resources served as an important source of cheap or low cost animal protein in the rural

Philippines, particularly in the landlock areas. In this respect, though specialization of HYV rice production would increase cereal food supply, it may also reduce the supply of fish and consequently, may create protein-calorie malnutrition.

There is a need to increase production to meet diverse human food requirements. The trend of per capita consumption of basic food items in the Philippines is shown in Table I.1. Carbohydrates, protein, and other nutritional elements must be made available in the right quantity and proportion to achieve proper diets. Both rice and fish are important food items. Rice, being the staple food, is the major source of carbohydrates. Fish constituted about 60 percent of the total animal source protein intake of the average citizen (Ministry of Agriculture (MA), 1981). While the Philippines has already achieved self-sufficiency in rice (Palacpac, A., 1982), the production of fish from all possible sources is still less than domestic consumption (Bureau of Fisheries and Aquatic Resources (BFAR), 1982). The prospect for increasing marine fish production has been diminished by the high cost of farshore fishing and over-exploitation of the fishery resources in the Philippine marine zone (Smith, I.,

Table I.1 Trend of the per capita consumption of basic food items in the Philippines, 1970-1980.

Food Items	Reference Year 1970	1976	1977 (In Kgs.)	1978	1979	1980
Cereals	140.1	135.0	137.5	133.1	136.5	128.4
Fish	37.6	25.1	24.1	24.4	22.4	20.6
Dairy	13.2	8.2	6.6	6.5	6.1	5.6
Poultry meat	6.3	3.9	3.6	3.3	3.7	3.8
Egg	5.6	3.4	2.5	2.5	2.7	2.9
Pork	12.6	7.9	6.3	6.4	6.6	7.3
Beef & carabeef	6.0	3.2	2.3	2.2	2.2	2.0
Fresh fruit	47.2	29.0	32.4	34.4	28.4	33.6
Fresh vegetable	16.8	14.4	54.9	54.9	44.7	35.8

Source: Ministry of Agriculture, Republic of the Philippines, 1981.

1980). Thus, if fish supplies are to be increased, the development of the lowland paddy fields offers the greatest opportunity.

I.1 The Research Problem in Perspective

Rapidly developing technology for rice-fish culture offers important opportunities for improving Philippine food supplies. Many uncertainties, however, surround this technology - uncertainties which do not concern so much technological breakthroughs, since some form of the technology has already existed for generations (Khoo, H. and E.S. Tan, 1979; Dela Cruz, C. 1979; Nambiar, K.P., 1970, etc.), but uncertainties which are mainly concerned with socioeconomic factors which may affect, or be affected by, widespread adoption of the rice-fish culture technology.

Public policy decision-makers, extension workers, research administrators, agribusiness managers, or the farmers themselves, each have different views and interests. Interested public policy decision-makers have argued, for instance, that the ultimate concern about the technology will be its economic effects, and that much more information on this area is needed as a guide to policy decision-making. Aquaculture (i.e., fish culture) which has to be integrated with agriculture (i.e., crop production), is a relatively young science in the Philippines (Dela Cruz, C., 1980). There are costs and economic risks associated with the technology. There are also the complex institutional differences and linkages which are attendant to, or likely to attend, future developments of the rice-fish culture technology. Concerted efforts must, therefore, be initiated to generate relevant information that would help clarify and increase the society's awareness of those uncertainties.

I.2 Objectives of the Study

This study addresses rice-fish culture technology development issues. The study focuses primarily on problematic questions concerning policy and technological decision-making. Specific objectives are:

1. to summarize and generalize valuable insights and observations of previous research results and development experiences;

2. to develop the theoretical model for economic analysis of simultaneous rice-fish culture system in the context of multi-output production technology;

3. to estimate technical coefficients of production for simultaneous rice-fish culture sytem;

4. to use the estimated coefficients of production in examining the interdependence of rice and fish production and in predicting the levels of production and marginal productivity of inputs from the given levels of inputs application;

5. to demonstrate the application, interpretation, and use of "composite output" production function analysis as a decision-making tool for simultaneous rice-fish culture production system;

6. to develop a generalized research framework for a comprehensive assessment of the rice-fish culture technology;

7. to identify those areas for policy action which have the greatest potential for contributing to further development of the rice-fish culture technology.

The hypothesis and expectations in this study have been stated explicity in the chapters where they are deemed relevant, and consequently, the various chapters of this manuscript will, then, answer more specific questions, such as: 1) What is the state-of-the-art of the rice-fish culture technology? 2) How is it developing and being used in the Philippines? 3) What are the micro-level economic and technical relationships of the rice and fish production? 4) How does the production of rice affect total production of fish, and vice versa? 5) What are the current economies of scale?

I.3 Organization of Thesis

An overview of the rice-fish culture technology development in the Philippines is presented in Chapter II. The chapter includes: a (1) review of the technology's historical background; (2) description of different rice-fish culture technology being practiced, not only in the Philippines but also in other countries of Southeast Asia; (3) identification of the probable reasons for the decline of paddy field fish culturing during the past decade; and (4) exploration of the reasons and strategy for the renewed emphasis of rice-fish culture technology in the Philippines. Primarily, Chapter II summarizes and generalizes from the review of previous research results and development experiences in the belief that valuable insights can be gained by taking stock of what is already known.

Chapter III has two specific objectives. First, to develop a theoretical model for the economic analysis of simultaneous rice-fish culture system, and second, to propose quantitative procedure for such an analysis, taking into consideration that technologically, simultaneous rice-fish culture is one of the real world examples of multi-output production systems. Multi-output production system is defined and discussed in detail. In addition to simultaneous rice-fish culture, several other examples of the production systme are identified in the chapter. It is proposed that the production inputs aside from being classified as either "fixed" or "variable" inputs, can be further classified into "basic or non-basic output-specific" and "basic or non-basic non-output-specific" inputs, these classifications are based on the definition of multi-output production system as formulated in the chapter. In pursuing the objectives set forth, the concept of "multi-output symbiotic maximum yield" in production has been also formulated. The necessary conditions in attaining symbiotic maximum yield and its economic implications are discussed using a hypothetical example.

The results of the applied economic analysis of simultaneous rice-fish culture production are presented in Chapter IV. Primarily, the chapter addresses objectives 3, 4, and 5. Primary farm survey (cross section) data, (wet and dry seasons, 1982-83) were used in the analysis.

Results of the standard analysis of costs and returns of simultaneous rice-fish culture production according to seasons and locations are discussed in

Chapter IV. The cost and return analysis includes the evaluation of the individual components output contribution to the gross return and the total costs of production. The profitability of simultaneous rice-fish culture production at the farm level was determined and presented.

A Cobb-Douglas log linear model was used in analyzing the technical coefficients of the input-output relationships. The individual components output and composite output production functions, and the functional form input-output structural relationships for simultaneous rice-fish production, on the per farm and per hectare specifications, were estimated with the use of the ordinary least squares (OLS) and the two stage least squares (2SLS) regression procedures, respectively. Appropriate statistical tests were used to determine the significance of the technical coefficients as well as the input-output models estimated. The estimated technical coefficients of the production relationships are summarized in the various tables presented in Chapter IV.

In that chapter, specific hypotheses about the technical input-output relationships, and the nature of the product-product relationships are explicity stated. The results of the production relationships analyses are then used to test the expectations in this study. Some of the analyses gave a "partial counter intuitive" result. An indepth interpretation and discussion of the economic implications of the estimated technical coefficients of the simultaneous rice-fish production are presented in the chapter along with appropriate supporting references and documentation of what is already known.

Estimates of economies of scale, the predicted levels of total production (in both physical units and money values) and the marginal productivity of inputs from the given levels of inputs application in simultaneous rice-fish culture production are presented in Chapter IV.

One other important content of Chapter IV, is the application of the composite output production function analysis in determining the optimum level of input application in production. The concept of marginal productivity, i.e., marginal return-marginal cost principle, was applied in the evaluation of the levels of input application of the average simultaneous rice-fish culture farm and the appropriate recommendations have been made. Finally, the policy implications of empirical results are discussed in the chapter.

A research framework for comprehensive assessment of the rice-fish culture technology is proposed in Chapter V. The rationale for undertaking comprehensive technology assessment, not only for the rice-fish culture but also for other technologies as well, is discussed explicity. The difficulties confronted in implementing comprehensive technology assessment initiatives are identified and described. The framework for mapping-out the impacts of rice-fish culture technology is proposed. Some of the different policy issues and institutional problems that are attendant to, or likely to attend to the technology per se, is enumerated, and agenda for future research are suggested. It is also articulated that policy and institutional analyses can form the "core" of a comprehensive technology assessment.

The final chapter (Chapter VI) summarizes the results of the study as a whole. It enumerates and discusses the policy implications that are deduced from various parts of the study. And finally, some recommendations for policy consideration and conclusion of the study are presented.

Chapter II

AN OVERVIEW OF THE RICE-FISH CULTURE TECHNOLOGY DEVELOPMENT

This chapter is a synthesis and review of both published and unpublished materials concerning the historical background of rice-fish culture technology, the state-of-the-art of the technology, and the strategy of the Philippine government in the implementation of its nationwide program on rice-fish culture technology development. The chapter seeks to summarize and generalize, from previous research results and development experiences, in the belief that valuable insights can be gained by taking stock of what is already known. More specifically, the chapter will identify those policy actions which have the greatest potential for contributing to further development of the rice-fish culture technology in the Philippines; and to provide general information which are useful in modeling and analysis of the economics of the multi-output production technology.

II.1 Rice-Fish Culture in Southeast Asia

It can be deduced from numerous published literature (Temprosa, R. 1980; Coche, A.G. 1967; Hora, S. and T.V. Pillay, 1952, etc.) that rice farmers of the Philippines are not unique in practicing fish culture in the lowland rice fields. Rice-fish culture is known worldwide, particularly in the irrigated rice production areas of the tropics. Indeed, it has a lengthy history.

II.1.1 Historical Background of the Technology

The practice of harvesting wild fish for food from rice fields is probably as old as rice cultivation itself. However, the exact date when rice and fish were deliberately grown in the same paddy fields is unknown. The Chinese people are the most likely originators of this practice (Rodgers, M.D. and U.E. Green, Jr., 1977). The oldest written record of rice-fish culture in Japan dates back to 1844, although it is believed that it was practiced long before that (Tamura, 1961). It has been suggested by Tamura that fish culture in rice fields was introduced into Southeast Asia from India approximately 1,500 years ago. Rice-fish culture in Indonesia started about the middle of the 19th century (Ardiwinata, 1971). Its early development in Indonesia was associated with religious schools and later with government agencies (Khoo, K.H. and E.S.P. Tan, 1980).

In the Philippines, aquaculture is a much younger science than agriculture. This does not suggest however, that exploitaion, i.e., harvesting of fish and other aquatic resources in the lowland paddy fields has lagged behind rice production. Available literature indicates that the concept of growing fish in combination with rice crop in the Philippines was proposed only in 1960 (Manacop, 1960). Since fish constitute a substantial proportion of the Filipino diet, traditional practice of harvesting wild fish from the lowland paddy, as well as from natural waterways and ponds is probably as old as rice production itself. The varieties of rice crops grown in the early days were not as demanding, as present varieties, for agricultural chemical inputs. Thus, fewer quantities of these inputs were used. The lower level of chemical inputs caused less damage to the paddy environment, rendering the lowland irrigated paddy fields to be still hospitable to many species of valuable wild fish.

II.1.2 Decline and Revival of Rice-Fish Culture

Rice-fish culture has been especially successful with the older traditional rice varieties. The harvesting of wild fish was the common practice in previous years and had occupied a fairly large area of the rice producing region. A list of the major fish species grown or found in paddy fields is shown in Appendix Table 1. Estimates of the total area of irrigated paddy fields and those with rice-fish culture in some Asian countries is indicated in Table II.1. In the Philippines, the total area of irrigated lands which are primarily used for rice production has increased from 0.7642 m. ha. in 1960 to 1.4662 m. ha. in 1979 (Alcaide, P., et al., 1981). Although harvesting of wild fish including shellfish, frogs, and other aquatic fauna, from the paddy fields had been traditionally practiced in the country, statistics on its extent, in terms of the total area covered by the practice and the quantity of harvest

Table II.1 Estimated total area of irrigated ricefields and those with fish culture in some Asian countries

COUNTRY	TOTAL IRRIGATED AREA	AREA WITH RICE-FISH CULTURE (hectares)	ORIGINAL SOURCE OF INFORMATION
Cambodia	1,400,000	--	Hora & Pillay, 1962
Hong Kong	8,080,000	200	Hora & Pillay, 1962
India	4,500,000	1,619	
Indonesia	4,500,000	90,492 (+4,000,000)1/	Ardiwinata, 1957
Japan	2,991,100	3,380	Hora & Pillay, 1962 Nambiar, 1970
Malaysia	332,060	45,500	Hora & Pillay, 1962
Sri Lanka	350,000	--	Rabanal, 1974
Thailand	4,000,000	200,000	Rabanal, 1974
Vietnam	4,067,000	1,500	Hora & Pillay, 1963

1/ 90,492 ha. under the cultural system and 4 m. ha. under the <u>captural system</u>.

Source: Khoo, K. & E.S.P. Tan, 1980 (adapted from Pullin, R.S.V. & Z.H. Shehadeh, ed. 1980).

are not available or had never been documented.[1] Wild fish harvesting is even practiced in the "highland rice terraces" which occasionally suffer from insufficient water supply.[2] Thus, it is reasonable to assume that since the Philippine lowland rice fields do not suffer insufficient water supply, traditional rice-fish culture (captural system) had been earlier adapted to a large extent. In an international conference on integrated agriculture-aquaculture farming systems (Pullin, R. and Z.H. Shehadeh, 1980), it was concluded that heavy

1/ Considering that public policy decisions are normally based on documented facts, the absence of such documentation may suggest that those who primarily depend on this traditional practice as source of subsistence were not represented in the past public policy decision making. From the other point of view, it may also imply that the value of total production or harvest was too low or insignificant and did not justify the cost of generating statistical data and documentation.

2/ It was recently highlighted in the Gintong Butil News, an official paper of the National Food Authority, Philippines that the natives (Ifugao) of the Mountain Provinces, Philippines are even simultaneously growing vegetables and fish in their paddy fields (rice terraces). The newly developed system called fish-pingkol (mudmound) paddy culture can give them an estimated gross income of about ₱ 22,000 per half hectare for 6 months culture period (NFA, Gintong Butil, Vol. IX, No. 4, April 1982, p. 6).

farm usage of agricultural chemical inputs would be a major constraint to the widespread adoption of rice-fish culture technology. The Green Revolution technology has been mainly associated with intensive use of agricultural chemicals. The most popular agricultural chemicals in rice crop production in the Philippines are shown in Table II.2. Unfortunately a majority of the agricultural chemical inputs are highly toxic to fish and other aquatic life (Grist, 1965; FAO, 1971; J.C. and J.N. Lewis, 1967; Bosch, R., 1978). Thus, what had been concluded in the conference on integrated agriculture-aquaculture farming systems would also implicity suggest that the widespread adoption of Green Revolution technology had caused the unanticipated decline of fish catches from irrigated rice fields and consequently, the temporary loss of popularity of the rice-fish culture. This additional interpretation in the conference conclusion is not to antagonize but to emphasize what is known to be "true" - "its a fact", such that the best options may be developed soon enough to minimize the unintended negative effects of the technology in question.

Table II.2 Estimated usage of pesticides by major crops, Philippines, 1976

CROPS	PESTCIDES					
	Insecticides	Herbicides	Fungicides	Rodenticides	Fumigants	Miticides
	(In percent of the total for each type)					
1. Rice*	54	54	--	80	--	--
2. Corn	1	1	1	--	--	--
3. Sugarcane	--	18	--	15	--	--
4. Vegetables	16	3	30	--	--	40
5. Fruits (mangos, melon, etc.)	25	--	5	--	--	50
6. Banana/Pineapple	--	21	60	--	95	--
7. Cotton	1	--	--	--	--	--
8. Tobacco	1	--	--	--	--	--
9. Others	2	3	4	5	5	10
TOTALS	100	100	100	100	100	100

*Ninety-five (95) percent of 3.6 million hectares of land planted in rice in 1977 were treated with pesticides.

Source: Agricultural Pesticides Institute of the Philippines, 1976 Sales Statistics. Adopted from Philippine Farmer's Journal, September 1978.

Due to the absence of supportive empirical data, the above statement is only a subjective reinterpretation of the Philippines case. Statistics which might indicate the decline or increase of rice-fish culture in the country, are not available. In other countries like Japan, these statistics are available. The increase and decline of rice-fish culture in Japan are shown in Table II.3. Many experts (Tan, et. al., 1973; Lim, 1970; Moulton, 1973; etc.) firmly maintain that the unfortunate decline of valuable fish harvest from the paddy fields has been directly attributed to increasing intensity in the use of agricultural chemicals. It can also be argued that such a decline cannot be totally attributed to the phenominal increase in the use of toxic chemical inputs. Such a decline can also be attributed to many other factors. For instance, farmers may have lost interest in raising fish in their paddy fields due to the increased availability of fish supplies from the sea (Hickling, 1962). And also, the harvesting of fish in earlier dates may have been beyond the sustainable capacity of the fishery resources and thus the availablity of harvestable fish on the latter dates declined due to the incapability of the resource to rejuvenate naturally.

Table II.3 Production of fish and area of rice-fish culture in Japan.

Year	Area (ha)	Production (tons)	Production Per ha. (kg.)
1909	2,225.7	401.8	180.53
1913	2,741.8	599.5	218.65
1923	3,856.5	1,206.7	312.90
1933	5,691.5	1,923.2	337.90
1943	13,896.3	4,437.7	319.30
1953	7,743.0	995.7	128.59
1963	3,388.0	250.0	73.79

Source: Nambiar, 1970

The revival of rice-fish culture in the Philippines cannot be exclusively attributed to the food problem, that is, the necessity to achieve a proper nutritional balance, but also attributed to the recent concern about the deteriorating quality of the agricultural environment. The strategies of rice-fish culture revival in this country are explicity discussed in Sections II.3 and II.4.

II.2 Methods of Fish Culture in Paddy Fields

The techniques used for rice-fish culture differ considerably not only from country to country, but also among regions within the country. In general fishery resources utilization methods in the lowland rice fields may be classified as captural system and cultural system.

II.2.1 Captural System

This system involves minimal production cost and very few inputs. The fields are not especially prepared for the retention of fish, except for the digging of sumps, about 40 to 50 m^2 in area and 2 m. deep, in the lowest portion of a group of paddies. The rice fields are not stocked with fish fingerlings. Wild fish stocks make their way into the paddy fields through irrigation and drainage water as well as flood water during heavy rains.

The captural system has been very successful due to the introduction of *Trichogaster pectoralis* (Mirapina) from Thailand into the rice growing areas (Soong, 1951). This fish specie, *T. pectoralis*, has established itself as the main fish crop. The captural system had occupied a far greater area than cultural system and was important in all the rice growing areas of Southeast Asia (Khoo, K.H. and E.S. Tan, 1979). Under this system the harvesting of wild fish stocks is normally done at the end of the rice growing season, when the water in the paddy fields is low. The other methods of harvesting wild fish utilizes any of a variety of fish traps such as "baklad" installed in waterways such as irrigation and drainage canals, streams and creeks. Wild fish going in and out of the paddy fields that pass through the fish traps will be caught and harvested regularly (daily) during the duration of the rice growing season.

II.2.2 Cultural System

In this system, the rice fields are deliberately stocked with fish as in a fish pond. The cultural system is more costly than the captural system. The cost would vary depending upon the cultural system followed. When referring to the timing of production and harvest of rice and fish, the cultural system can be differentiated further into: a) rotational rice-fish culture and b) simultaneous rice-fish culture systems.

a). Rotational rice-fish culture: This system would involve the consecutive production of rice and fish in the same paddy field. The dikes of rotational rice-fish culture paddies are constructed to a greater height and strength then those required in pure rice culture in order to retain much deeper water when used for the production of fish. Under this sytem, the water depth is about half that of conventional fish ponds (Dela Cruz, 1979), and the paddies should be drainable such that the consecutive rice crops can be either directly seeded or transplanted.

Rotation permits better care for both rice and fish. It has the advantage of allowing the use of machinery, insecticides and herbicides for rice production. It also allows greater water depth for fish production. Basically, all the necessary cultural requirement of each crop could be followed since the fish and rice are not grown at the same time in the same production space.

Under this type of culture system, at least two methods of production are envisioned: the (a) Palawidja and (b) Panjelang methods of rotational rice-fish culture of Indonesia (Khoo, K.H. and E.S. Tan, 1979). The Palawidja method involves a single annual crop of fish which is cultured after a single rice crop. It is basically aimed at producing fish at marketable size. The Panjelang method, on the other hand, involves the cultivation of fish between two rice crops and is aimed at the production of fry or fish fingerlings.

In the Philippines, wet season rice crops often give lower yields than the dry season rice crops due to low solar intensity, typhoons, strong winds, prolonged rains, and flooding. Growing fish in the rice fields during the wet season instead of rice, offers a logical alternative crop during this period of climatic risk. The rotational rice-fish culture system has the following advantages as suggested by Dela Cruz, 1979:

1) The hazards of pesticide accumulation in fish tissue are reduced, since rice and fish are grown at different times, and pesticides will have been

degraded partially by harvest time of the rice and the subsequent stocking of fish.

2) Mutually beneficial interaction between the fish and rice crops; residues from fish culture can serve as fertilizers for planted rice; and rice stubble submerged in water after harvest provides a medium for growth of fish food organisms like algae and phytoplankton, which when decomposed, provide further fertilization for the succeeding rice crop.

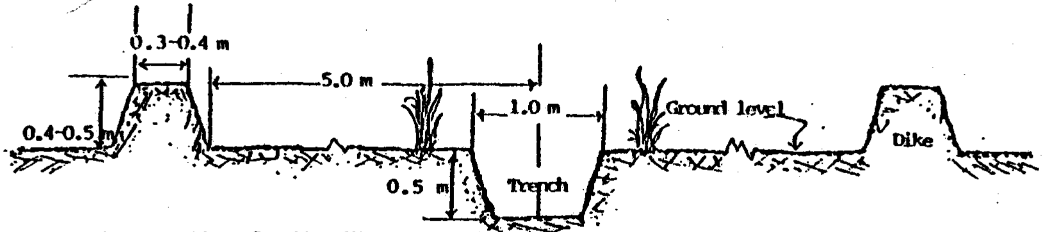
3) The cost of rice production tends to decrease, due to (a) reduced pest control cost since the life cycle of insect pests are disrupted; and (b) lower land preparation cost, since the paddy bottom is soft and clean after fish harvest and allows immediate seeding or transplanting. When filamentous algae are abundant, a single harrowing of the soil is sufficient.

4) Lower construction cost when compared to regular fish ponds, as dike construction cost is reduced given that the water depth in the modified paddy fields is only about half that of conventional fish ponds.

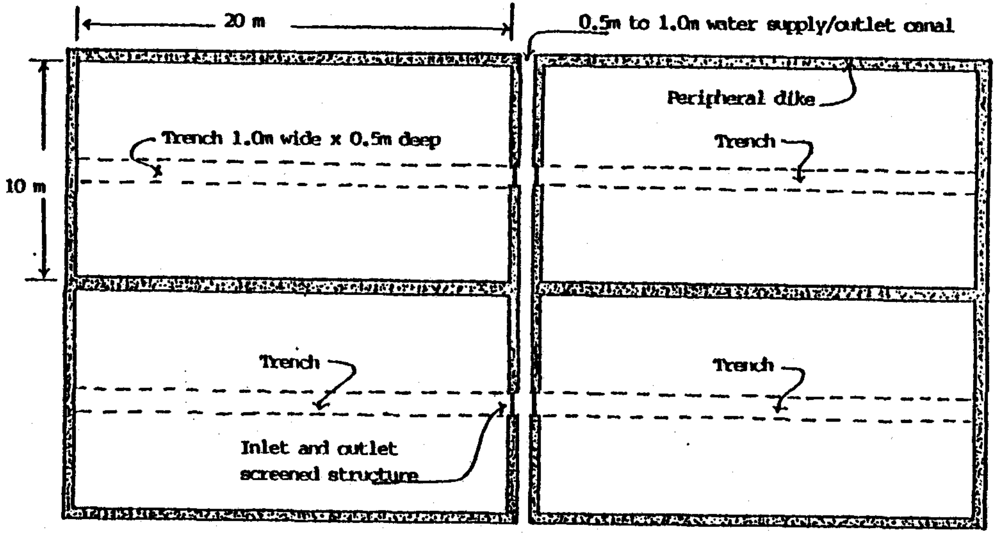
This system would tend to increase land use intensity. It could be feasible in rice land areas with minimal flooding, such as the more than 3,000 hectares 3R rice lands of the service area of Upper Pampanga River Project as per classification by the NIA and USBR (National Irrigation Administration and United States Bureau of Reclamation), 1971.

Though the system would yield two different outputs in the same production space within a given time frame, it should not be mistakenly taken to fall under the heading of multi-output production system. Outputs of the rotational rice-fish culture system are alternately produced and therefore not consistent with the definition of multi-output production systems use here.

b) Simultaneous rice-fish culture: In this system, the production of rice and fish are undertaken concurrently in the same production space (paddy field). The ordinary rice paddy field when used for this purpose has to be physically modified in accordance with the requirements of this method of rice-fish culture. A standard simultaneous rice-fish culture paddy must be surrounded by earthen dikes approximately 50 cm. wide at base, 30 to 40 cm. at top, and 40 cm. high, to maintain 10 to 15 cm. water depth. The design paddy must include trenches of about 0.4 m. deep and 0.5 to 1.0 m. wide. These trenches would serve as a fish refuge, in case of an unexpected drop in water level; as a passage way for easy movement of fish around the paddy, and as a catch basin when fishes are harvested by draining the paddy. A typical layout of a simultaneous rice-fish culture paddy is illustrated in Figure II.1. The average estimated cost of developing a hectare of lowland rice fields into rice-fish culture paddies is shown in Table II.4.



Cross section of paddy, dike and trench (not drawn to scale)



Location of trench for a 10m x 20m paddy. Scale 1 : 200.

Figure II.1. Typical layout of rice-fish culture paddy.
Adopted from Dela Cruz, C. 1980.

Table II.4 Physical description and average per hectare development cost of rice-fish culture paddy field as surveyed in Central and Southern Luzon, Philippines, 1982.

I. Physical characteristics:	
1. Area of R-F paddies/farm	0.5874 ha. (0.8738)
2. Average area/R-F culture paddy	0.2171 ha. (0.2753)
3. Number of R-F culture paddyies/ha.	4 to 6
4. Average dimension of R-F culture paddy dikes	
base	1.50 m.
top	0.88 m.
height	1.14 m.
5. Sample reporting by types of trenches;	
(a) Peripheral	32
(b) Central	12
(c) Combination	3
(d) No trenches	6
6. Number of farm with fish breeding ponds	32
7. Average area of fish breeding pond	0.0229 ha. (0.0205)
II. Development cost:	₱/ha.
1. Labor services in construction	1,585.35
2. Water control devices installed	260.02 (252.06)
3. Wire screens	195.18 (449.30)
4. Fish nets and other fencing materials	350.86 (644.58)
AVERAGE TOTAL COST/HA.	2,000.45 (1,936.77)

NOTE: Figures in parenthesis are the standard deviations.
Exchange Rate: US $1.00 = ₱8.00

SOURCE: Tagarino, R.N., 1983a.

This method of rice-fish culture would involve vertical "integration" of the normally unrelated and distinctly different production system, into one production system which is multi-output oriented. Such integration necessitates modification of the cultural practices, including the types of input application normally used or required by crops when grown and produced separately. Modification of the cultural practices is aimed at achieving complementary and compatible production of rice and fish in order to maximize the efficiency of farm resources; i.e., to utilize the excess flow resources which are basically underutilized in the specialized single output production system.

The empirical problems, relating to the complementarity or compatibility of rice and fish grown under the conditions of a simultaneous cultural system, have been the key subject of technology generation research for the past seven years or so at the Freshwater Aquaculture Center - Central Luzon State University (FAC-CLSU). The technical problems include questions on compatible rice varieties and fish species, optimal mix of production inputs, the paddy field's maximum carrying capacity, of fish stocks and questions relating to the other cultural and management needs of simultaneous rice-fish culture system. Results of the FAC-CLSU applied research leading to rice-fish culture technology generation and packaging are reviewed and summarized in section II.3 of the chapter.

The simultaneous rice-fish culture system would entail a higher intensity of land use than that of the rotational culture system. While this method of fish culture in the paddy fields would require the reduction of the effective area for rice production due to trenches, it would not significantly reduce rice production because of the beneficial effects of fish on the growth and yield of rice crops. It will also reduce the need for chemical fertilizer, herbicides and insecticides. The ex ante assessment of the economics of simultaneous rice-fish culture as compared to rice mono-culture, which was made by R. Arce (1981) as shown in Table II.5, indicate higher profitability for the simultaneous rice-fish culture.

Table II.5 Comparison of the per hectare cash costs and returns of rice monoculture and simultaneous rice-fish culture, 1981

Item	Rice Monoculture		Rice-Fish Culture	
	Qty.	Value (P)	Qty.	Value (P)
I. ADDITIONAL CAPITAL COSTS				
Construction of dikes and trenches [1/]		-	8 days	144.00
Screens (1-ft size @ P8/unit [2/]		-	25 units	200.00
Harvesting buckets @ P35 each		-	5 units	175.00
TOTAL				455.00 [2/]
II. OPERATING COSTS				
Seeds @ P75/cav	2 cav	150.00	1.8 cav	135.00
Fingerlings, *T. nilotica* @ P0.15		-	5,000 pcs.	750.00
Fertilizer:				
16-20-0 @ P94/bag	6 bags	564.00	5.4 bags	508.00
45-0-0 @ P98/bag	3 bags	294.00	2.7 bags	265.00
Insecticides:				
Furadan 3G @ P130/bag	2 bags	260.00	2 bags	260.00
Others		224.00		
Hired Labor @ P18/day plus rotavation cost of P300/ha	58 days	1,344.00	65 days	1,470.00
Other Expenses [3/]		200.00		200.00
TOTAL		3,036.00		3,588.00
III. GROSS RETURNS				
Sale of palay @ P75/cav	130 cav	9,750.00	123 cav	9,225.00
Sale of fish @ P10/kg			245 kg	2,450.00
TOTAL		9,750.00		11,675.00
IV. NET RETURNS		6,714.00		8,087.00
V. DIFFERENCE IN NET RETURNS				1,373.00

[1/] Computed based on the amount of labor spent (no. of days) at ₱18/day.

[2/] Needed only during the initial operation; screens and buckets are expected to last for 3 years.

[3/] Include transportation expenses, food, etc.

SOURCE: Courtesy of Dr. R. Arce, Director, CLSU-FAC, Munoz, N.E. Philippines

II.3 Research and Development of Rice-Fish Culture Technology in the Philippines

A program for research on rice-fish culture (Manacop, P., 1960) had been conceived and proposed to the IRRI as early as 1960. The research program proposal was not carried out by the institute. Review of literature further revealed that no other attempt had been initiated for the development of the technology from that year (1960) until the year 1974; when the technicians of CLSU and UPCF conducted an exploratory trial of culturing fish with rice in the province of Ilo-ilo, Philippines (Anon., 1974). Hence, it took more than a decade before the concept of rice-fish aquaculture technology had actually begun to evolve. The IRRI collaborated with FAC-CLSU in planning the institutional program for research on rice-fish culture in October 1973 (Anon., 1974). Thus, the Institute terminated its lengthy silence concerning the rice-fish culture research by its active participation in the initial implementation of the program.

Actual activities relating to rice-fish culture technology development started in 1974 at the FAC-CLSU, Nueva Ecija, Philippines. At first, production trials on rice-fish aquaculture were done in fish ponds and in rice fields until a rice land area of more than 2.5 hectares was developed for the purpose (Arce, R. and C.R. Dela Cruz, 1978). The experimental rice-fish aquaculture paddies were permanently developed and have been continuously utilized up to the present.

The rice-fish aquaculture research and development program that was launched, has as an immediate objective to develop low-cost appropriate technology for the production of fish in rice farms. Its ultimate long-term goal is to increase the availability of animal protein and improve the nutrition of the people in landlocked areas. More specifically, the immediate objective of the research program is to develop a production system that would maximize the efficiencies of the utilization of limited farm resources - land and water - in particular.

The development of appropriate methodologies and techniques of simultaneously as well as rotationally culturing fish with rice crops in the same paddy was then the priority task of the established research program. The results of the completed researches and production trials on rice-fish culture that were mainly undertaken at the FAC-CLSU are summarized in Appendix Table 2. The efforts on technology generation have a distinct technological bias of considering the fish that are to be grown with rice as only a supplementary crop in the production system. Thus, the main focus of the research and development activities was on determining the appropriate fish culture techniques which would adapt to the conditions and requirements of the rice crops.

II.4. Nationwide Implementation Strategy of the Rice-Fish Culture Program in The Philippines

The package of technology for rice-fish culture described in Table II.6 has emerged from a series of experimentation (see, Appendix Table 2) and nationwide production trials (Table II.7) of growing fish with rice crops in paddy fields. This technological package was introduced nationwide in the late 1970's and has become one of the important government policies on food and nutrition.

A national rice-fish culture program coordinating body was formed to carry out effective implementation of the food policy. The composition of the coordinating body with their respective roles and functions in the implementation of the rice-fish

Table II.6 Recommended technological package for simultaneous rice-fish culture production system.

I. Technical Inputs of Production

Kind	Recommended quality and quantity of application
Palay seeds	IR-36, IR-42 and other pest resistant varieties; to be transplanted at a distance of 20 x 20 cm. between hills
Fish stocking material	Tilapia nilotica - 5000 fingerlings/ha or Common carp - 2000 to 3000 fingerlings/ha
Inorganic fertilizer	Urea (45-0-0) - 75 kgs/ha Complete (14-14-14) - 200 kgs/ha Zinc sulfate - 5 kgs/ha
Pesticides & weedicides	Carbofuran 1-3 bags/ha 2-4-d IPE weedicides - 25 kgs/ha Insecticides at 0.01% concentration such as Furadan 3G, Azodrine 202, etc.

II. Schedule and Activities of Production

Cultural day	Production Activities
0	prepare and fertilizer seedbed
1	soak palay seeds
3	broadcast germinated palay seeds on seedbed
5	treat growing seedlings with recommended insecticides
10-24	prepare the rice-fish paddies - plowing, harrowing, clearing and improving dikes, trenches, etc.
	basal fertilization and pesticide application
24	pull palay seedlings
25	transplant palay seedlings
28-39	irrigate paddy fields, 3-5 cm. water-depth
29	apply recommended herbicides
32	stock the paddies with fish fingerlings
	increase irrigation water, 7 to 10 cm. deep
75	reduce irrigation water depth to 5 cm., apply fertilizer top dressing
76-95	irrigation water level must be increased to 10-15 cm. deep
96-124	increase irrigation water depth to 20 cm.
125-130	drain the paddies and harvest the fish
131-135	harvest and thresh palay crops

Source: Based from the Rice-Fish Culture: Part I. Paddy Culture of rice fish and Part 2 Production of tilapia fingerlings in net enclosures and rice paddies published by the National Rice-Fish Culture Coordinating Committee. National Food and Agriculture Council-Ministry of Agriculture (NFAC-MA). Diliman, Q.C. Philippines (not dated).

Table II.7 Results of the rice-fish culture field testing in the Philippines, October 1977 to March 1978.

LOCATION Region	LOCATION Province	FISH SPECIES USED	FISH CROP Yield/ha. (kg.)	FISH CROP Recovery (%)	FISH CROP Culture days	RICE CROP Yield per ha. With fish	RICE CROP Yield per ha. Without fish	EFFECTS OF FISH ON RICE YIELDS [a/] (cav./ha.)
I	Pangasinan	*T. nilotica*	128.25	73	90	177.33	187.33	- 10.00
II	Nueva Viscaya	*T. nilotica*	104.33	74	116	85.30	91.30	- 6.00
		T. nilotica	75.48	76	118	77.23	84.26	- 7.03
III	Pampanga	*T. nilotica*	590.60	98	118	100.00	108.23	- 8.33
		T. nilotica	310.00	95	66	95.50	96.00	- 0.50
IV	Batangas	*T. nilotica*	164.00	71	64	97.50	103.50	- 6.00
V	Sorsogon	*T. mossambica*	187.50	85	115	87.70	31.20 [b/]	+ 56.60
	Camarines Sur	*T. mossambica*	238.00	95	[c/]	144.50	113.66	+ 30.84
VI	Iloilo	*T. mossambica*	140.50	77	87	122.00	120.50	+ 1.50
		T. mossambica	142.50	83	77	126.00	119.00	+ 7.00
		T. mossambica	183.62	87	[c/]	116.25	120.95	- 4.60
VII	Negros Oriental	*T. nilotica*	113.00	51	72	141.50	144.50	- 3.00
		T. nilotica	183.00	73	71	115.30	123.60	- 8.30
VIII	Leyte	*C. carp*	299.00	73	104	95.00	106.00	- 11.00
IX	Zamboanga	*T. nilotica*	295.00	76	75	111.70	107.40	+ 4.30
X	Bukidon	*C. carp*	113.87	43	70	103.40	104.00	- 1.00
		T. mossambica	103.30	81	65	83.30	85.00	- 1.70
		T. nilotica	155.90	57	78	102.80	100.97	+ 1.83
XI	Davao del Norte	*T. mossambica*	138.50	91	90	100.00	105.50	- 5.50
XII	Davao del Sur	*C. carp*	428.75	80	[c/]	278.78	296.25	- 17.47
Ave. for all locations and species			200.98	77		118.05	117.45	+ 0.60

[a/] Estimated as the difference of rice yields under the with and without fish culture.

[b/] Production is affected by insect infestation.

[c/] Not reported

SOURCE: Ministry of Agriculture, Republic of the Philippines, Diliman, Quezon City culture program are presented in Table II.8.

The program implementation strategy includes the provision of recommended technical inputs such as high yielding variety (HYV) palay seeds, monosex tilapia fingerlings; credit support, training of both the production technicians and farmers, etc. Monitoring and evaluation of the rice-fish culture farm operation has been an important aspect of the program implementation strategy. However, the monitoring and evaluation activity that is being undertaken is still open to further improvement. This program activity requires improvements such that the micro and marco level impacts of the introduced rice-fish culture technology can be made readily available to policy decisions. One of the major limitations of the monitoring and evaluation that is being carried-out is that the basic information on the technical input-output relationships of farm level production have not been obtained. And hence, the economic analysis of rice-fish culture at farm level cannot be undertaken out of the available information generated by the program monitoring activity. The result of the initial implementation of rice-fish culture program in the country is shown in Table II.9.

Table II.8 Degree of participation of the different national government agencies/institutions in the nationwide rice-fish culture program implementation, Philippines.

PROGRAM IMPLEMENTATION ACTIVITIES	NATIONAL GOVERNMENT AGENCIES/INSTITUTIONS									
	NFAC	MNR	BPI	BAEx	BFAR	CLSU	FIDC	TBAC	CB	NIA
1. Technology generation and packaging						1				
2. Technology transfer (field demonstration				1		2				
3. Program formulation and policy generation	1	1					1			
4. Training of farmers and technicians	2					1				
5. Program information and dissemination							1			
6. Monitoring and evaluation	1		3			2		3		
7. Socio-economic research/studies	2		3			1	2	3		
8. Provision of technical inputs/manpower										
a. Fish stocking		2			1					
b. HYV palay seeds			1							
c. Irrigation water										1
d. Extension personnel	2			1	1	2				
9. Credit assistance										
a. Packaging credit scheme								1		
b. administration of funds									1	
10. Source of seed money	1	1			2					
11. Over-all program coordinator	1									

Legend:

1 - Primary function and leading agency/institution in the implementation of its specific rice-fish culture program activities.
2 - Secondary function and will render collaborative support to the leading agency/institution.
3 - Shall provide collaborative support if requested.

NFAC - National Food and Agriculture Council
MNR - Ministry of Natural Resources
BPI - Bureau of Plant Industry
BAEx - Bureau of Agricultural Extension
BFAR - Bureau of Fisheries and Aquatic Resources
CLSU - Central Luzon State University
FIDC - Fisheries Industry Development Council
TBAC - Technical Board on Agricultural Credit
CB - Central Bank
NIA - National Irrigation Administration

Source: Rice-Fish Culture Program Implementation Guidelines, unpulbished document of the National Food and Agriculture Council, Ministry of Agriculture, Diliman, Q.C., Philippines

Table II.9 Number of farmer cooperators, average area and production level of the pilot rice-fish culture farms in the different regions of the Philippines, Crop Year 1980.

Region[1/]	No. of farmer Cooperators	Ave. Area Per Cooperator (ha.)	Ave. Production Level/ha.[2/] Rice (cav.)	Fish (kg.)
I	168	0.50	79.40	137.67
II	27	0.40	83.38	662.06
III	24	1.62	90.18	184.28
IV	9	0.29	83.15	121.72
V	42	0.77	86.51	80.34
VI	84	0.74	107.79	223.34
VII	1	0.25	88.10	20.00
VIII	91	0.19	64.52	104.23
All regions	446	0.56	89.06	193.50

Major problems incurred[3/]

a. Few interested farmer-cooperators
b. Lack of adequate supply of fish fingerlings (tilapia species)
c. Insufficient financial assistance to farmer-cooperators.
d. Poor construction of the rice-fish culture paddies, i.e., no adequate water control facilities, especially in the lowland areas.
e. Incidence of predators.

[1/] Regions IX to XII of the country have no pilot rice-fish culture farms.

[2/] The rice varieties and fish species grown and harvested were not reported.

[3/] Incidence of these problems according to the number of farmer-cooperators and extent of damage were not indicated in the reports.

SOURCE: Summarized from various Farm Management Technician Reports submitted to the Central Offices of National Food and Agriculture Council (NFAC), Ministry of Agriculture (MA), Diliman, Quezon City, Philippines.

II.5 Summary and Implication of the Literature Review

The foregoing discussion has developed: a view of the state-of-the-art rice-fish culture technology, a notion of the extent to which the technology has been used in the past, its decline and revival in the Philippines and nationwide rice-fish culture program implementation strategy.

In the Philippines, the assessment of the fishery resources in the lowland paddy fields and the manner and extent these resources were exploited have not been a serious matter in the past. Thus, statistics about it are not available. This unavailability of data is probably the reason why the biological engineers failed to take into account the paddy fishery resources in their previous framework of developing the present day HYV rice technology. Further, if ever they were aware of it, the relative value of the paddy fishery resources might have been sufficiently significant at that time to justify its inclusion in the design of HYV rice technology. In hindsight, this would imply the need for careful assessment of the resources' future potential values -- this is, the resources may be less valued now, but, it may become extremely valuable in the future. Such an assessment is necessary so as to provide a basis for evaluation of delayed negative side effects of technological innovations. And in this way the undesirable impacts of technological developments can be successfully avoided, before they are a problem.

In early 1960, biological engineering of rice varieties began and a research program for the development of rice-fish culture technology was proposed but was not funded. Had it been funded at that time, it could have contributed earlier to the development of rice-fish culture technology, and also, it could have induced the application of a different framework in the bio-engineering of rice crop varieties that are not too dependent on and highly demanding of agricultural chemical inputs, and sufficiently tall rice plants which could tolerate the recurring natural phenomena of flooding.3/ Furthermore, it could have guided the multi-national firms in the early development of agricultural chemicals that are not toxic to valuable fishery resources4/ and thus, these resources would be

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3/ A pest resistant nitrogen auto-self sufficient rice variety have been developed.

4/New agricultural chemicals such as carbo-furan, azodrine 202 if properly used were proven not toxic to fish in the paddy fields. (Estores, R.A., F.M. Laigo and C.I. Adordionisio, 1980).

available in the paddy fields of today.

In the design of the rice-fish culture technology, the fish grown simultaneously with rice crop are only considered as a supplementary crop. Clearly, this is a technological bias in packaging rice-fish culture technology. The bias is in favor of the rice crop which may not be irrational, if the ultimate objective is to maintain the production level of rice, while at the same time increase income through the production of fish as a supplementary crop. One problem relating to this bias is that the need for adequate data on technical relationships between and among inputs and outputs, will remain. Relevant questions along this line which cannot yet be answered include the following: (1) How does it compare economically if one attempts to grow rice with fish in fish ponds, rather than growing fish with rice in paddy fields. (2) How would the production system perform if the technological bias did not exist? And of course, there are questions relating to the optimal input mix and output mix at a given market situation. With the available limited technical data, an analysis of some of these specific issues concerning the economics of the production system are undertaken in Chapter IV.

There is the question that the rice-fish culture technology R & D in the Philippines has been somewhat biased in favor of the seller, i.e., producer of agricultural chemical inputs, rather than the small rice farmer.[5] The number of experiments or field production trials clearly indicates a bias towards agricultural chemical dependency. Furthermore, studies on the utilization of agricultural chemical inputs in rice-fish culture system are the main subject matter and emphasis of the recent R & D of the technology. Agricultural chemical inputs are applied before the output of the rice-fish culture system could be realized. Thus, this would mean that the agricultural chemical producers were served first - way ahead of the small rice farmers.

The collaborative action and function of the various support systems or agencies is clearly desirable in the widespread promotion of the rice-fish culture technology. The only problems with this strategy are that interagency collaborative action is difficult to achieve, duplication in function may exist, and finally, there is potential difficulty

[5] No particular R & D efforts have been reported to explore for possible substitute of agricultural chemicals. Research efforts towards the utilization of resources, such as azolla pinata & ipil ipil leaves for fish feeds, which are indigenous in the farm have only been initiated in the latter years.

of farmer cooperators to deal with so many bureaucrats which in turn may discourage them from adopting the introduced technological innovations.

Chapter III

ON THE ECONOMIC THEORY OF MULTI-OUTPUT PRODUCTION SYSTEM

This chapter defines the multi-output production system; identifies some of the multi-output production system examples and reviews the existing models for multiproduct firms. This chapter has two objectives: first, to develop a theoretical model for the economic analysis of simultaneous rice-fish culture system; and second, to propose quantitative procedures for such an analysis. Simultaneous rice-fish culture production provides a model real world multi-output production system. The concept of multi-output "symbiotic maximum yield" in production has also been formulated and its economic implication is theoretically explored.

III.1 Conceptual Definition of Multi-Output Production System

Multi-output production system (MOPS) is a method or technique of production that simultaneously yields more than one type of output in the same production space, i.e. paddy field, as in the case of simultaneous rice-fish culture. Outputs command positive market prices and all are taken into account in the producton management decisions.

Different MOPS outputs can also be separately produced through single-output oriented production systems in different production spaces, or in the same production space but at different times.[6] Hence, MOPS involves vertical integration of various single-output oriented production into one production technology. MOPS occurs not only because of the problem of limited production space but also because resource use efficiency can be maximized and thus, the benefit of production can be maximized.

III.2 Some of the Real World Examples of Multi-Output Production System

Numerous cases of agricultural production practiced for generations can be considered as MOPS. The various cases of MOPS in agriculture could be grouped into: (a) fauna-fauna production system; (b) flora-fauna production system; and (c) flora-flora production system.

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[6]/This makes a distinction between MOPS and ordinary joint-output production wherein one output could not be produced without the other output. Theoretical economic analysis of joint output production is common in most intermediate economic theory texts. However, theoretical discussion of MOPS has only recently begun to appear in the literature. See Shumway, C.R., et al. (1984).

The growing i.e., husbandry of different species of fish (i.e., polyculture of fish) in a fishpond is one of many examples of the first group. The simultaneous rice-fish culture system, which is the case of this current research is an example of the flora-fauna production system. Vertical integration of livestock (such as cattle, goat, sheep, etc.) and orchard (like coconut, citrus, etc.) production can be considered under this category. The intercropping of various kinds of economic plants, such as the corn-peanuts intercrops, the coconut-coffee-pineapple intercropping, etc., could be cited as flora-flora production systems which are more popularly known as multi-storey crops farming systems in today's agriculture.

Generally speaking, MOPS as a technology of farm production has received less attention in the past. This could be due to the predominance of the basic notion that specialization in production, i.e., single-output oriented production system, such as the monoculture of rice crop, would maximize economic efficiency.

III.3 Multi-Products Firm Models

Based on the definition of MOPS, formulated above, it would not perhaps be naive to state that "a firm that follows the concept of MOPS is a sufficient condition to consider such firm as a multi-product firm, but a multi-product firm is not necessarily using the concept of MOPS." In terms of the production function structure as well as input allocation among different outputs, distinctions of various multi-product firms could be easily made as to whether they follow the concept of MOPS.

An excellent review of the multi-product firm model development in production was provided by C.E. Ferguson (1979):

> "Speculation about the selling behaviour (revenue side) of multi-product firm could be traced back to the time of Pigou(1932) and Robinson (1933). The multi-product firm was given more thorough and conventional treatment by Hicks (1939), whose approach was extended by Samuelson (1947), Dorfman (1951) and Kuenne (1963). Basically, Hicks and his followers used conventional marginal methods to analyze the profit maximizing behaviour of a firm that produces a variety of output by means of a variety of inputs. The existence of fixed inputs is more significant in the theory of multi-product firms than in the theory of single-product firms. It was Pfouts (1961) who first realized the difference and constructed a model of multi-product firm that permitted switching, i.e. reallocation, of fixed inputs among various outputs. Pfouts' model and subsequent ones (Dhrymes, 1964 and Naylor, 1965) based upon it, cannot be solved by the usual methods of calculus. The solution can be achieved through a complex and intricate mathematical procedure - the "vector optimization technique" which was first operationalized by Kuhn and Tucker (1951)."

And finally, C.E Ferguson indicated that the vector optimization technique was not developed until the 1960's when efficient computing technology facilitated the use of numerical techniques, the so-called "computational algorithms".

The theory of multi-output-multi-input production function models do exist (Henderson and Quandt, 1971; Dillon, J.,1977; Pinto and McFadden, 1979, etc.). However, most of the models were presented in a very generalized manner. Thus, the models are not adequate for applied economic analysis.

In general, most of the multi-output firm models discussed in numerous intermediate economic theory texts give emphasis on output mix optimization as it is associated with the basic problem of production management of allocating (reallocating) inputs among different outputs. This is not appropriate to a MOPS such as simultaneous rice-fish culture.

III.4 Structure of the Production System

In the simultaneous rice-fish culture system, a set of "output-specific" and "non-output-specific" inputs are combined in one production space to simultaneously produce rice and fish. The production system is illustrated in Figure III.1.

where:

$\vec{X}$ - vector of exogenous variables

$\vec{Y}$ - vector of endogenous variables

Figure III.1 A generalized multi-output production system model.

In algebraic form, the production system can be stated as:

$$Y\Gamma + X\beta = U \qquad (1)$$

where:

Y - is the 1 x 2 vector of endogenous variables (i.e., the two outputs - rice and fish).

Γ - is the 2 x 2 outputs interaction coefficient matrix;

X - is the 1 x k vector of exogenous variables (inputs - which are composed of the "output specific" and "non-output specific" technical inputs such as palay seeds, fish stocking materials, labor inputs, water, etc.), and k is the number of inputs in the production system;

β - is a k x 2 input coefficient matrix;

U - is a 1 x 2 vector of random errors;

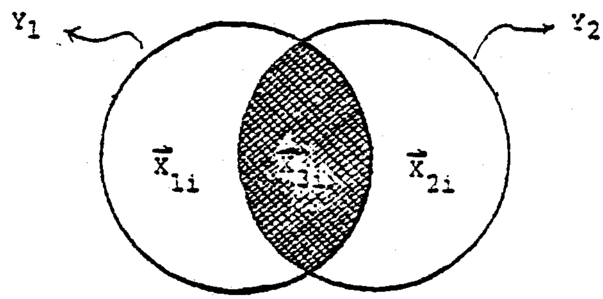
Without MOPS technology rice and fish are separately grown and separately produced through single-output production systems (SOPS). The individual output responses to technical inputs of production can be given as:

Rice: $Y_1 = f(X_1, X_2 \dots X_n)$ (2)

Fish: $Y_2 = g(X_1, X_2 \dots X_m)$ (3)

The X's are the technical inputs of production where the number of different rice production inputs is not necessarily equal to the number of different fish production inputs. Some of the technical inputs (i.e., X_3) in rice production could also be necessary in fish production. Thus, rice and fish production can be technically related with one through common input utilization.[7/] In a simplified form, the jointness of the individual components output (rice-fish) production processes in MOPS can be illustrated by Figure III.2.

7/ Technically related production functions is one of the important motivation and/or reasons for vertical integration (Williamson, O., 1971).



where:

$\vec{X}_{1i}$ - vector of specific inputs to output Y_1;

$\vec{X}_{2i}$ - vector of specific inputs to output Y_2 ;

$\vec{X}_{3i}$ - vector of non-output-specific inputs of production of Y_1 and Y_2;

Figure III.2 Jointness in multi-output production system.

Generally speaking, the common inputs (X_3) are underutilized or not fully exploited in SOPS. Irrigation water in the monoculture of rice production at the lowland paddy fields is an example.[8] This could be due to the inability of monoculture crop to fully consume the available X_3 or excessive quantities of X_3 is being applied. Thus, the total productive capacity of inputs (resources) in the SOPS are not fully exploited. This excess capacity has been one of the major considerations for vertical integration of production. Such integration is made so as to increase efficiencies in the use of not only X_3 but also other technical inputs included in the system. The extent through which MOPS can increase efficiency of resources (technical inputs) used in production can be assessed through production function analysis.

[8] Fertilizer is another good example of X_3 in rice monoculture, that when applied in the paddy, it is either consumed by competing micro and macro flora like planktons, weeds, etc., or leached through irrigation water.

III.5. Multi-Output Production System Economic Efficiency

Production function analysis is undertaken not only for "purely positivistic" purposes (describing the response processes) but also for "normative" purposes (solving empirical production problems). Economic efficiency is the main concern in production. The attempt to achieve economic efficiency is basically governed by four decision questions as distinguished by Baumol (1960):

1. how much of each final output to be produced?
2. how much budget, in total, should be spent on the acquisition of inputs and/or input services?
3. how should this budget be allocated among the various inputs? and,
4. how much of each input will be allocated to each output?

Basic information needed for these decisions can be generated from production function analysis. However, there are methodological problems and difficulties in specifying a sensible and estimable functional form for the case of MOPS. The usual procedure is to estimate an aggregate (i.e., composite) production function. But this is not a single-valued function, and its parameters are dependent on output composition and on prices.

III.5.1 Composite Output Production Function

For the following theoretical analysis of the economics of simultaneous rice-fish culture as a case of MOPS it is assumed that prices are fixed; the individual output responses to technical input application can be estimated; and that the objective of production is profit maximization regardless of the output combination. With fixed output prices, a <u>composite output</u> is defined as

$$Q = \sum_{i=1}^{2} P_{y_i} Y_i$$

which will have the usual properties of a single output.[9]

When various output-specific and non-output-specific technical inputs (the X_is) are combined in the paddy, they produce a variety of outputs (Y_1 and Y_2). It involves a "multiple response" to input

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[9] This is within the confines of Hicks' theorem on Value and Capital (1946) which states that if the relative prices within a group of commodities are fixed the value aggregates of such commodities behaves as if it were a separate intrinsic commodity. This is the basis of using <u>Hicks-Allen money</u> in popular two dimensional geometry of demand analysis. It should also be recognized that the assumptions of fixed output prices is not always true. Hence, it is possible to have a situation where an increase in total quantity of inputs (when accompanied by an appropriate change in relative output prices) could result in an increase, no change or a decrease in composite output (Boyne, 1963, p. 444).

application (Dillon, 1977). In this situation, inputs are allocated internally by the rice plants and fish stock in the system. The composite output production function can be expressed in general form as

$$Q = \sum_{i=1}^{2} P_{y_i} Y_i = F(X_1, X_2, X_3) \quad (4)$$

This is formed by the individual output responses.

$$Y_1 = f(X_1, X_3, X_2) \quad (5)$$

and

$$Y_2 = g(X_2, X_3, X_1) \quad (6)$$

The individual components output (Y_1 and Y_2) production function in MOPS are not necessarily the same (in terms of form or shape) as that of the SOPS Y_1 and Y_2 production functions. In other words, the shape of the curve formed by Eq. 5 is not necessarily the same as the shape of the curve formed by Eq. 2. This is also the case of Eq. 6 and Eq. 3. The application of inputs for a particular output would also affect the other output in the system, i.e. $dY_1/dX_1 \lesseqgtr 0$ and $dY_2/dY_1 \lesseqgtr 0$. For instance, the application of rice pesticides may negatively affect the growth and yield of fish stock.

The profit function (π) is

$$\pi = \sum_{i=1}^{2} P_{yi}Y_i - [\Sigma P_{xi}X_{1i} + \Sigma P_{x2i}X_{2i} + \Sigma P_{x3i}X_{3i}] \qquad (7)$$

$$= Q - [\Sigma P_{x1i}X_{1i} + \Sigma P_{x2i}X_{2i} + \Sigma P_{x3i}X_{3i}] \qquad (7a)$$

and subject to the second-order condition that the differential $d^2\pi < 0$. The net returns to production is maximized when $d\pi/dx_i$ equals zero. This is when the following solution is attained:

$$dQ/dX_i - P_{xi} = 0 \qquad (8)$$

The optimal quantity of input (X_i) should be that level where the numeraire value of composite marginal product of X_i (dQ/dX_i) is equal to input price (P_{xi}).

The above solution in attaining the best operating condition for simultaneous rice-fish culture assumes that the production budget is not limited. With limited production budget ($\vec{C}$) , the constrained profit function can be stated as:

$$\pi = Q - \Sigma P_{x_i}X_i + \lambda[\Sigma P_{x_i}X_i - \hat{C}] \qquad (9)$$

The main problem then is to allocate the total limited budget ($\vec{C}$) to acquire various inputs (X_i's). It does not include the question of allocation of each type of X_i among Y_i because of the intrinsic nature of the production system. The π function (Eq. 9) is differentiated with respect to X_i's and λ, and the resulting equations are set to zero:

$$\partial Q/\partial X_i - P_{x_i} + \lambda P_{x_i} = 0 \qquad (10)$$

$$\Sigma P_{x_i} X_i - \vec{C} = 0 \qquad (11)$$

After eliminating λ by simultaneous manipulation of the equations, the optimality condition for the allocation of $\vec{C}$ among inputs (X_i) is determined by:

$$\frac{\partial Q/\partial X_1}{P_{X_1}} = \frac{\partial Q/\partial X_2}{P_{X_2}} = \ldots\ldots = \frac{\partial Q/\partial X_n}{P_{X_n}} \qquad (12)$$

If there are only two variable inputs, an efficient allocation of a limited budget can be achieved using the following rule:

$$\frac{\partial Q/\partial X_1}{P_{x1}} \neq \frac{\partial Q/\partial X_2}{P_{x2}} \qquad (13)$$

The rate of technical substitution (RTS) in MOPS must be equal to the negative of the inverse of input-input price ratio. The equilibrium condition is at point where the composite isoquant is tangent with the budget line, as indicated in Figure III.3. The theoretical optimal input mix will be OX_1^* and OX_2^* quantities of input X_1 and X_2, respectively. With this input combination, the total limited budget ($\vec{C}$) is efficiently allocated, since the highest level of composite output production (Q) is attained.

Composite output production function analysis would not provide complete technological decision making information. It is only limited to production budget optimization and total budget allocation to obtain optimal input mix. Input allocation to each type of output is exogenous to management decision because of the intrinsic nature of the production technology. Hence, such an input allocation is done internally in the production processes of the individual component output of MOPS.

While the necessary information for profit optimization can be easily obtained through composite output production function analysis, it does not directly provide information as to how the various

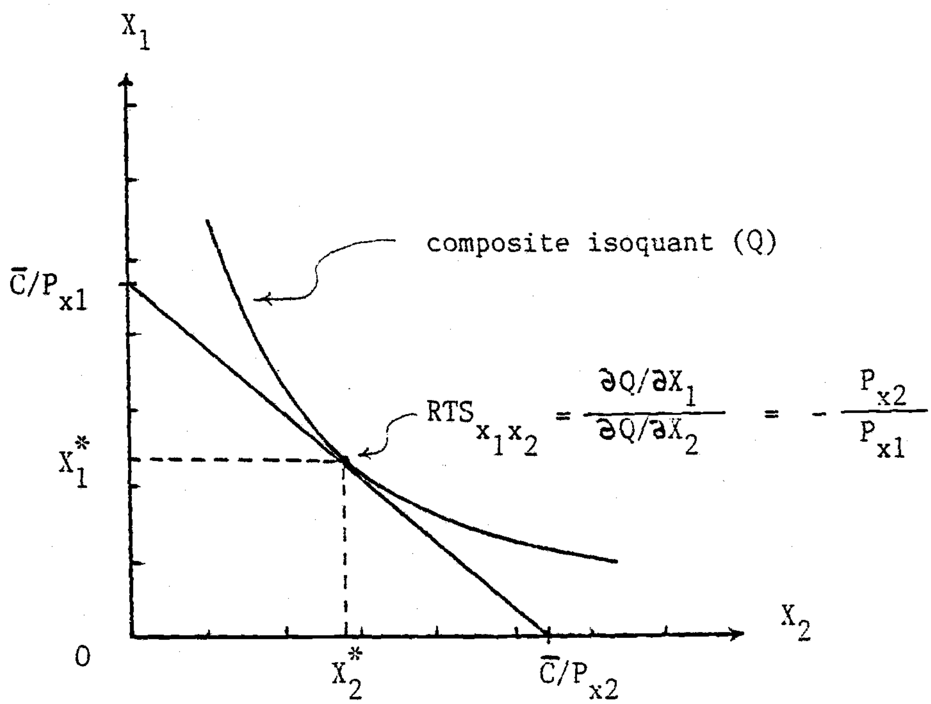

Figure III.3 Theoretical composite isoquant in multi-output production system.

outputs are technically related to one another. This is a limitation of the composite output production function. Such a limitation would become very evident when the production objective does not emphasize profit maximization, i.e., the "money objective", but instead, for instance, it is aimed at increasing one output, such as fish, while maintaining the other output of the system. It is necessary that the individual components output production functions in MOPS must be known.

III.5.2 Multi-Output Production Mix Optimization

Determining the optimum mix of MOPS production under a given economic situation would require detailed data about the various outputs technical relationships. Technical relationships can be fully appreciated through knowledge of the internal structure of the involved functional relations, i.e., the individual component output functions.

Internal structure of production function

In the introduction to a "Theory of the Internal Structure of Functional Relationships", Leontief (1947) begins with the problem of simplifying an overall production function $Y = F(X_1, \ldots, X_n)$ of variables X_1, ..., X_n into a function of few new <u>intermediate variables</u> ϕ_1, ..., ϕ_r, where $r < n$. These intermediate variables, ϕ_i's are themselves functions of subsets of the variables X_1, ..., X_n such that the subsets were mutually exclusive so the following identity would hold,

$$F(X_1, \ldots X_n) = g\ [\phi_1(X_1^1, \ldots X_n^1), \ldots\ldots,$$
$$\ldots\ldots, \phi_r(X_1^r, \ldots X_n^r\ ] \qquad (14)$$

According to Leontief, a complex production scheme can be represented through a set of <u>intermediate production functions</u>, $\phi_1(X_1, \ldots, X_n)$, (see pp. 362, Econometrica, 1947) provided there exists appropriate technical information in the intermediate steps of the overall production process. The intermediate production function, ϕ_1 (. . .) can be easily combined to construct the overall function, $g(\phi_1, \ldots, \phi_r)$, but the reverse process of determining $\phi_1, \ldots, \phi_r$ given the properties of $F(X_1, \ldots, X_n)$ is not easy. This is why it is not done in applied production function analysis. Therefore, the outputs (rice and fish) do not directly respond to the application of technical inputs of production.[10] Instead, the level of production is really dependent upon the changes in quality of the environment where production processes takes place.

A simplified theoretical model for simultaneous rice-fish production is presented in Figure III.4. The simultaneous rice-fish production responses to various levels of ϕ are indicated in quadrants II and IV. The variable ϕ is a parameter (measure) of the degree of the paddy environment alteration resulting from a technical input (X) application, i.e., $\phi = F(X)$. The variable ϕ is an intermediate product of the application of X in the overall production process. It is important to recognize that the intermediate product (ϕ) is the determining factor for the individual components output of the production

[10]/In other words, the technical inputs must first pass through a media before it can be assimilated by the crops. The individual responses are also a function of the media where technical inputs are applied.

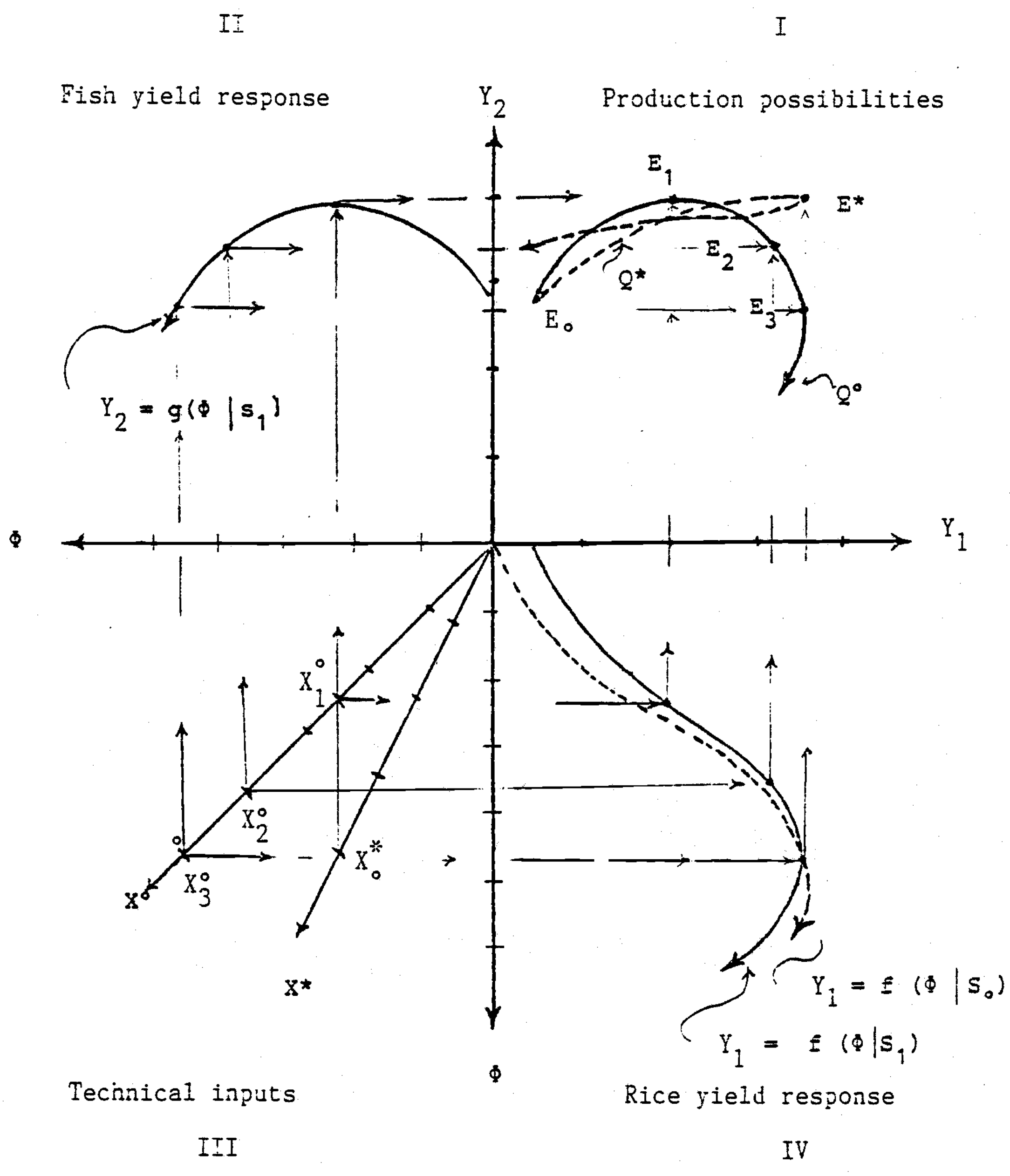

Figure III.4 Hypothetical yield responses, multi-output production possibilities, optimum input quality and symbiotic maximum yields in simultaneous rice-fish culture system.

system to be not non-joint in the over-all production process.[11] The level of rice (Y_1) and fish (Y_2) production are no longer independent from one another due to ϕ even though the technical input (X) applied in the production system is specific to Y_1 or Y_2.

The individual component output functions, $Y_2 = g(\phi/s_1)$ for fish and $Y_1 = f(\phi/s_1)$ for rice, in quadrants II and IV, respectively, assumes that stocking of fish fingerlings is at biologically optimal density level of S_1. And if there is no fish stock ($S_0 = 0$), the system is a SOPS and rice production is given by $Y_1 = f(\phi/s_0)$. It further assumes all other factors of production except technical input X, are held constant. The quantity as well as the quality of variable input X is indicated in quadrant III. The technical inputs X^* and X^o are of the same type (say, chemical fertilizer) but are different in quality such as urea versus super phosphate. Thus, their effects on ϕ would be different, even though the physical quantities of X^o and X^* are the same.

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[11]/A multiple output technology is non-joint if the output of any single process depends only on the inputs used in that process and not on the levels of inputs or outputs into any other production process (Denny, M. & C. Pinto, 1979).

<u>Production possiblities</u>

The theoretical production possibilities (PP) for simultaneous rice-fish culture is described by the Q^o and Q^* curves in quadrant I of Figure III.4. The production possibilities curves are formed by tracing-out the output response curves as indicated in the figure. The production possibility curves indicate the level and combination of rice-fish production as affected by technical input application. The Q^o curve describes the production possibilities for simultaneous rice-fish culture using the X^o technical input X. If the X^* type of technical input is used, the relevant production possibilities for the system is described by Q^*.

The production possibilities curves would clearly indicate the nature as well as degree of Y_1 and Y_2 interdependence. This is also referred to as the production transformation curve. The slope indicates the rate of production transformation that results from increasing technical input application. From point E_0 to E_1 on production possiblity curve Q^o, the rate of product transformation is greater than zero. X^o application is creating an intermediate product that is favorable to both Y_1 and Y_2. Hence, Y_1 and Y_2 production are both increasing in this region (from E_0

to E_1). This could be thought of as complementarity in production. Increasing the level of X^o application would increase ϕ to certain levels that are not favorable to one of the outputs. This is the case when the rate of product transformation is less than zero between E_1 and E_3. The increase in X^o tends to increase Y_1 while at the same time Y_2 decreases. Obviously, there is a trade-off between Y_1 and Y_2 as the application of X^o becomes excessive. It is also in this region (from E_1 to E_3) of the production possibility frontier that management decisions become critical concerning levels of X^o application. Hence, it raises the issue of multi-output production mix optimization.

In Figure III.5 the relative weights of Y_1 and Y_2 in the production system are indicated by the price line. It should be recognized that the production transformation between the two outputs described by the Q curve is a result of increasing the level of X application. Hence, $\partial Y_1/\partial X^o > 0$ while $\partial Y_2/\partial X^o < 0$ (or vice versa) as X^o is being increased to a large quantity. This production transformation is not due to the reallocation of a fixed quantity X^o among competing outputs as is generally formulated, discussed and analyzed in most intermediate economic

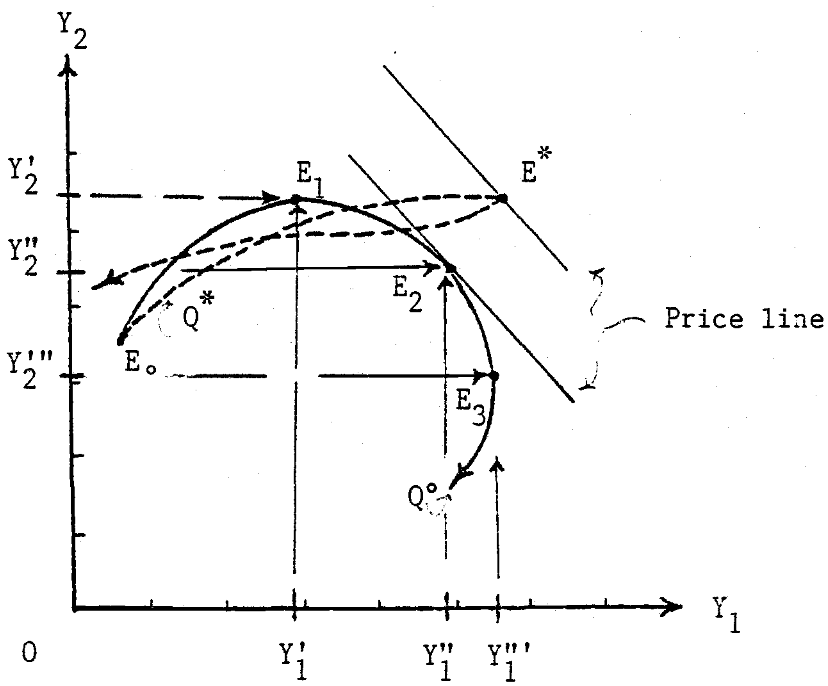

Figure III.5 Theoretical price line and production possibilities curves for simultaneous rice-fish culture system.

theory texts (Henderson & Quandt, 1971, pp. 89; Ferguson and Gould, 1975, pp. 443; Layard, 1978, pp. 14). Thus it follows that the traditional production mix optimization principle which states that the rate of production transformation must be equated to the ratio of product prices, i.e.:

$$\frac{\partial Y_2 / \partial X^o}{\partial Y_1 / \partial X^o} = \frac{MP_{X^o} \text{ in } Y_2}{MP_{X^o} \text{ in } Y_1} = \frac{P_{Y_2}}{P_{Y_1}} \tag{15}$$

will not be a sufficient guide in determining the optimum production mix for simultaneous rice-fish culture system. The principle will only hold true when the problem of production mix optimization is associated with the allocation of the limited fixed quantity of input among competing outputs.

Technically, input allocation which is internal to the system is not a real problem in simultaneous rice-fish culture. This would suggest that for a given fixed quantity of input X, there would only be just "one product mix" which is a point on the production possibility curve. Hence, there will be no production transformation for the given fixed quantity of input X; production transformation in the simultaneous rice-fish culture would only arise, as the application of input X is being increased or decreased, as long as, the simultaneous production responses of Y_1 and Y_2 to the input application will not be of the same direction, i.e., $\partial Y_1/\partial X < 0$ and $\partial Y_2/\partial X > 0$ or vice versa.

The individual components output production functions must be known. The optimum mix of production will still be where the input X application is at an optimum. This can be directly estimated using the composite production function.

Multi-output symbiotic maximum yield

Changes in the quality as well as combination of technical inputs may alter the paddy environment such that the individual components output responses to ϕ will not be conflicting (competitive) with one another. In other words, both Y_1 and Y_2 will be increasing or decreasing at the same time as the technical input application is increased. This is described by curves Q^* in Figures III.4 and III.5. Both Y_1 and Y_2 will be maximized at point E^* of the production possibility curve Q^*. The combination of Y_1 and Y_2 yields at point E^* could be thought of as the multi-output "symbiotic maximum yield" (SMY). It is a SMY in the sense that the levels of production of both output (Y_1 and Y_2) are simultaneously maximized with a given level of X^* at X_0^*. Note that if X^o type of technical input is used, Q^o is the relevant production possibility curve and that obviously, Y_1 and Y_2 cannot be simultaneously maximized. At X_1^o level $\partial Y_2/\partial X^o = 0$, Y_2 is maximized, while $\partial Y_1/\partial X^o > 0$, signifying that Y_1 is still increasing. Similarly, at $X^o{}_3$ level $\partial Y_1/\partial X^o = 0$ and $\partial Y_2/\partial X^o < 0$. Therefore Y_1 is maximized while Y_2 is not maximized but rather, is already decreasing. Thus, the SMY cannot be achieved with the use of technical input X^o.

The SMY is unique and can only be attained with the use of X^* type of technical input. Thus, X^* is also a unique type of technical input.[12] The multi-output SMY (E^*) could be considered as the most technically efficient production mix because Y_1 and Y_2 are maximized. This SMY is, however, not the economically optimum level of production. This is

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12/If X^* represents a set of variable technical inputs which are combined together in a certain constant proportion, then a such constant proportional combination of variable technical inputs can also be considered unique.

because the combined value of marginal product of X_0^* in Y_1 and Y_2 is equal to zero at point E^*. Thus, there would be an incremental loss (in terms of the cost of input X^*) in production at SMY.

Given constant output prices, the optimum production mix will be that combination of products where the combined value of marginal product of X in Y_1 and Y_2 is equal to unit cost or price of the input, i.e., $\sum_{i=1}^{2} P_{yi}\ \partial Yi/\partial X = P_x$. The optimal level of input application in production will also be that level of X^* where $\sum_{i=1}^{2} P_{yi}\ \partial Y_i/\partial X = P_x$ is attained, and obviously, it will be less than the level of X_0^*.

III.5.3 A Generalization of the Theoretical Model

The theoretical model for two outputs (Y_1 and Y_2) and one variable technical input (X) of production, described by Figure III.4, can be used to represent a real production system involving more than one variable technical input. The model can represent two outputs by n variable technical inputs production relation by redefining the X's in quadrant III of Figure III.4. The X^o or X^* represents a set of variable technical inputs, and thus, makes the model more realistic.

The two ouput by n variable technical inputs production relation is illustrated, in Figure III.6. Vector $\vec{X}_0$ represents a set of variable technical inputs X_1, X_2, .., X_n which are combined in a pre-determined constant proportion. The $\vec{X}_A$ is likewise a set of variable technical inputs, X_1, X_2, ..., X_n and it is distinguished from that of $\vec{X}_0$ in terms of the differences in the constant proportional combination of the technical inputs. Similarly $\vec{X}_B$ is different from $\vec{X}_0$ and $\vec{X}_A$ in terms of the constant proportional differences in the X's. The $\vec{X}_0$, $\vec{X}_A$, and $\vec{X}_B$ involve the same types of variable technical inputs, X_1, X_2, .., X_n. The intermediate products in the over-all production process, from using $\vec{X}_0$, $\vec{X}_A$, and $\vec{X}_B$variable are not the same, i.e., $q_0 = F(\vec{X}_0) \neq q_a = F(\vec{X}_A) \neq q_b = F(\vec{X}_B)$. Consequently, the characteristics of the different sets of multi-output PP will be distinctly different from one another. Hence, the theoretical multi-output PP for $\vec{X}_0$, $\vec{X}_A$, and $\vec{X}_B$ are described by curves Q_0, Q_A and Q_B, respectively (quadrant I of Figure III.6).

One of the important points which the theoretical model demonstrates is the technical criterion and/or notion concerning the selection (or formulation) of the most technically efficient alternative set and

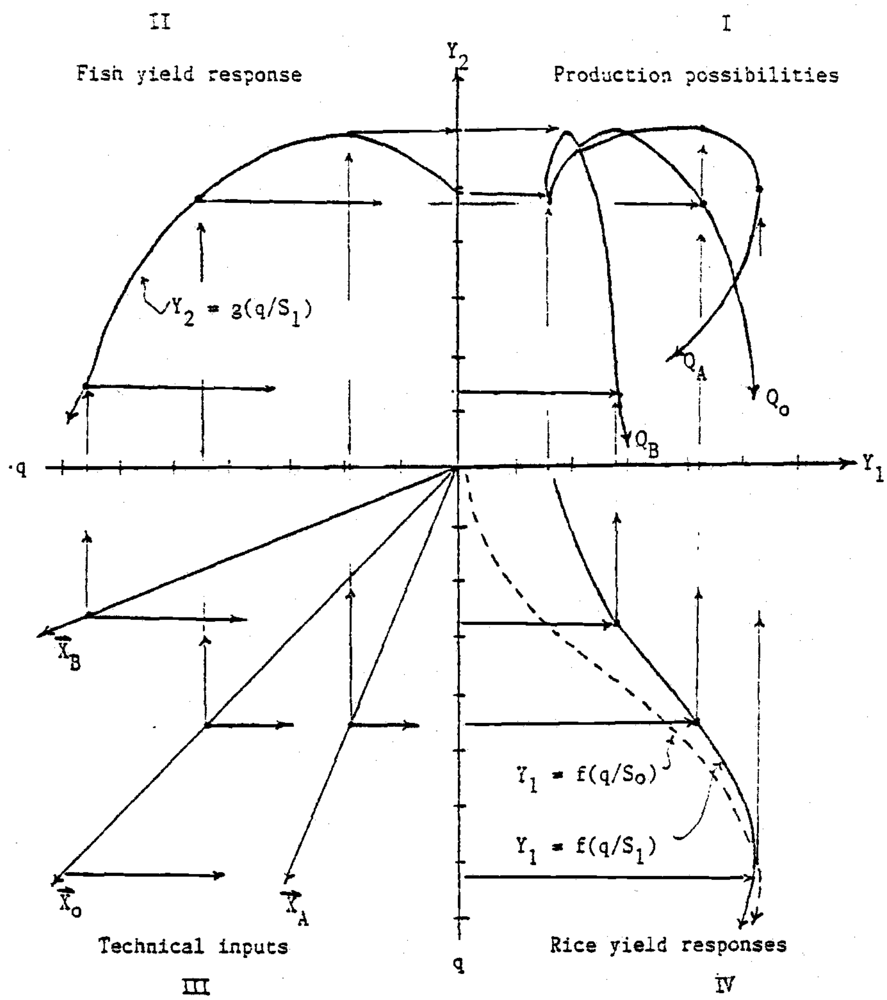

Figure III.6 Hypothetical rice-fish yield responses, production possibilities and variable technical inputs mix in simultaneous rice-fish culture system.

proportional combination of variable technical inputs of production. It is the most technically efficient since it would give the highest possible output mix of MOPS. Technically, it is that set and proportional combination of variable technical inputs which would expand the production possibilities to the outer right most frontier of the product-product space of Figure III.6.

III.6 Proposed Analytical Model

An indepth understanding of the potentials of simultaneous rice-fish production system can be accomplished through estimation and analysis of production functions, not only for the composite output but also for the individual components output. The identification of relevant variables and selection of the appropriate functional form of the production functions are the tasks in model specification. A working familiarity of the involved physical, technological, and biological processes is indespensable in modelling the production system. The candidate explanatory variables categorized into "output-specific" and "non-output-specific" inputs of simultaneous ricefish production are presented in Table III.1. These variables are further categorized into "basic" and "nonbasic" inputs of production. An

Table III.1 Classification of production inputs of simultaneous rice-fish culture in the context of multi-output production system.

Inputs Classification	Individual Component Output: Rice	Fish
A. Output-specific-inputs		
Palay seeds	basic	
Fish fingerlings		basic
Pesticides	non-basic	
Supplemental feeds		non-basic
Specialized labor inputs	basic	basic
B. Non-output-specific-inputs		
Production space(land)	basic	basic
Water	basic	basic
Fertilizer	non-basic	non-basic
Other farm chemicals	non-basic	non-basic
Labor services	non-basic	non-basic

Note: If one will have to compare the above production system (i.e., micro-level economic activity) with a large development activity/project, such as the multi-purpose dam and resevoir, the above input classification would in general sense become synonymous with the concepts of "joint" and "non-joint" or "separable" and "non-separables" project costs. The input is classified to be "basic input" in the sense that without such input, production would not take place.

output is said to be basic, if without such an input, production would not take place.

Normally, it is not possible to incorporate all the explanatory variables in the model because some of them are not measurable in quantitative terms. Only those important variables that are believed to explain the variability of production are included in the model. The exclusion of important variables from the model can result in specification bias and the extent of such bias depends on whether those omitted variables are correlated with the variables considered in the model. To the extent that the omitted and included variables are highly correlated more bias is expected and conversely, bias would not arise if the variables are not correlated. The exclusion of important variables from the model are captured by the error terms. Thus, an examination of the magnitude of the error term or residual would indicate whether there are important variables excluded from the model. Also the analysis of the error terms will indicate whether the functional form is correctly specified.

As discussed earlier, a composite output production function would have the usual properties of a single-output production function. Thus, any mathematical/functional form that may be appropriate for each of the individual components output, may also be appropriate for composite output production function. There are several functional forms that can be used in the estimation of the relevant production functions for simultaneous rice-fish culture but there is no one functional form that has all the desired features. Attempts have been made in numerous studies to derive mathematical forms of production functions which are both theoretically and empirically applicable (Garrod and Aslam, 1977). Each alternative functional form has advantages, but each usually imposes certain restrictions or limitations on the nature of the input-output relationships. The applicability and limitations of the various functional forms of production functions are discussed in a report on "A Survey of Functional Forms in the Economic Analysis of Production" by Fuss, M., et.al., 1978. Finally, the selection of a mathematical function to describe the relevant production processes depends upon knowledge of the behaviour of those processes.

It is proposed that the Cobb-Douglas form production function is appropriate for estimating relevant production processes, i.e., the composite output and the individual components output responses to input application in simultaneous rice-fish culture. The selection of the Cobb-Douglas production function model is appropriate because: (a) the production system that is being studied is complex and thus justifies the use of a simple functional form in order to have a clear understanding and interpretation of results. Hence, this study is only just beginning to establish the relevant input-output coefficient estimates for simultaneous rice-fish culture; and (b) the inherent advantages of the Cobb-Douglas form which includes (1) computationally simple to estimate since it is linear in the logarithmic form; (2) ease in interpreting the elasticities of production and estimation of marginal products; (3) thrifty on degrees of freedom when compared to other mathematical forms and thus has definite advantage for small sample size; and (4) ability to depict any one of three relationships: increasing, constant, and decreasing returns when it is unconstrained.

According to Heady (1946), the logarithmic transformation of the variable required under the Cobb-Douglas form also presumes, to a substantial degree, normality in the distribution of errors in survey data. This is consistent with the basic requirements or assumptions of the ordinary least squares (OLS) estimation method (Johnston, J., 1972).

The Cobb-Douglas form of the production function also has some limitations. It does not account for interaction terms between variables. Elasticity of production is constant throughout the entire range of the function and thus, it does not depict the three stages of production. Also when the sum of elasticities is equal to one (unit) or is less than one, it does not give a distinct peak. These limitations are minor when compared to the advantages of the Cobb-Douglas production function model. The decision to use Cobb-Douglas log linear form for the relevant technical input output relationships, for simultaneous rice-fish culture is not only due to the advantages of the Cobb-Douglas model but also to be able to simplify the analyses and interpretation of the involved complex production processes in MOPS.

III.6.1 Production Function Models for Simultaneous Rice-Fish Culture System

It is proposed that the generalized econometric model (Eq. 1) for simultaneous rice-fish production should be empirically specified as follows:

$$\ell Y_1 = \ell\beta_{10} + \beta_{11}\ell X_1 + \beta_{12}\ell X_2 + \beta_{14}\ell X_4 + \beta_{16}\ell X_6 + \beta_{170}\ell X_{70} + \beta_{171}\ell X_{71} + \alpha_{12}\ell Y_2 + \epsilon_1 \qquad (16)$$

$$\ell Y_2 = \ell \beta_{20} + \beta_{21}\ell X_1 + \beta_{23}\ell X_3 + \beta_{24}\ell X_4 + \beta_{25}\ell X_5 + \beta_{270}\ell X_{70} + \beta_{272}\ell X_{72} + \beta_{28}\ell X_8 + \alpha_{21}\ell Y_1 + \epsilon_2 \qquad (17)$$

where:

Y_1 and Y_2 = total product of rice (in cav.) and fish (in kgs.), respectively;

X_1 = land area harvested (ha.);

X_2 = palay seeds (kgs.);

X_3 = fish fingerlings (pcs.);

X_4 = inorganic fertilizer (bags);

X_5 = supplemental feeds (pesos);

X_6 = pesticides (pesos);

X_{70} = non-output-specific labor inputs (man-days);

X_{71} = rice-specifics labor inputs (man-days);

X_{72} = fish-specifics labor inputs (man-days);

X_8 = size (cm.) of stocked fingerlings

β_{io}, β_{ij}, and α_{ij} = technical coefficients of the functional form input-output relationships;

ϵ_i = error terms distributed with mean zero and constant variance

Equations 16 and 17 are structural equations representing the functional form input-output relationships in simultaneous rice-fish production. These structural equations seek to demonstrate how the individual components output of the production system are functionally dependent on one another; i.e., how the level of rice production affects the level of fish production and vice versa. Variables X_1, X_4, and X_{70} are non-output-specific inputs of production and therefore, these variables are specified in both structural equations. This is to indicate that the inputs will be jointly utilized in the production processes of the individual components output.

The individual component output functions are empirically specified as:

$$\begin{aligned}\ell Y_1 = {} & \ell\pi_{10} + \pi_{11}\ell X_1 + \pi_{12}\ell X_2 + \pi_{13}\ell X_3 + \pi_{14}\ell X_4 + \pi_{15}\ell X_5 \\ & + \pi_{16}\ell X_6 + \pi_{170}\ell X_{70} + \pi_{171}\ell X_{71} + \pi_{172}\ell X_{72} + \\ & \pi_{18}\ell X_8 + e_1 \end{aligned} \tag{18}$$

$$\begin{aligned}\ell Y_2 = {} & \ell\pi_{20} + \pi_{21}\ell X_1 + \pi_{22}\ell X_2 + \pi_{23}\ell X_3 + \pi_{24}\ell X_4 + \pi_{25}\ell X_5 \\ & + \pi_{26}\ell X_6 + \pi_{270}\ell X_{70} + \pi_{271}\ell X_{71} + \pi_{272}\ell X_{72} + \\ & \pi_{28}\ell X_8 + e_2 \end{aligned} \tag{19}$$

And the composite output production function for the simultaneous rice-fish culture production can be estimated as:

$$\begin{aligned}\ell Q = {} & \ell\pi_0 + \pi_1\ell X_1 + \pi_2\ell X_2 + \pi_3\ell X_3 + \pi_4\ell X_4 + \pi_5\ell X_5 + \\ & \pi_6\ell X_6 + \pi_{70}\ell X_{70} + \pi_{71}\ell X_{71} + \pi_{72}\ell X_{72} + \pi_8\ell X_8 + \epsilon \end{aligned} \tag{20}$$

The variables Y_i's and X_i's in equations 18, 19 and 20 are defined as the above, since they are the same variables specified in the structural form equations. The π's are the technical coefficients to be estimated. The Q which represents composite output is defined as $\sum_{i=1}^{2} P_{yi}Y_i$ - the sum of the products of P_{yi} (price) and Y_i (total product) of outputs, i = 1 and 2 which is rice and fish, respectively. The output prices are assumed fixed at the particular levels, and in practice, the average prices for each of the output are used as the individual components output weights in the composite output estimation.

III.6.2 Estimation Procedure

The parameters of the individual components output (Eq. 18 and 19) and the composite output (Eq. 20) production functions can be directly estimated through ordinary least squares (OLS) regression procedure. The procedure assumes that the independent variables (X's) are nonstochastic, the error term has zero expected mean value and constant variance for all observations, errors corresponding to different observations are uncorrelated and the error te m is normally distributed. The OLS regression procedure is equivalent to searching for parameter estimates which minimizes the residual (or error) sum of squares, and thus, the estimated parameters are generally consistent and unbiased (Pindyck, R.S. and R.L. Rubinf eld, 1981; Johnston, J. 1972; Rao, P. and R.L. Miller, 1971; etc.). The computational procedures for an OLS regression is normally presented in detail in various econometric texts particularly those mentioned above and therefore shall not be repeated here.

The system of structural equations (Eq.'s 16 and 17) specified for simultaneous rice-fish production system is an overidentified structural model. The number of excluded predetermined variables is greater than the number of included (endogenous) variables, and the number of unknown α_i's in each of the equations is less than the number of equations in the system. For the overidentified case, it is suggested by many econometric texts (Pindyck, R.S. and D.L. Rubinfeld, 1981, pp. 319-353; Johnston, J. 1972, pp. 376-409; etc.) that the two stage least squares (2SLS) regression is an appropriate estimation procedure. The 2SLS method uses all the information available in the equation system (Eq. 16 and 17) to obtain unique structural parameter estimates.

In matrix notation, the 2SLS estimation can be done as follows:

Let the system of equation 16 and 17 be rewritten as:

$$y_1 = Y_1\alpha_1 + X_1\beta_1 + \epsilon_1 \tag{21}$$

where:

y_1 = N x 1 vector of observations on endogenous variable with coefficient of 1 in the first equation

Y_1 = N x (G-1) matrix of observations on endogenous variables included in first equation (on right-hand) side

α_1 = (G-1) x 1 vector of coefficients for included endogenous variables

X_1 = N x K_0 matrix of observations on included predetermined variables

β_1 = K_0 x 1 vector of predetermined variable coefficients

ϵ_1 = N x 1 vector of disturbances associated with first equation

The application of OLS procedure to Eq. 21 will yield inconsistent parameter estimates due to the fact that Y_1 and ϵ_1 are (asympotically) correlated. 2SLS yields consistent estimates by purging Y_1 of the component which is correlated with ϵ_1 and then running the new regression using OLS.

The first step will involve regressing each of the endogenous variables on the entire set of predetermined variables in the model. This involves estimation of Eq. 18 and Eq. 19 which are specified as the individual components output production functions for rice and fish, respectively. Furthermore, this is also equivalent to estimating the reduced form equations associated with the G-1 right-hand endogenous variables. In matrix notation, Eqs. 18 and 19 could be stated as:

$$Y_1 = X\pi + \epsilon \tag{22}$$

The resulting first-stage estimator is:

$$\hat{\pi} = (X'X)^{-1} X'Y_1 \tag{22a}$$

from which calculate the fitted values for Y_1

$$\hat{Y}_1 = X\hat{\pi} \tag{22b}$$

In the second stage, the fitted values of $\hat{Y}_1$ endogenous variables are used in place of the observed value of Y_1. Thus, the second stage model will be

$$y_1 = \hat{Y}_1\alpha_1 + X_1\beta_1 + \epsilon_1 \tag{23}$$

and through OLS procedure of y_1 on $\hat{Y}_1$ and X_1 would yield the 2SLS parameter estimates of α_1 and β_1. In matrix notation, the second-stage estimates are

$$\begin{bmatrix} \hat{\alpha}_1 \\ \hat{\beta}_1 \end{bmatrix} = \left\{[\hat{Y}_1X_1]'[\hat{Y}_1X_1]\right\}^{-1} \left[\hat{Y}_1X_1\right]' y_1 \tag{24}$$

The references cited above have presented a theoretical proof that the structural parameters estimated through 2SLS procedure, are consistent and unbiased estimators. For statistical purposes the variances of the parameters are estimated as:

$$\text{Var}\begin{bmatrix}\hat{\alpha}_1\\ \hat{\beta}_1\end{bmatrix} = \sigma^2\left\{\begin{bmatrix}\hat{Y}_1 X_1\end{bmatrix}'\begin{bmatrix}Y_1 X_1\end{bmatrix}\right\}^{-1} \tag{25}$$

In practice, σ^2 is estimated by

$$s^2 = \frac{\bar{\epsilon}_1' \hat{\epsilon}_1}{N - [(G - 1) + k_o]} \tag{25a}$$

where:

$$\hat{\epsilon}_1 = y_1 - Y_1\hat{\alpha}_1 - X_1\hat{\beta}_1 \tag{26}$$

III.7 Concluding Comments

Several quantitative models for multi-products technology have been identified. These include the "flexible functional forms" developed by Diewert (1971) and Christensen, et.al., (1973) and Mundlak's

(1964) transcendental production function model. These models are characterized by the following: (a) both the transcendental production function model and the flexible functional forms would require a combination of "time series" and,"cross-sectional" data on the technical input-outputs of the multi-product firms being modelled, and likewise the models assume input allocation among output of the firm which is not the case of simultaneous rice-fish production; (b) the Diewert and Christensen, et.al., models would involve the estimation of the translog cost function for the multi-product firm, and consequently, lead to output supply and factor demand analysis. Hence, the actual technical input-output relationships in MOPS are not directly known; and finally, (c) the above mentioned models would involve complex mathematical formulation and thus, requires intricate estimation procedure, making them unattractive for applied analyses. Furthermore, this research is just beginning to establish estimates of the technical input-output coefficients for simultaneous rice-fish culture production. For these reasons the above mentioned models are not considered in the applied simultaneous rice-fish culture production function analyses.

Finally, it is relevant to make distinctions between a "frontier" production function and an "average" production function that is estimated using the OLS method. The frontier production function represents the most technically efficient input-output combinations since it is derived by connecting the points of maximum total product for each level of input. The estimated production function on the other hand, is an industry average production function because it is derived by the OLS method that takes into account all observed input-output combinations, not just the most technically efficient (Garrod and Aslam, 1977). The estimated production function would portray the input-output relationships of the average farm in the industry. The pertinent production function for any one particular farm may conceptually be obtained from the industry average production functions, in terms of the farm's ability to implement optimal values of parameters in the industry (Aigner and Chu, 1968).

Chapter IV

ECONOMICS OF SIMULTANEOUS RICE-FISH CULTURE TECHNOLOGY

Economic analyses beyond feasibility studies and costs-returns analysis on any of the rotational and simultaneous rice-fish culture technologies in the Philippines are only just beginning (Tagarino, 1983a). While field research has been conducted and has led to technology development, estimates of the input-output technical coefficients are yet to be established. A more rigorous analysis of the production system is necessary for generation of more useful conclusions and recommendations. This chapter establishes estimates of the simultaneous rice-fish culture input-output technical coefficients using cross sectional (actual farm) survey data, and predicts the expected levels of composite output and individual components output, and the marginal productivity of inputs for a given input application in a simultaneous rice-fish culture system.

The chapter also expounds on the implications of the estimated technical input-output relationships in the context of multi-output production technology, and attempts to determine the optimum operating conditions for simultaneous rice-fish culture. It also includes the results of cost-return analysis of the production system at the farm level. The final section of the chapter discusses the implications of the empirical results for policy and technological decision making.

IV.1 Sources of Data and the Study Area

The data used in this chapter were obtained directly from rice-fish culture operators through personal interviews. The interviews were undertaken with the use of a pre-tested survey questionnaire. The information that was gathered concerns the rice-fish culture business operations during the 1982 wet season, and the 1983 dry season months of July to December and January to June, respectively. It includes rice-fish production data, area harvested, inputs used, output and input prices, labor used, etc. From the survey there were 75 usable questionnaires. No strict sampling procedure was followed in the selection of the sample respondents. A census type (search and interview) of sample identification and data collection was adopted.[13] An attempt has been made to maximize the sample of rice-fish culture farms. The surveyed rice-fish culture farms with zero fish harvest were excluded. About fifty-five percent (or 41) of the total sample are in the Central Luzon area and the remaining 45 percent (or 34) are in the Bicol Region (Table IV.1).

Not all of the sample farmers were able to practice the rice-fish culture technology in both the wet and dry seasons, 1982-83 which was set as the reference period of the study. The sample rice-fish culture operators generally do not keep farm records. Thus, the data that were obtained and analyzed in this chapter were based on farmers' memory.

The study area included the provinces of Nueva Ecija, Tarlac, Pampanga, and Bulacan in Central Luzon and the provinces of Camarines Sur and Albay in the Bicol Region, Philippines. Refer to the Philippine map (Figure IV.1) for the specific locations of these areas. The Central Luzon sample provinces are nearly land-locked with only the province of Bulacan having a coastal zone. The Bicol Region is a penninsula,

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13/ A complete list, or exact number of rice-fish culture farms was not available at the time the field survey was implemented.

Table IV.1 Population and number of sample rice-fish culture operators, total farm size and area of rice-fish culture paddy operated by the survey samples in Central Luzon and Bicol Region, Philippines, 1982-83.

Particular	Study Areas: Central Luzon	Study Areas: Bicol Region	All Study Areas
Number of Operators[1/]	59	157	216
Sample Size:			
Number	41	34	75
Percent[2/]	69.50	21.66	34.70
Ave. Total Farm Size (ha)	3.24 (2.29)	1.84 (1.49)	2.61 (1.93)
Ave. Area of Rice-Fish Culture Per Sample Farm (ha)	0.59 (0.89)	0.41 (0.45)	0.53 (0.81)
Percent Total Farm Size Devoted to R-F Culture	18.21	22.28	19.54
Number of Sample Farms Harvested During:			
Wet Season, 1982	38	24	62
Dry Season, 1983	18	23	41
TOTAL	56	47	103

NOTE: Figures within parenthesis are the standard deviations.

1/ Based from the National Food and Agriculture Council, Ministry of Agriculture (NFAC-MA). Rice-Fish Culture Program Accomplishment Report for 1981. NFAC-MA, Dilman, Q.C. Philippines. (unpublished mimeo.)

2/ Proportion of the number of sample with respect to the reported number of rice-fish culture farm operators.

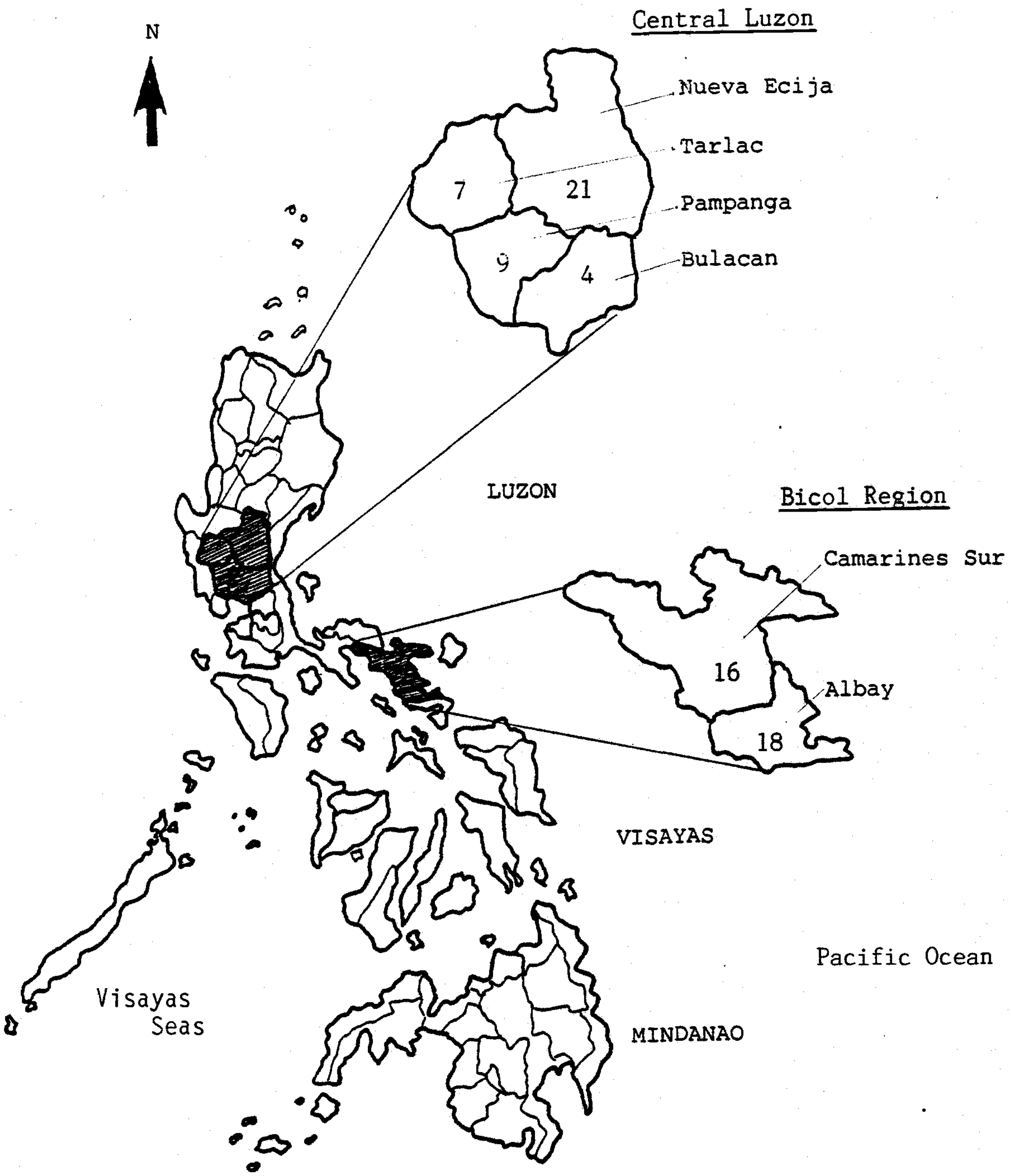

Figure IV.1 Map of the Philippines showing the locations of the study areas.

meaning that the two sample provinces of Camarines Sur and Albay are nearly enclosed by the Pacific Ocean on the eastern side and the Visayas Seas in the Southwest. This makes marine fisheries an important industry in the Bicol area.

Distinct wet and dry weather during the months of July to December and January to June, respectively, are the pronounced climatic conditions in Central Luzon. The Bicol Region has no pronounced wet and dry climatic condition with precipitation sometimes evenly distributed thoughout the year.

In general, the study areas are mainly agricultural with rice production as the major industry. Slightly less than 3.0 hectares is the average farm size (International Bank for Reconstruction and Development (IBRD), 1976). The farm field conditions where the sample farmers' operate are mostly irrigated lowland areas, with either the government or private-communally established gravity irrigation systems as sources of irrigation water supply.

IV.2 Production Techniques and Net Returns

Rice farming is the main occupation of most farmers in the selected study areas. The total farm size operated by an average farmer is 2.61 ha. for all the study areas. Only about 20 percent (or 0.53 ha.) of the total farm area has been devoted to the rice-fish culture production system (Table IV.1). Such a small proportion of the farm area having been devoted to rice-fish culture might indicate that the farmers are still in the process of technology adoption. Hence, no one sample farmer interviewed reported to have used his entire field for rice-fish culture production.

The rice-fish culture paddies are generally close to the source of irrigation water. In an earlier study (Tagarino,1983a), it was estimated that it would cost ₱2000.45 to develop a hectare of ordinary rice paddy into rice-fish culture paddy (Table II.4). The cost includes trench construction, increasing dike heights, installing water control devices and wire screens, and materials such as wire screens, and fencing materials which are installed around the rice-fish culture paddies. Fencing prevents entry of predators and fish escapements. Cost also includes the imputed value of the unpaid operator and family labor which constitute more than fifty percent of the total.

IV 2.1 Cultural and Management Practices

The recommended technological package for simultaneous rice-fish culture described in Table II.6 was not strictly followed by most of the sample farmers. For instance, none reported to have applied the recommended 5.0 kgs. zinc sulfate to their rice-fish culture paddies. Basal and top dressing methods of inorganic fertilizer application were generally followed, but the operators did not strictly use the recommended quantity and quality of fertilizer. Most of the interviewed farmers indicated that they had grown HYV rice but not the pest resistant varities, such as the IR-32 and IR-42. Technical inputs application in simultaneous rice-fish culture as surveyed is shown in Table IV.6 for the wet-dry seasons average in all study areas; and in Appendix Table 6 for each specific study area and season. One of the possible reasons why farmers were not able to strictly follow the recommended technological package, and use the recommended quantity and quality of technical inputs, is the non-availability of these technical inputs. This is particularly true of the recommended application of zinc sulfate which is not locally marketed. The high cost of the technical inputs is also another possible economic reason.

The ordinary wet-bed and dapog methods of growing palay seedlings were practiced by most of the sample operators while others directly seeded their main rice-fish culture paddies. Palay seedlings were grown at an average age of 25 to 30 days and transplanted at average distances of 20 cm. by 30 cm. between hills of 2 to 4 seedlings per hill. Generally, the palay seedlings were transplanted in the main paddies just after the final harrowing had been done. Basal application of fertilizer was done during the final harrowing of the paddies, allowing proper distribution and incorporation of the fertilizer materials into the paddy soil.

Stocking the rice-fish culture paddies with fingerlings was done an average of 5 to 7 days after the palay seedlings were transplanted. Some of the operators indicated that their fish stocking operation was carried out as soon as the water in the main rice-fish culture paddies cleared. Those operators that were assisted by extension agents, followed an intricate stocking procedure. The procedure involves a process of acclimatization of the fingerlings to reduce unnecessary stress due to difference in water salinity and temperature. For those operators that have established breeding and nursery ponds, stocking only involves the opening and removal of the water gates' wire screens of the breeding ponds and allowing the fish to swim into the main rice-fish paddies.

During the growing period of fish and rice crops, the necessary management and cultural activities include: insect pest control through the spraying of appropriate pesticides; the regular supplemental feeding of the fish stocks; the top dressing application of inorganic fertilizer; the maintenance of adequate water supply and the regular checking and repair of the paddy dikes to prevent the stocked fish from escaping. These activities required little man power and were normally done by the operator and a member of his family.

Harvesting operations were undertaken with the help of hired labor. In general, fish stocks were harvested prior to the harvesting of the rice crops. This is usually done by draining the paddies and allowing the fish to settle in trenches. The size of harvested fish varied from farm to farm, and is generally, dependent upon the size of fingerlings stocked. Some of those farmers maintaining breeding/nursery ponds indicated that harvested fish of small size were put back into the breeding/nursery ponds. The average fish and rice production per hectare during the 1982-1983 croppings are presented in Table IV.2 The average rice and fish harvest under farm field conditions was not significantly different from production obtained under experimental field conditions. For further comparison see Appendix Table 3.

The cultural management practices for simultaneous rice-fish culture production are, in general similar to pure rice culture practices except for the addition of some specific activities that became necessary due to the inclusion of fish in the production system.

IV 2.2 Costs and Returns of Production

Several "ex ante" economic assessments (Sevilleja, 1979; Dela Cruz, 1980; etc.), suggested that simultaneous rice-fish culture is a profitable venture which the farmers should adopt.[14]/ Costs and returns analysis using actual farm data was undertaken to verify whether the "ex ante" economic assessment holds true at the farm field conditions. As surveyed,

[14]/ Ex ante economic assessment in the sense that the data used in the analysis are based on laboratory (field experiment) results.

Table IV.2 Average area harvested and level of production of simultaneous rice-fish culture farms as surveyed in Central Luzon and Bicol Region, Philippines, 1982-83.

Particulars	Study Area: Central Luzon	Study Area: Bicol Region	All Study Areas
Wet Season, 1982			
Sample Farms Harvested	38	24	62
Area Harvested/farm (ha)	0.61	0.36	0.51
	(0.92)	(0.39)	(0.71)
Level of Production/hectare:			
Rice (cav.)	76.29	98.92	82.96
	(133.23)	(104.17)	(126.14)
Fish (kgs.)	133.15	287.64	176.20
	(176.36)	(439.83)	(249.47)
Dry Season, 1983			
Sample Farms Harvested	18	23	41
Area Harvested/farm (ha)	0.60	0.49	0.54
	(1.17)	(0.64)	(0.88)
Level of Production/hectare:			
Rice (cav.)	103.32	80.94	92.06
	(245.93)	(89.16)	(167.46)
Fish (kgs.)	93.27	211.45	152.17
	(93.48)	(235.10)	(164.07)
Wet-Dry Seasons Average, 1982-83			
Sample Farms Harvested	56	47	103
Area Harvested/farm (ha)	0.61	0.44	0.53
	(0.99)	(0.52)	(0.78)
Level of Production/hectare:			
Rice (cav.)	82.80	89.40	85.30
	(173.69)	(91.41)	(143.92)
Fish (kgs)	119.69	246.62	163.85
	(154.66)	(311.66)	(215.04)

NOTE: A cavan (cav.) of rice is equal to 50.0 kilograms (kgs.). Fish grown and harvested were generally composed of tilapia species such as the T. nilotica and T. mossambica species. Specific statistics on fish yield by species were not obtained.

Figures in parenthesis are the standard deviations.

the average per hectare cost and return of simultaneous rice-fish culture production according to cropping seasons in Central Luzon and Bicol Region, are presented in Table IV.3. The results confirm the economic profitability of the production system.

The average per hectare gross returns of production were estimated to vary according to location and season. It ranges from ₱7,200.00 to more than ₱9,600.00 per hectare. The variations in gross returns were not mainly associated with the differences in the level of production, but also attributed to the differences in the actual prices received by the farmers for the products. The harvested rice accounted for a major portion of the gross returns, however the harvested fish contributed at least 20 and as much as 40 percent of the gross returns. This relatively small contribution of fish to the gross return, may support the implicit suggestion of Singh, V.P. (1980) that fish is only a supplementary crop and therefore, it should adapt to the cultural requirements of rice, which is considered the main crop.

Averages and variations of product and input prices are shown in Table IV.4 and Appendix Table 4. The average price of fish in Bicol Region is much

Table IV.3 Average per hectare costs and returns of simultaneous rice-fish culture production as surveyed in Central Luzon and Bicol Region, Philippines, 1982-83.

Particulars	Study Areas Central Luzon (in pesos)	Study Areas Bicol Region (in pesos)	All Study Areas
Wet Season, 1982			
Returns	7202.66	9290.56	7818.72
Rice	5394.74	6491.00	5728.41
Fish	1807.92	2799.56	2090.31
Costs[a/]	3387.57	4266.81	3649.23
Net Return	3815.09	5023.75	4169.49
Dry Season, 1983			
Returns	9615.25	8366.04	8948.94
Rice	8415.98	6027.31	7173.44
Fish	1199.27	2338.73	1775.50
Costs[a/]	2692.03	3971.69	3334.91
Net Returns	6923.22	4394.35	5614.03
Wet-Dry Seasons Average, 1982-83			
Returns	7927.48	8440.79	8158.23
Rice	6321.51	5996.61	6227.38
Fish	1605.97	2444.18	1930.85
Costs[a/]	3149.82	3947.11	3466.26
Net Returns	4777.66	4493.68	4691.97

[a/] Does not include the opportunity cost of land i.e., land rent, capital cost and/or depreciation charges on capital assets such as farm tools and equipment. The itemized inputs' share in production are presented in Table IV.4 and Appendix Table 4 for the wet-dry seasons average, and the wet season, 1982 and dry season, 1983, respectively.

NOTE: Exchange Rate = US $1.00 equals ₱ 8.00 and ₱ 11.00 on the average for the wet season, 1982 and dry season, 1983, respectively.

Table IV. 4 Average prices of output and input of simultaneous rice-fish culture production as surveyed in Central Luzon and Bicol Region, Philippines, wet-dry season average, 1982-83.

Particulars	Symbol	Study Area: Central Luzon	Study Area: Bicol Region	All Study Areas
		(in Pesos Per Unit)		
Output				
Rice (cav.)	P_{y1}	70.12 (22.46)	69.91 (16.87)	70.03 (19.94)
Fish (kgs.)	P_{y2}	12.95 (2.25)	9.84 (2.18)	11.54 (2.22)
Inputs				
Palay seeds (kgs.)	P_{x2}	1.58 (0.45)	1.71 (0.63)	1.64 (0.53)
Fingerlings (pcs.)	P_{x3}	0.21 (0.09)	0.18 (0.07)	0.19 (0.08)
Inorganic fertilizer(bags)	P_{x4}	116.76 (23.09)	121.41 (20.89)	118.86 (22.09)
Labor Services (man-days)	P_{x7}	18.56 (5.85)	15.84 (3.40)	17.33 (4.74)

Note: Figures within parenthesis are the standard deviations.

Exchange Rate = US $1.00 = ₱ 9.50 on the average for 1982-83.

lower than in Central Luzon. The Bicol Region is a peninsula and therefore, the comparatively lower price of fresh water fish in this area is due to marine fisheries production. Generally, input costs (prices) vary from farm to farm. Such differences in the input prices is due to many economic reasons. Input price variation would influence producer's input utilization decisions and consequently affects the cost of production, and finally, the total product.

The itemized shares of inputs in simultaneous rice-fish production costs are shown in Table IV.5 and Appendix Table 5. The average production cost per hectare ranges from ₱2,600 to more than ₱4,000 in different study areas. These cost estimates do not include the opportunity cost of land, and capital cost/charges for depreciation of farm tools, equipments, etc. Fingerlings accounted for the largest share in the total material input cost. Thus, the question of efficiency in the use of fingerlings is an important aspect of decision-making in a simultaneous rice-fish culture system.

The information provided in Table IV.3 indicates that growing fish simultaneously with rice would be profitable. The net returns to production are positive, ranging from ₱3,800 to as much as ₱6,923

Table IV.5 Itemized inputs' share in simulteanous rice-fish culture production cost (pesos/ha.) as surveyed in Central Luzon and Bicol Region, Philippines, wet-dry seasons average, 1982-83.

Input Items	Study Area				All Study Areas	
	Central Luzon		Bicol Region			
	Cost	%	Cost	%	Cost	%
1. Material Inputs	(1567.85)	(49.78)	(2323.02)	(58.85)	(1860.15)	(53.66)
a. Palay seeds	155.20	4.94	164.25	4.16	159.32	4.60
b. Fingerlings	856.75	27.19	887.36	22.48	872.28	25.16
c. Inorganic Fert.	298.26	9.47	814.71	20.64	494.30	14.26
d. Supplemental feeds	177.20	5.62	256.95	6.51	208.23	6.00
e. Pesticides	80.44	2.56	199.75	5.06	126.02	3.64
2. Labor Inputs	(1214.36)	(38.55)	(1268.95)	(32.15)	(1240.60)	(35.79)
a. Hired Labor	839.24	26.64	966.54	24.49	891.30	25.71
b. O & F labor	375.12	11.91	302.41	7.66	349.30	10.08
3. Miscellaneous operating cost[a/]	(367.61)	11.67	(355.14)	(9.00)	(365.51)	(10.55)
Total Production cost/ha.	3149.82	100.00	3947.11	100.00	3466.26	100.00

NOTE: Figures in parenthesis are sub-total of each input category.

a/ Includes all other costs and incidental operating expenses such as food served to farm workers, transportation expenses, etc.

per hectare for the different farms across the study area. While cost and return analysis indicates the success or failure of the farm business, the analysis does not provide information concerning the relative contribution of each of the various inputs to production. Furthermore, it does not indicate the efficiency of input utilization in production. Such information is very much needed in prodcution management decision-making. This makes it necessary that the involved production functions for the production system be efficiently estimated.

IV.3. Estimated Productions Functions for Simultaneous Rice-Fish Culture System

A Cobb-Douglas production function model was employed to estimate the relevant composite output and individual components output responses to input application, and to determine the structure of the production technology under average farm field conditions. The relevant production functions and structure of production were estimated on the per farm and per hectare specifications for the different study areas. An ordinary least squares (OLS) regression method under the time series processor package, TSP 35, of the Oregon State University Computer Center was used to estimate production functions.

The proposed analytical model for simultaneous rice-fish culture input-output relationships described in Section III.6 of Chapter III, was used with minor modifications in the variables specification. Accurately measured data on inputs and outputs are needed in the estimation of efficient production functions. Faulty data have normally been the source of poor fit and insignificant estimates. Recognizing the importance of accurate data, a discussion of the variables used in estimating the relevant production functions, and the problems of measurements are provided after presenting the assumptions in the study.

Assumptions of the production function models

The assumptions of the model relate to both the theory of the firm and regression analysis. The theory of the firm assumes that the rice-fish culture operator is a profit-maximizer and has perfect knowledge of input and output (products) prices. The product prices used in this analysis are fixed at a particular level (survey mean for each study area, and for all the study areas). They refer to the 1982-83 average price levels, as indicated in Table IV.4.

It is also assumed that no product of any kind is forthcoming if no inputs are applied. The inputs used in simultaneous rice-fish culture production are assumed to be homogenous and there are no qualitative differences among inputs available in each study area and across the two study areas. In other words, the data or the variables of interest are assumed to be measured without error.

Further, since the technology was only recently introduced, it is assumed that the sample farmers for this cross-sectional study, are well informed about the technology and have it well implemented during the reference period of this study, the 1982 wet season and the 1983 dry season.

Unbiased and minimum-variance estimates of the regression coefficients are obtained if certain least squares-multiple regression assumptions hold true (Heady and Dillon, 1961). These assumptions are applicable if the data, i.e., sample observations, are obtained through random sampling design. The random sampling method was not strictly used because it was impossible to construct an adequate sampling frame with the limited budget available. Also, the number of rice-fish culture farmers in the area was not known at the time data collection was completed, because farmers were still in the process of technology adoption. A census type (search and interview) of sample identification and data collection was employed. Because of this it is felt that the assumption of ordinary least squares regressions mentioned above have not been seriously violated.

IV.3.1 Explanatory Variables and Expected Technical Relationships of Input-Output of Production

The explanatory variables or inputs are sometimes known as target variables because they are subject to influence by the decision makers (producer or policy makers). It was hypothesized that the variability of production, viewed in terms of pesos for the composite output, and in terms of cavans of rice, and kilograms of fish for the individual components output, of simultaneous rice-fish culture are explained by the variables ennumerated in Table IV.6 and Appendix Table 6 along with their respective survey means. With reference to the nature of the production technology, it was further hypothesized that there is product-product interdependence -- that is the variability in any particular output (say, fish) is also explained by the level of of the other output (rice) in the production system. Furthermore, it was hypothesized

Table IV.6 Survey means of the explanatory variables of simultaneous rice-fish culture production in Central Luzon and Bicol Region, Philippines, wet-dry season average, 1982-83.

Variables	Symbol	Study Area: Central Luzon	Study Area: Bicol Region	All Study Areas
Farms report.	n	56	47	103
Area Harvested (ha.)	X_1	0.61 (0.99)	0.44 (0.52)	0.53 (0.81)
Palay seeds (kgs.)	X_2	54.02 (98.67)	39.11 (57.48)	47.22 (82.45)
Fingerlings (pcs.)	X_3	2602.11 (3335.68)	1992.02 (1698.35)	2323.72 (2719.15)
Inorganic Fert. (bags)	X_4	1.55 (1.88)	2.89 (3.75)	2.16 (2.95)
Supplemental feeds(pesos)	X_5	108.09 (170.69)	113.06 (265.11)	110.36 (217.75)
Pesticides (pesos)	X_6	49.07 (72.03)	87.89 (94.06)	66.79 (84.65)
Labor inputs (man-days)	X_7	41.99 (46.22)	36.42 (35.66)	39.45 (41.63)
Average size of stocked fingerlings (cm.)	X_8	2.29 (1.29)	2.19 (1.24)	2.24 (1.26)

NOTE: Figures within parenthesis are the standard deviations.

that while the variability of a particular output is influenced by inputs specific to that output, it is also expected to be influenced by inputs specific to other outputs.

Unlike other functional forms, the Cobb-Douglas form does not allow the technical coefficient signs to be specified prior to estimation. The marginal products, however, are distinct as the only technical coefficients (parameters) which are expected to have either positive or negative signs. The expected technical coefficient signs of the relevant production functions for simultaneous rice-fish culture are summarized in Table IV.7. The variables included in the production function estimates are described as follows:

<u>Total Product: Individual Components, Rice (Y_1) - Fish (Y_2) Output and Composite Output (Q)</u>. The total production for each of the individual components output, Y_1 and Y_2, refers to the quantity of rice (in cavans) and fish (in kilograms) harvested during the reference period of the study. Composite output (Q) is the value aggregate of harvested rice and fish. The value aggregation procedure that was adopted is discussed in Chapter III. The output prices that were

Table IV.7 Expected signs of the technical coefficients of the input-output relationships in simultaneous rice-fish culture production.

Explanatory Variables		Structural Form Rice (Y_1)	Structural Form Fish (Y_2)	Reduced Form Rice (Y_1)	Reduced Form Fish (Y_2)	Composite Output (Q)
Land (area harvested)	X_1	+	+	+	+	+
Palay seeds	X_2	+		+	-	+
Fingerlings	X_3		+	+	+	+
Inorganic fertilizer	X_4	+	+	+	+	+
Supplemental feeds	X_5		+	+	+	+
Pesticides	X_6	+		+	-	-
Labor inputs	X_7	+	+	+	+	+
Size of stocked fingerlings	X_8		+	-	+	+
Rice production	$\hat{Y}_1$		+			
Fish production	$\hat{Y}_2$	+				

used as the individual output weights in the aggregation were constant at their respective survey means, which are indicated in Table IV.4.

Other products such as shrimps, frogs, snails, mudfish, etc., have been excluded from the total product although the relative values of these products might be quite significant. These were excluded because their occurrence is not widespread. The total product includes the rice and fish that were consumed at home, given away as gifts, and the harvesters' shares. It also includes the harvested fish stocks that were retained as breeder/seed stock for the succeeding cropping. The total product of the individual components output as well as the composite output, therefore, reflects all rice and fish harvested from the rice-fish culture paddies, marketed as well as non-marketed.

Area harvested (X_1). This refers to the total land space devoted to the production of both fish and rice crops. A majority of the sample farmer respondents have only devoted a small portion (about 18 to 22%) of their respective total farm land to rice-fish culture. No one sample farmer reported using his entire rice fields for rice-fish culture production. On the average, the area used for rice-fish culture was only 0.53 ha. Farmers can still expand their rice-fish culture operations to the total area of their irrigated rice fields. Thus, at the farm level, the space devoted to rice-fish culture has not yet reached a limit at this stage of technology development. For this reason, X_1 has been considered as one of the important explanatory variables of simultaneous rice-fish culture production.

Palay seeds (X_2). The total quantity of palay seeds in (kilograms) used in production varies considerably from farm to farm. The variation can be associated with the method of seeding, growing palay seedlings, and transplanting distances of seedlings. Some of the sample farmers directly seeded their main rice-fish culture paddies, a method which would normally require a greater amount of palay seeds per hectare, and the rice plants were grown at random in the paddies. Most of the sample farmers did not directly seed their main rice-fish culture paddies. Instead, they grew palay seedlings through wet-bed or dapog methods, and then transplanted the grown-up seedlings in the main rice-fish culture paddies.

These methods generally would require a smaller quantity of palay seeds than the direct seeding method per hectare. The palay seeds used by the farmers were either produced or purchased from seed growers within the locality, as well as outside. The cost of palay seeds varied depending on the variety.

Fingerlings (X_3). No one sample farmer reported to have grown fish other than tilapia species. Very few of them were able to indicate the exact species of tilapia fish which they grew and harvested from their respective rice-fish culture paddies. It is believed, however, that a combination of tilapia nilotica and tilapia mossambica species were predominantly grown by the sample farmers, since these were the tilipia species distributed by the rice-fish culture extension program agents.

The rate at which the main rice-fish culture paddies were stocked with tilapia fingerlings varies from farm to farm and to a small degree from season to season. The mean stocking rate of fingerlings as surveyed was 2,323 pieces per farm (or about 6,000 pieces per hectare) for the wet-dry seasons average in all study areas (Table IV.6 and Appendix Table 6). This surveyed mean stocking density is greater than the recommended level of 5,000 fingerlings per hectare (Table II.6).

Obviously, X_3 is a basic and specific input of fish production and the rate at which it is being used can directly influence the total quantity of fish production (Y_2). It was also hypothesized that X_3 can also influence the total quantity of rice production (Y_2), considering that the stocked fish can serve as a biological control of the insect pest that attack rice plants, and also improve soil fertility by facilitating in the decomposition of organic matters and micro-plants in the paddy (Schucter, et. al., 1955; Hora and Pillay, 1962, etc.). From the other point of view, it was also hypothesized that rice production (Y_1) may negatively be affected by increased stocking rates of X_3, taking into consideration that the stocked fish will also disturb or even feed on the roots of rice plants (Ardiwinata, 1957).

Inorganic fertilizer (X_4). As surveyed, farmers fertilized their rice-fish culture paddies with more than 4.0 bags (or 200 kgs.) of commercially available inorganic fertilizer per hectare for the wet-dry seasons average in all study areas (Table IV.6). The actual quantity of inorganic fertilization varied considerably from farm to farm as well as from season to season as indicated in Appendix Table 6.

Inorganic fertilizer can either positively or negatively affect the total quantity of production of both Y_1 and Y_2, depending upon the level of application. The effect of fertilizer application on fish stocks grown in the paddy is similar to that of pasture fertilization. Fertilizer application improves soil fertility not only for rice crops but also for the increasing growth and production of phytoplanktons, which in turn could be used as feed for fish stocks in the paddy (Hickling, 1962; Mortimer, 1954; etc.). The benefits of inorganic fertilization in rice-fish culture would depend on the quantity and quality of the fertilizer materials. The application of too much inorganic fertilizer might cause excessive growth of rice plants, which would result in poor harvests of rice grains. It might also increase water salinity that could cause fish mortality or if the fish withstand the changing water quality their growth might become stunted (Dela Cruz, 1978).

Supplemental feeds (X_5). A rice paddy is similar to some extent to a freshwater lake that has maximum carrying capacity to support the normal growth and production of a certain density of fish stocks. Thus, supplemental feeding would become necessary if the paddy were to be stocked beyond its maximum carrying capacity.

Although supplemental feeding was not explicitly included in the technological package (Table II.6) that was introduced to farmers, it was observed that they are applying feeds of various kinds. A mixture of rice bran and dried chicken manure was the most commonly used supplemental feed. Some of the sample farmers reported having used fresh "kang-kong", and ipil-ipil leaves, while the others even used kitchen left-overs as the supplemental feeds of the stocked fish. Several of the interviewed farmers in the province of Albay, Bicol Region, reported using azolla, "micro-fern plants", in combination with rice bran as supplemental feeds. Azolla is an indigenous resource in the paddy of some areas of the country. The exploitation, i.e., utilization, of the resource may be attributed to the government's National Azolla Action program (UPLB-MA, 1983).

The relatively limited number of sample observations along with the wide differences in the units of measurement and kinds of supplemental feeds, makes it not worthwhile to use the actual physical units of supplemental feeds in the estimation of production functions. Instead, the variable was specified in monetary terms, i.e., the total imputed peso value of the different kinds of feeds. As surveyed, the imputed peso values of supplemental feeds vary considerably among the farms, as reflected by the relatively large standard deviation of the mean observed value of the variable.

Research information on the subject of the supplemental feeding of fish in simultaneous rice-fish culture is still limited and hence not conclusive (Appendix Table 2). Based on the available research results (Appendix Table 7), however, it was hypothesized that supplemental feeds application would positively affect the level of production of both Y_2 and Y_1.

Pesticides (X_6). Many pesticides used in rice production such as endrin, dieldrin, thiodan (endosulfan), DDT and Gamma-BHC, are toxic to fish (Grist , 1965). The intensive use of pesticides has caused a rapid decrease in the production of fish in the paddy fields of Malaysia (Tan, et. al., 1973). Fish mortalities arising from insecticide usage have resulted in significant financial losses to farmers in Indonesia (Saanin, 1960).

It was originally believed that the use of pesticides is being discouraged in simultaneous rice-fish culture. The survey, however, showed that the farmers were using various types and different intensities of application of pesticides. The pesticides that were used by farmers vary not only in physical forms, i.e., liquid, powder or granulated, but also in terms of the level of concentration of the active ingredients of the pesticide materials. In general, the highly concentrated pesticides, which are normally more effective in killing insects, as well as fish would command much higher prices. Thus, the use of monetary units, in terms of the imputed peso value of the pesticides, in the estimation of the relevant production functions, is more reasonable than the physical units of pesticides. The use of the physical units of pesticides in the estimation of production function might not be at all workable because of wide differences in the measurement units of this variable. As surveyed, the imputed peso value of pesticides that were used in rice-fish culture production vary considerably from farm to farm with a mean value of ₱66.79 per farm for the wet-dry seasons average in all study areas.

Pesticides are an output-specific but non-basic input of rice production and therefore, applying it in the rice-fish culture system is expected to have a significant positive influence on rice production. Pesticides are generally toxic to fish and therefore it is expected to negatively affect fish production. Overall, it is hypothesized that the application of pesticides would do more harm than good in the simultaneous rice-fish culture system, i.e., it is expected that the relative loss on fish prodution outweights relative gains in rice production of the simultaneous culture system.

Labor inputs (X_7). This is the quantity of man-power services, in man-days, that has been used in the various cultural and management requirments/activities of rice-fish culture production. Labor inputs includes the services in seedbed preparation, preparation of the main rice-fish culture paddies, transplanting/direct seeding, fertilization, and many activities in production until the rice and fish products are harvested. The amount of labor inputs varies greatly from farm to farm. As surveyed, the mean total labor inputs was 39.45 man-days per farm for the wet-dry seasons average in all the study areas. This includes hired labor and services provided by the operator and his family members.

The various cultural and management activities, i.e., labor inputs, could be delineated into "output-sepcific" and "non-output-specific" inputs, however, this has not been done in this empirical analysis because of some limitations in the collection of more disaggregated labor input data. The limitations have necessitated the respecification of the disaggregated labor input variables, namely X_{71}, X_{70}, and X_{72}, the rice-specific, non-output-specific, and fish-specific, labor inputs into an aggregated labor input variable, X_7, of the simultaneous rice-fish culture production functions.

<u>Average size of stocked fingerlings (X_8)</u>. The decision to consider this variable in the estimation of production functions was made in view of the relatively short culture or growth period for the fish stocked. It is assumed that the larger the size of the stocked fingerlings the greater the quantity of the fish harvest. Field experiment results (Appendix Table 8) support this assumption but it does not give clear information as to whether rice production is positively or negatively affected by the size of stocked fingerlings.

In general the farmers were unable to indicate the exact size (in cm.) or weight (in grams) of the fingerlings that they had stocked in their rice-fish culture paddies. A system of obtaining more or less accurate data by requesting them to compare the sizes of fingerlings with ipil-ipil, camatchile and acacia leaves was used. On the average, the sizes of fingerlings that were stocked from farm to farm range from less than 1.0 cm. to more than 3.0 cm. with a survey mean of 2.24 cm. for the wet-dry seasons average in all study areas.

Excluded variables

Several explanatory variables of production were not included in the model primarily because of the limitations in obtaining technical data, and also, their occurrence and use is not widespread. These include water depth, temperature and salinity, physical layout of the rice-fish paddies and trenches design, rainfall data and other environmental factors that in one way or the other influence the level of production.

The physical layout of the rice-fish paddies and the design of the trenches can be important explanatory variables of production. Hence, the greater the number of paddy plots per hectare, the greater the area occupied by dikes and trenches, and thus, the lesser the effective area for rice production, and consequently, rice production would be lower than expected per hectare.

The significance of the excluded variables in the model are, however, reflected by the relative value of the residuals or error terms of the estimated production functions. Thus, an examination of the error terms of the estimated production functions is an important aspect of the coming analysis and discussion.

Interdependence and/or correlation of the explanatory variables

The estimated correlation coefficients of the variables included in the production function model for simultaneous rice-fish culture are presented in Appendix Tables 9 and 9a for the per farm and per hectare specifications, respectively. This correlation analysis was purposely undertaken not to be used as a basis for the elimination of the highly correlated variables, but rather to provide general information on how the variables are related to one another. Hence, it can be used as a guide to proper analysis and interpretation of results of the estimated production functions.

On the per farm specification correlation matrix (Appendix Table 9), it can be noted that the estimated values of the coefficients of some of the explanatory variables, X_2 with X_1, X_3 with X_1, X_7 with X_1, and X_7 with X_2, are significantly high, indicating potential multicolinearity among the variables. However, the application rate for different inputs on the per hectare basis are generally independent, i.e., uncorrelated, from one another as indicated by the relatively low absolute values of the etimated correlation coeficients of the variables (Appendix Table 9a).

Positive multicolinearity among the variables are obvious and expected on the per farm specification. Hence, the greater area (X_1) planted would obviously need a greater quantity of X_2, a greater amount of X_3 will be used, a greater quantity of X_7 will be required, and so on. The high degree of correlation is caused by the technical relationships among the variables. Hence, the per hectare specifications could be used, given that multicolinearity problems do not exist in the specification. Multicolinearity is more of a theoretical rather than an empirical problem (Rao and Miller, 1971), and no hard and fast rule has been devised to deal with potential multicolinearity problems (Smith, I., 1981). Using larger sample sizes would reduce the multicolinearity problem but would not eliminate it altogether.

IV.3.2 Fit of the Model

The relevant production function estimates are presented and discussed explicity in the succeeding sections of the chapter. These include the estimated general "all-study-areas-all-seasons" production functions, and the "study-area-specific", and "all-study-areas" wet-dry seasons average production functions for the individual components output and composite output on the per farm and per hectare specifications. The relevant production functions for each cropping season were not estimated, because the dummy variable (D_1) which was used to distinguish seasonal differences in the level of production appeared to be insignificant in the estimated general production function. Furthermore, the number of observations for each cropping season were relatively small and hence, using the combined wet-dry seasons data will have the benefit of increase the degrees of freedom of the relevant production function estimated. Consequently, with the increase in the number of observations, the potential problem of multicolinearity is reduced.

Only the second stage least squares (2SLS) regression estimates of the structural form input-output relationships for simultaneous rice-fish culture production system in the different study areas are reported in this chapter. The first stage least squares (1SLS) regressions are not reported, since they will give biased estimates of the structural form production relationships, as suggested by econometric textbooks (Pindyck and Rubinfeld, 1981; Johnston, 1972; etc.). The efficacy of the reported 2SLS regression estimates were validated by the ACT-FIT test procedure. The relevant ACT-FIT test statistics which include correlation coefficients (R), absolute mean error, Theil's inequality coefficients, etc., were reported along with the 2SLS reduced form input-output relationships of the relevant output.

In general, the Cobb-Douglas equation fitted the data well as indicated by the significant F-values and high R^2. The F-value statistics which were used to test the overall significance of the independent variables chosen for inclusion in the model appeared to be significant in all cases, as can be seen from the various tables. The usefulness of the estimated production functions to "explain" variations in the total product were evaluated in terms of their respective R^2 (coefficient of determination). The R^2 statistic, which is a measure of goodness of fit, was found to be statistically significant and have fairly large values in the per farm specification production functions. The R^2 values of the estimated per farm production functions range from 0.80 to 0.95. The corresponding R^2 values on the per hectare specification production functions are quite low, however, ranging only from 0.22 to 0.62. The low R^2 values are not unusual with the use of cross-sectional farm data and also can be attributed to the internalization of variable X_1 (area harvested) in the model.

The sign test was also applied in the various tabulated production function results to determine if each of the technical coefficients have the expected positive or negative sign. It appeared that the signs of the technical coefficients of several variables in some of the estimated production functions were inconsistent with their respective expected signs (Table IV.7). The t-tests statistics were also used to determine the significance of the individual technical coefficients of variables. Not all the included variables in the production function model have significant technical coefficients. The variables X_1, X_2, X_3, and X_7 appeared to have significant technical coefficients in most of the estimated production functions. Furthermore, variable X_1 (area harvested) seems to appear as a powerful variable in the model, as it has consistently large and significant technical coefficients when compared with the other variables in the various estimated per farm specification production functions.

Since the purpose of this study is to examine the nature of the factor-product relationships and the magnitude of the estimates of the technical coefficients, all the coefficients for the different explanatory variables of the relevant production functions were reported, even though some of them are not significant as shown by low t-values.

From the various relevant production functions estimated, selected production functions are used to derive broad economic and technical conclusions. In all cases, the selected production functions have sufficient degrees of freedom for statistical significance, and are stable with respect to the signs of their technical coefficients. The probability level used in accepting significant variables is either one (1) or ten (10) percent.

IV.3.3 Individual Components Output and Composite Output Production Functions Results

An examination of the relevant production function regression estimates in Table IV.8 and Table IV.8a for the combined areas and seasons simultaneous rice-fish culture production would clearly reveal the following:

(a) Those explanatory variables with significant technical coefficients in the composite output production function estimates appeared to be also significant in either one or both of the individual components (rice-fish) output production functions. This result has an obvious explanation, being of the intrinsic nature or property of composite production function as discussed in Chapter III of this study.

(b) Some of the explanatory variables that have significant coefficients in either one or both of the individual components output production functions are not significant in the composite output production functions estimates. For example, variable X_5 (in Table IV.8) has been estimated to be significant in

Table IV.8 Estimated individual components output and composite output production functions (per farm specifications) for simultaneous rice-fish culture showing differences in level of production according to seasons and locations, Philippines, 1982-83.

Variable and Description	Individual Components Output				Composite Output (Q)	
	Rice(Y_1)		Fish(Y_2)			
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Intercept (constant)	3.662	4.51	1.801	1.65	7.583	12.01
X_1	0.868**	6.31	0.707**	3.82	0.826**	7.72
X_2	-0.162*	-1.77	-0.223*	-1.81	-0.194**	- 2.74
X_3	0.059	0.95	0.445**	5.29	0.158**	3.24
X_4	0.081	0.92	0.065	0.55	0.047	0.68
X_5	-0.059*	-2.41	0.053*	1.62	-0.028	- 1.48
X_6	0.023	0.83	0.062*	1.65	0.034	1.54
X_7	0.187*	2.03	-0.108	-0.87	0.132*	1.84
X_8	0.079	1.04	0.227*	2.19	0.134*	2.25
D_1	-0.057	-0.43	0.118	0.67	0.075	0.73
D_2	0.231*	1.68	0.584**	3.16	0.331**	3.09
R^2	0.90		0.83		0.93	
F-value	85.40**		46.18**		132.41**	
D.W. Stat.	1.71		1.41		1.73	

D_1 and D_2 are dummy variables representing seasons and locations with wet season and Central Luzon being the bench marks, respectively.

* significant at 10%
**significant at 1%

Table IV 8a. Estimated individual components output and composite output production functions (per hectare specification) for simultaneous rice-fish culture showing differences in level of production according to seasons and locations, Philippines, 1982-38.

Variable and Description	Individual Components Output: Rice (Y_1)		Individual Components Output: Fish (Y_2)		Composite Output (Q)	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Intercept (constant)	3.932	5.18	2.184	2.12	7.881	13.38
X_1	-	-	-	-	-	-
X_2	-0.172*	-1.88	-0.226*	-1.82	-0.199**	-2.79
X_3	0.036	0.59	0.436**	5.42	0.136**	2.84
X_4	0.089*	1.53	0.030	0.38	0.066	1.43
X_5	-0.041*	-2.06	0.048*	1.80	-0.016	-1.01
X_6	0.015	0.79	0.046*	1.76	0.021	1.35
X_7	0.163*	1.89	-0.147	-1.27	0.099	1.49
X_8	0.056	1.25	0.116*	1.91	0.082*	2.33
D_1	-0.069	-0.53	0.112	0.63	0.066	0.65
D_2	0.214*	1.57	0.582**	3.13	0.314**	2.94
R^2	0.24		0.54		0.45	
F-value	3.23**		11.93**		8.46**	
D.W. stat.	1.72		1.41		1.75	

D_1 and D_2 are dummy variables representing seasons and locations with wet season and Central Luzon being the benchmark, respectively.

** significant at 1%
* significant at 10%

both Y_1 and Y_2 functions, but appears to be insignificant (or has a relatively very low significance level) in the Q production function. This result is easily explained by the differences in signs of the estimated technical coefficients of that variable (X_5) in Y_1 and Y_2. This means that the effects of X_5 in Y_1 and Y_2 cancel out in the value aggregation, leading to no statistically significant observable effects on the variation of Q. The variables that are significant in any one of the individual components output function may appear to be either significant or insignificant in the function Q. For example X_7 and X_6 are respectively significant in the Y_1 and Y_2 functions, but are not both significant in Q function. This can be explained by the relative magnitudes of their respective technical coefficients, as well as by the relative weight (i.e., price) of the individual output where the specified variable(s) is (are) found to be significant.

(c) Some of the inputs that are specific to a particular output appeared to be significant in explaining the variation of production of not only that particular output, but also the other output of the production system. For instance, variable X_2

(palay seeds) a specific input of Y_1, has been found to be a significant explanatory variable of not only Y_1 production, but also Y_2 production. Similarly, variable X_5 is a significant variable in explaining the variation in the level of Y_1 production. This confirms expectations in this study. It implicitly suggests that the variation in the level of production of a particular output is not only influenced by the inputs specific to that output, but also by the level of production of the other output. This point of view deserves some confirmation and shall be verified in the results of the analysis of the structural form input-output relationships.

(d) The area harvested (X_1) variable appears to be a fairly powerful explanatory variable in all of the estimated per farm specification production functions. It is considered to be a dominant explanatory variable in view of the magnitude of its technical coefficient. Aside from being highly significant, is comparatively much larger than the coefficients of the other variables. This is not a surprising result because the farm size, i.e., area of the paddy fields devoted to simultaneous rice-fish culture production are relatively small. Hence, the current scale of production with respect to variable

X_1 is probable near the boundary of the first stage of the production function, and thus, it was expected that the technical coefficient of X_1 would be comparatively much larger than those of the other variables.

(e) In most cases, the signs of the estimated coefficients of variables other than X_1, are generally consistent with their expected signs, but their estimated absolute values are generally small. The relatively low absolute values of the technical coefficients of variables can be explained by the rate or quantity of the variables that have been used in production. It is possible that the input application rates are becoming excessive, which would result in low absolute values of the coefficients. This means that production is about to peak, and hence, the marginal productivity of input application is approaching zero. This will be further clarified in the analysis of the study-area specific production function results.

(f) The t-test of the estimated coefficients of the dummy variables D_1 and D_2, which were used to distinguish respectively the seasonal and locational differences in the level of production of the individual components output, and composite output, reveals that: (1) there are no significant differences in the expected level of production between the wet and dry seasons cropping as suggested by the insignificant and relatively small absolute values of the D_1 coefficient in all the relevant production functions, and (2) the levels of simultaneous rice-fish culture production in the Bicol Region are generally much higher than in Central Luzon as indicated by the fact that the coefficient of D_2 is not only statistically significant but also its absolute value is comparatively large. This distinct locational variation in production can be attributed to the differences in input use, as well as to the distinct differences in the production environments and climatic factors.

The decisions to focus the succeeding analysis on the average wet-dry seasons production functions for the different study areas and for all study areas combined is due to the fact that the estimated coefficients of D_1 and D_2 are insignificant and significant, respectively.

Study-area-specific production functions

The nature of the area-specific wet-dry seasons average input-output realtionships for simultaneous rice-fish culture production is presented in Table IV.9 and Table IV.9a for the per farm and per hectare specifications, respectively. For the most part, inputs applied at the reported levels, do influence the level of total product of the individual output components, Y_1 and Y_2, and consequently, the composite output, Q. Eight (8) variables were hypothesized to explain the variation in simultaneous rice-fish culture total products. About 84 to 95 percent, and 22 to 62 percent, of the variation in total products on the per farm and per hectare basis, respectively, were explained by these variables. In all cases there are sufficient degrees of freedom for statistical tests.[15]/ Not all the regression or technical coefficients were statistically significant even at the low probability levels.

In an examination of the relevant production functions (per farm) for the Bicol Region, only two variables for Y_1, five variables for Y_2, and three variables for Q regressions, were determined to have significant technical coefficients. More than 50 percent of the variables of the relevant production

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[15]/ Note: The degrees of freedom is said to be sufficient in the sense that the number of observations, i.e., samples is greater than the number of variables considered in the model.

Table IV.9 Estimated individual components output and composite output production functions for simultaneous rice-fish culture system in the different study areas, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Variable and Description	Central Luzon			Bicol Region			All Study Areas		
	Y_1	Y_2	Q	Y_1	Y_2	Q	Y_1	Y_2	Q
Intercept (constant)	3.895	2.129	7.997	4.037	-0.157	7.207	3.673	1.907	7.645
X_1	0.981**	0.635*	0.882**	0.835*	0.618*	0.795*	0.862**	0.681**	0.811**
X_2	-0.285*	-0.069	-0.207*	-0.055	-0.321*	-0.152	-0.170*	-0.217**	-0.191**
X_3	0.091	0.365**	0.142	-0.017	0.782**	0.214**	0.065	0.454**	0.163**
X_4	-0.026	0.166	-0.014	0.237*	-0.209*	0.074	0.121*	0.159	0.099*
X_5	-0.116**	0 088**	-0.069*	0.001	0.011	0.017	-0.059*	0.049*	-0.031
X_6	0.034	0.083*	0.041*	0.020	-0.055	0.0004	0.033	0.090*	0.049*
X_7	0.275*	-0.242	0.152	0.061	0.172	0.105	0.174*	-0.155	0.105
X_8	0.061	0.109	0.073	0.064	0.391*	0.154*	0.078	0.209**	0.123*
ΣBi	1.01	1.13	1.01	1.15	1.39	1.21	1.10	1.27	1.12
R^2	0.90	0.86	0.94	0.94	0.84	0.95	0.89	0.81	0.92
F-value	53.59**	35.43**	90.25**	69.47**	24.15**	90.46**	105.44**	51.11**	149.39**
Std. error of regression	0.47	0.58	0.35	0.33	0.53	0.28	0.43	0.61	0.35
D.W. Statistics	1.73	1.90	1.70	1.98	1.20	1.66	1.66	1.29	1.48

** significant at 1%
 * significant at 10%

t-values and standard error of the above estimated parameters are shown in Table IV.12, Appendix Table 8 and Appendix Table 9.

Intercepts are in natural logarithmic values

Table IV.9a Estimated individual components output and composite ouput production functions for simultaneous rice-fish culture system in the different study areas, Philippines, per hectare specifications, wet-dry seasons average 1982-83.

Variables and Description	Central Luzon			Bicol Region			All Study Areas		
	Y_1	Y_2	Q	Y_1	Y_2	Q	Y_1	Y_2	Q
Intercept (constant)	3.745	0.923	7.428	3.731	1.207	7.406	3.548	1.342	7.309
X_1	-	-	-	-	-	-	-	-	-
X_2	-0.311**	-0.076	-0.226*	-0.049	-0.351*	-0.149*	-0.183*	-0.220*	-0.198**
X_3	0.091	0.447**	0.017**	0.030	0.612**	0.194**	0.069	0.506**	0.184**
X_4	0.019	0.044	0.016	0.151*	-0.026	0.079	0.124*	0.121*	0.117*
X_5	-0.087**	0.078*	-0.050*	-0.001	0.012	0.012	-0.042*	0.039	-0.020
X_6	0.024	0.061*	0.025	0.007	-0.014	0.0008	0.017	0.055*	0.024
X_7	0.302**	-0.025	0.245**	0.089	0.079	0.096	0.208**	-0.056	0.166**
X_8	0.108	0.065	0.094	0.059	0.359*	0.144*	0.087	0.202*	0.125*
ΣBi	0.13	0.59	0.26	0.29	0.68	0.36	0.29	0.64	0.40
R^2	0.30	0.39	0.32	0.24	0.62	0.55	0.22	0.48	0.38
F-value	2.88*	4.32**	3.26**	1.73	9.13**	5.88**	3.74**	12.49**	8.43*
Std. error of regression	0.48	0.61	0.37	0.33	0.53	0.27	0.43	0.61	0.35
D.W. Statistics	1.74	1.89	1.79	1.98	1.05	1.72	1.68	1.32	1.63

** significant at 1%
* significant at 10%

t-values and standard errors of the above estimated parameters are shown in Table IV.12a, Appendix Table 8a and Appendix Table 9a.

Intercepts are in natural logarithmic values functions estimates for Central Luzon and for all study areas were determined to have significant technical coefficients at 10 percent significant level. The presence of some insignificant coefficients could possibly be attributed to uncertainties due to memory recalled survey data.

In general, a comparative examination of the magnitudes of the technical coefficients estimated for the per farm and per hectare relevant production functions by study area, showed slight differences between the corresponding coefficients, estimated for the same explanatory variables of the same type of output. The magnitudes of the technical coefficients estimated for the relevant production functions measure the degree of the variation of the relevant total products, i.e., the elasticity of production with respect to the application of inputs. For instance, in the all study areas per farm model, fingerling (X_3) stocking contributes 0.065, 0.454 and 0.163 percent to total product of Y_1, Y_2 and Q respectively, for each 1.0 percent increase in stocking. The coefficients with the exception of 0.065, are statistically different from zero as indicated by t-test.

For all cases, the estimated magnitudes of the technical coefficients of the different explanatory variables for the different per farm and per hectare production functions, range from -0.351 to as high as 0.981. Some of the variables determined to have significant negative technical coefficients are inconsistent with the expectation in this study. The unexpected negative technical coefficients are not really surprising, because obviously the simultaneous rice-fish culture production system is governed by the natural law of dimishing returns. The statistically significant negative technical coefficients of the explanatory variables, indicate a negative marginal productivity of the inputs. This result might be attributed to the excessive application of the identified production inputs.

The estimated technical coefficients for most of the variables were not statistically different, (in terms of absolute values and signs) between the per farm and per hectare production functions of a particular output, for a given study area as well as for all the study areas taken as a whole (Table IV.9 and Table IV.9a). The comparability of the per farm and the per hectare functions for each of the different outputs is discussed in reference to the all study areas average production functions results.

<u>All study areas average production functions</u>

A closer examination of the estimated relevant production functions (per farm and per hectare) for all study areas taken as a whole, reveals that not all of the significant variables in one particular output (say, Y_1) function are also significant in the other output (Y_2), as well as in composite output (Q) functions. Of the eight (8) variables hypothesized to explain the variation in total products of simultaneous rice-fish culture, four variables in the per hectare and five of the variables in the per farm specifications rice (Y_1) production functions are statistically significant. Five of the variables are in the per hectare and six variables in the per farm specifications fish (Y_2) production functions are statistically significant; and in the composite output (Q) functions, six and five variables are statistically significant in the per farm and per hectare specifications, respectively. In general, all those variables that are significant in the per farm basis are likewise significant in the estimated per hectare specification production functions for Y_1, Y_2, and Q.

On the basis of the estimated per hectare production functions, palay seeds (X_2), fingerlings (X_3), inorganic fertilizer (X_4), and labor inputs (X_7), are the most commonly encountered significant variables in any of the individual output components and composite output functions. The magnitudes of the estimated coefficients of the variables as differentiated with respect to each output, showed some significant differences in absolute values as well as the sign, especially if the coefficients being differentiated are that of the output-specific-inputs.

Area harvested (X_1) was found to be statistically significant and the most powerful explanatory variable in explaining the variation in total products of the different outputs under study. A one percent increase in land area devoted to production would result in a 0.811 percent increase in Q (gross revenue), and 0.862 and 0.681 percent increases in the physical products of rice and fish, respectively. Thus, considering the expansion of area to be devoted to rice-fish culture from farm to farm is obviously a reasonable strategy for increasing the availability of fish supply in the rice producing areas.

Palay seeds (X_2) are specific inputs of rice production and have been determined to have significant negative technical coefficients in all of the different output production functions in both the per hectare and per farm specifications. This indicates that the rate of X_2 applications is beyond what is needed, thus, causing the coefficient of the input to be negative which would mean negative marginal productivity of the input. The quantity of palay seeds used in production is dependent upon the method of growing seedlings and the transplanting distances as well as to whether the main rice-fish culture paddy is directly seeded or not. Randomized or direct seeding methods as well as closed transplanting distances would need more seeds and consequently will leave the main rice-fish paddy with less space between rice plants for the fish to grow in. The crowding affects fish growth and hence explains the negative technical coefficients of X_2 in the estimated Y_2 production function.

Fingerling (X_3) stocking density on the average is much higher than what is recommended (Table II.6). It was hypothesized that fingerlings also explain the variation of the total products of Y_1 but the results as indicated in Table IV.9 and IV.9a do not support this expectation. Variable X_3 is statistically significant in explaining the variation of Y_2 production. For every one percent increase in the density of the stocked fingerlings in the rice-fish culture system, a 0.454 to 0.506 percent increase in the total product of fish will result, and consequently, the composite output Q will increase by as much as 0.163 to 0.184 percent, ceteris paribus.

Inorganic fertilizer (X_4) has been considered in this study as one of the non-output-specific inputs of the simultaneous rice-fish culture system. The application of X_4 would significantly influence the total products of both rice and fish, and consequently, the composite output. A 0.121 to 0.124 percent increase in Y_1, 0.121 to 0.159 percent increase in Y_2, and 0.099 to 0.117 percent increase in Q can be expected for every one percent increase in the quantity of inorganic fertilizer application for the average rice-fish culture farm. This result has important implications in production management decisions.

Supplemental feeds (X_5) and pesticides (X_6) are considered in this study as non-basic but output-specific inputs to fish and rice production, respectively. In either per farm or per hectare specification, these variables were found to be statistically significant in the relevant functions, though not in the manner expected. Supplemental feeds partially explained the variation by -0.042 to -0.059 percent of the total product of rice, but not of the total product of fish as was orginally deemed more pertinent. Similarly, pesticides partially explain the variation by 0.055 to 0.090 percent of the total product of fish, but not the variation of total product of rice where the input is more relevant. These results are most intriguing and perplexing at this stage of technology development, and hence, it deserves further biological studies.

Insignificant variables are those whose coefficients are not statistically different from zero (0); that is, increases in these inputs will have no significant impact on the total product. It is important to note that each of the variables considered in the simultaneous production function model have been verified to be statistically significant in any of the estimated production function regressions. But not all of the variables have been estimated to be simultaneously statistically significant in any one particular production function regression.

Based on the per hectare specification (Table IV.9a), variables X_3, X_6 and X_8 are statistically insignificant in the Y_1 production function regression estimate; variables X_5 and X_7 are statistically insignificant in the Y_2 production function estimate; and finally for the value aggregate production function (Q), only X_5 and X_6 are determined to have insignificant technical coefficients.

The technical coefficients of some of the variables are not statistically significant in a particular production function (say Y_1) but are significant in either or both of the Y_2 and Q functions. The difficulties in accurately measuring the variables in question and the relevance of including such variables in the production function model in question can explain the above observation. Finally, the finding that a variable, such as X_5 in Table IV.9 which is determined to have statistically significant coefficients in the Y_1 and Y_2 functions, but is not significant in the Q function can be attributed to the differences in the signs as well as the magnitudes of the coefficients. This means that the effects of the inputs in each of the outputs Y_1 and Y_2, would cancel out in the value aggregation, leading to no, or insignificant, observable effects in the composite output production function.

Economies of scale in production

Theoretically, the algebraic sum of the estimated coefficients (ΣB_i) of the specified variables in a Cobb-Douglas logarithmic form production function is a measure of the economies of scale in production. It indicates the proportional increase in production, i.e., the returns to production, if all the inputs specified in the function are increased by a certain percentage. The study-area-specific economies of scale for the individual components output and composite output on the per farm and the per hectare specifications are indicated in Table IV.9 and Table IV.9a, respectively.

In the per farm specification where all the inputs including land are allowed to vary, the estimated economies of scale are all greater than one, ranging from 1.01 to 1.39 for all the relevant individual components output and composite output in the different study areas. This indicates an increasing return to scale, i.e., if all the inputs along with land area are increased by a certain percentage, the relevant total products, Y_1, Y_2, and Q, will correspondingly increase by a larger proportion. However, when relevant production functions were specified on the per hectare basis (Table IV.9a), the absolute values of the economies of scale for the relevant output were all estimated to be less than one, ranging from as low as 0.13 to as high as 0.68. These comparatively low per hectare ΣB_i as compared with the per farm ΣB_i (1.01 to 1.39) are not a surprising result, given the high level of application of inputs per hectare. The per hectare ΣB_i results, suggest that the levels of application of all other inputs per unit land area (i.e., per hectare basis), are having declining marginal productivity and thus, yields a decreasing rate of returns to scale. More explicitly, the proportional increases in total products of the relevant outputs are smaller than the percent increase in the application of all other inputs per unit area of land.

Further examination of the estimated ΣB_i for the different relevant production functions in either the per farm or the per hectare specification would clearly reveal that (a) the proportional increase of the total products is greater in Y_2 than in Y_1, for the increase of all inputs. This pattern of ΣB_i is true for all areas under study; (b) the ΣB_i for any particular output is slightly higher in the Bicol Region than in Central Luzon which can be associated with differences of inputs application as well as environmental factors; and (c) the ΣB_i of Q in any particular study area of interest is the price-weighted sum of ΣB_i of both Y_1 and Y_2 in the particular study area. This is because of the intrinsic properties of composite output production function.

IV.3.4 Functional Form Input-Output Structural Relationships in Production

As earlier proposed in Chapter III the over-identified structural form analytical model for the simultaneous rice-fish culture system is applied in this section. This is to verify whether the production processes of the normally unrelated outputs, Y_1 and Y_2, have really become joint under the given nature of the production technology. The implicit interest in this structural form analysis is to determine the magnitude of influence (effects) of one output (Y_1) over the other output (Y_2), vice versa, should the hypothesized relationships be statistically verified. Hopefully, through this analysis, along with those already learned in the earlier results, concrete conclusions and workable recommendations can be formulated in view of the need to further improve the production technology.

Expectations in this particular analysis are based on the result of the earlier analytical effort. Some of the specific inputs of a particular output have been found not only to significantly influence that particular output but also the other output of the production system. This finding preliminarily supports the intuition about the nature of the production technology - that the production of Y_1 and Y_2 are not independent, and that it is expected that the variation in the level of total product of Y_1, aside from being determined by its specific inputs, is influenced by the level of Y_2 production and vice-versa. Furthermore, it is hypothesized that with the current levels of input applications, the interdependence of Y_1 and Y_2 is at the complementary stage of multi-output production. In other words, the expected signs of the product-product technical coefficients are positive as indicated in Table IV.7.

The 2SLS regression estimates of the functional form input-output structural relationships for simultaneous rice-fish culture production in the different study areas are summarized in Table IV.10 and Table IV.10a for the per farm and per hectare specifications, respectively. The consistency and significance of the 2SLS structural form regression estimates have been verified, aside from the normal F-values statistics, through ACT-FIT test procedure. This ACT-FIT test procedure which is included in the TSP 35 computer package, involves fitting (i.e., regressing) the actual observed values with that of the predicted values of the dependent variables. The predicted values of Y_1 and Y_2 are estimated at the actual level of input application with the use of the reduced form equations derived from the 2SLS structural form regressions. The 2SLS reduced form equations for Y_1 and Y_2 along with the ACT-FIT test results are shown in Appendix Table 10 for the per farm models and in Appendix Table 10a for the per hectare specification.

The ACT-FIT test results validate and/or confirm the consistencies and/or significance of the estimated 2SLS structural form regressions considering the following: (a) the regression coefficient of actual

Table IV.10 Estimated technical coefficients of the functional form input-output structural relationships in simultaneous rice-fish culture production in the different study areas, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Variable and Description	Central Luzon				Bicol Region				All Study Areas			
	Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)	
	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)
Intercept	4.472	3.21	-1.128	-0.42	3.915	3.70	-2.428	-0.95	4.034	3.88	-3.774	-1.66
	(1.392)		(2.662)		(1.057)		(2.566)		(1.040)		(2.274)	
X_1	1.039**	3.81	-0.089	-0.17	0.824**	4.07	0.112	0.19	0.906**	4.68	-0.625	1.25
	(0.273)		(0.530)		(0.202)		(0.596)		(0.193)		(0.498)	
X_2	-0.257*	-1.65	-	-	-0.068	-0.48	-	-	-0.176*	-1.82	-	-
	(0.155)				(0.140)				(0.096)			
X_3	-	-	0.349**	3.30	-	-	0.701**	4.14	-	-	0.361**	3.58
			(0.105)				(0.169)				(0.100)	
X_4	-0.102	-0.72	-0.007	-0.03	0.244**	2.32	-0.342	-1.43	0.094	1.01	-0.003	-0.02
	(0.142)		(0.216		(0.105)		(0.239)		(0.093)		(0.150)	
X_5	-	-	0.176*	2.18	-	-	0.046	0.44	-	-	0.141**	2.53
			(0.080)				(0.104)				(0.055)	
X_6	0.050	1.12	-	-	0.012	0.24	-	-	0.042	1.36	-	-
	(0.045)				(0.049)				(0.030)			
X_7	0.226	1.40	-0.346*	-1.77	0.072	0.56	-0.008	-0.02	0.155	1.38	-0.481*	-2.41
	(0.161)		(0.195)		(0.128)		(0.240)		(0.112)		(0.199)	
X_8	-	-	-0.047	-0.19	-	-	0.638*	2.02	-	-	0.153	0.86
			(0.250)				(0.315)				(0.178)	
$\hat{Y}_1$	-	-	0.864*	1.47	-	-	0.362	0.48	-	-	1.626*	2.31
			(0.588)				(0.755)				(0.702)	
$\hat{Y}_2$	-0.030	-0.24	-	-	0.012	-	-	-	0.019	0.16		
	(0.123)				(0.119)				(0.120)			
F-value	60.12**		40.55**		96.12**		24.74**		132.89**		58.19**	
Std. error of regression	0.516		0.587		0.331		0.553		0.445		0.610	

** significant at 1%
 * significant at 10%

Figures in parenthesis are standard error

Table IV.10a Estimated technical coefficients of the functional form input-output structural relationships in simultaneous rice-fish culture production in the different study areas, Philippines, per hectare specification, wet-dry seasons average, 1982-83.

Variable and Description	Central Luzon				Bicol Region				All Study Areas			
	Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)	
	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value)	(Coeff.)	(t-value
Intercept (constant)	3.980 (1.209)	3.29	-1.601 (2.682)	0.60	3.735 (0.935)	3.92	-3.588 (2.500)	-1.43	3.811 (0.781)	4.88	-3.696 (1.890)	-1.96
X_1	-	-	-	-	-	-	-	-	-	-	-	-
X_2	-0.243** (0.157)	-1.54	-	-	-0.034 (0.138)	-0.24	-	-	-0.155 (0.106)	-1.45	-	-
X_3	-	-	0.422** (0.104)	4.05	-	-	0.566** (0.134)	4.23	-	-	0.469** (0.082)	5.68
X_4	0.007 (0.094)	0.07	-0.045 (0.165)	-0.27	0.156** (0.069)	2.23	-0.167 (0.151)	-1.11	0.113* (0.056)	2.02	-0.043 (0.114)	-0.38
X_5	-	-	0.121* (0.063)	1.91	-	-	0.080 (0.070)	1.14	-	-	0.125** (0.048)	2.60
X_6	0.031 (0.032)	0.94	-	-	-0.0004 (0.028)	0.01	-	-	0.017 (0.021)	0.78	-	-
X_7	0.252** (0.113)	2.22	-0.131 (0.152)	-0.86	0.079 (0.109)	0.73	-0.079 (0.196)	-0.40	0.174* (0.077)	2.24	-0.171 (0.122)	-1.39
X_8	-	-	-0.064 (0.275)	-0.23	-	-	0.437* (0.305)	1.43	-	-	0.045 (0.204)	0.22
$\hat{Y}_1$	-	-	0.704 (0.666)	1.06	-	-	0.881 (0.714)	1.23	-	-	1.128* (0.493)	2.28
$\hat{Y}_2$	0.027 (0.118)	0.22	-	-	0.052 (0.099)	0.53	-	-	0.044 (0.076)	0.58	-	-
F-value	2.13*		4.74**		2.46*		9.69**		4.07**		14.52**	
Std. error of regression	0.514		0.616		0.328		0.551		0.440		0.613	

** significant at 1%
* signigicant at 10%

Figures in parenthesis are standard error observed values in relation to the predicted values of the variables are in general, equal to one, meaning that the predicted values are more or less equal to the actual observed values; (b) the correlation coefficient (R) and/or the coefficient of determination (R^2) of the predicted versus actual values of the variables are almost equal in the absolute term to the correlation coefficient (R) or coefficient of determination (R^2) of the OLS production function regression estimates; (c) the absolute mean values of error are not significantly different from the estimated standard error of the OLS regression production function; (d) the estimated Theil's inequality coefficients are not significantly different from zero indicating perfect fit of the actual and predicted values of the endogenous variables (the Y_i's). The predictive performances of the estimated 2SLS structural form regressions are thus indicative of the ACT-FIT test results.

The empirical analysis of the functional form input-output structural relationships in the simultaneous rice-fish culture system provided very intriguing "partial counter intuitive" results. Some of the results do not confirm the expectations in this study. Not all of the explanatory endogenous variables, Y_1 and Y_2, appeared to have statistically significant technical coefficients in the estimated functional form regressions. Only Y_1 appeared to have statistically significant technical coefficients in the estimated Y_2 functional form regressions. The technical coefficients of Y_2 as an explanatory endogenous variable in the estimated Y_1 functional form regressions were found not to be significant, even at the low level of probability. If the estimated Y_2 coefficients are not to be considered as statistically different from zero, their relative absolute values, in all cases, are small as compared with the estimated Y_1 coefficients.

Several research reports (China Freshwater Fish Committee, 1973; Grist, 1965; Hora and Pillay, 1962; Schucter, et.al., 1955) generally indicate a belief that producing fish along with rice crops in the same paddy fields contributes to an increase in rice yields. In this study Y_2 production was expected to influence Y_1 production, but the analysis did not give a result that supports this expectation, even though some of the Y_2 specific inputs have been determined in earlier analysis, to significantly influence variation of Y_1 production.

While many researchers such as those mentioned above, as well as those reviewed in Chapter II, report on the effects of fish production on rice yields, none of these researchers give due attention to the effects of rice production on the yield of fish in the simultaneous rice-fish culture system. The result of a highly significant coefficient of Y_1 in the structural form regressions for Y_2 is indicative of the fact that the total product of fish from the simultaneous rice-fish culture system is significantly influenced by rice production. On the basis of the Y_2 structural form regression for all-study-areas, a one percent increase in rice production would in effect, lead to a partial increase in the total product of fish by as much as 1.128 to 1.626 percent. This result supports part of the expectation and could be explained by the nature of the technology itself. Some of the specific inputs of rice production such as palay seeds (X_2) and pesticides (X_6) as indicated in Tables IV.9 and IV.9a directly influence the yield of fish, and if not, they improve the paddy environment which would consequently result in favorable conditions for fish growth and production. High yields of rice are due to the rice plants being in good stands, and being properly spaced between hills, and as a result, giving enough shade, preventing an increase in the temperature of the water in the paddy, and leaving enough space for the stocked fish to move around the paddy and graze on the available natural fish foods. In other words, there are biological processes that have been promoted by rice production which in turn improves paddy field conditions favorable to the increase in total product of fish.

The above results are important not only from the management view point but also for further improving the technology at hand. The above results have an implication that is inconsistent with IRRI scientists' stand and/or recommendations for further development of the rice-fish culture technology. They recommend that the cultural and management practices/inputs of fish production have to be readjusted and/or modified in favor of rice crops, that is to say, to meet the standard requirements of rice production, considering rice as the major crop in the rice-fish culture system (Singh, V.P., T. Wickham, et.al., 1980). However, since rice production significantly affects total products of fish and conversely, total product of rice is not affected by fish production, it would follow that the cultural and management practices/inputs of rice, instead of fish production, needs to be logically readjusted and/or modified with the end view of an economically profitable simultaneous rice-fish culture technology. Such a strategy should also take into account that some of the inputs specific to fish production also directly affects rice production, as indicated in the earlier analysis.

Furthermore, as far as the technology at hand is concerned, the structural input-output relationship analysis results clearly suggest that the average simultaneous rice-fish culture farm will be able to increase fish yields, not only by increasing the application of inputs specific to fish production but also by considering the increase of the inputs of rice production. Finally, the structural form input-output analysis indicates that with the given levels of inputs application, the rice and fish productions are at the "complementary stage", since the estimated product-product technical coefficients are positive. Some of the alternative formulations of the 2SLS functional form input-output relationships for simultaneous rice-fish culture that give results that are generally the same as those above, are estimated in Appendix Tables 11 and 11a. The method for optimizing input application in simultaneous rice-fish culture system shall be discussed in the following section.

IV.4 Expected Level of Total Product and Economic Optima of Input Application

The OLS regression estimates of the relevant production functions presented in Tables IV.9 and IV.9a can be used to predict the total products that will be forthcoming from simultaneous rice-fish culture. Depending on what is desired, the level of total products can be calculated at any one of three points: at the point of maximum biomass production (physical units) of either one of the Y_1 or Y_2 16/; at the point of maximum revenue (value measure), i.e., maximum Q; and at the point of inputs means (in this case, geometric means) of application. Only the third method of calculation is used in this study. Each of the relevant production functions estimated was used in the calculations of the expected level of total products of Y_1, Y_2, and Q at the given inputs geometric means application. The estimated total

16/ With the estimated production functions for Y_1 and Y_2, the symbiotic maximum of Y_1 and Y_2 can not be simultaneously attained given that the elasticities of production are distinctly different in absolute terms.

products of Y_1, Y_2, and Q are presented in Table IV.11 and Table IV.11a for the per farm and per hectare specificiations respectively for the entire-study-area. The study-area specific estimated total products are appended in Appendix Tables 12 and 12a for Central Luzon, and in Appendix Tables 13 and 13a for the Bicol Region.

At this point, a practical method of validating the reliability of the OLS production function regression estimates can be pursued by comparing the estimated relevant total products with those of the survey means of the different outputs. On the basis of the per hectare specification (Table IV.11a), the total products of 83.62 cav. Y_1 and 174.39 kgs. Y_2 at the input means application are not statistically different from the survey means of the products, 85.30 cav. of Y_1 and 163.85 kgs. of Y_2, as indicated earlier in Table IV.2. Given this result, the estimated OLS production function regressions for simultaneous rice-fish culture production appear to be efficient predictors, and therefore, are used to determine the economic optima of input application. Also, as indicated in the various tables being referred to hitherto, the OLS production function regression estimates were used to determine the

Table IV.11 Estimated production functions for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, in both the Central and Bicol Region, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Inputs		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (Y_1)									
Intercept = 3.673									
Technical coefficients		0.862**	-0.170*	0.065	0.121*	-0.059*	0.033	0.174*	0.078
t-value		6.24	-1.88	1.04	1.42	-2.42	1.19	1.89	1.02
Standard error		0.138	0.090	0.062	0.085	0.024	0.027	0.092	0.077
Marginal product (cav.)		69.597	-0.185	0.001	1.58	-0.038	0.033	0.140	0.762
Economies of scale (ΣBi) = 1.10		R^2 = 0.89	F = 105.44**						
Expected levle of Y_1 = 18.57 cav.									
Fish (Y_2)									
Intercept = 1.907									
Technical coefficients		0.681**	-0.217**	0.454**	0.159	0.049**	0.090*	-0.155	-0.209**
t-value		3.51	-1.71	5.16	1.33	1.41	2.34	-1.19	1.93
Standard error		0.194	0.127	0.088	0.119	0.034	0.038	0.129	0.108
Marginal product (kgs.)		111.654	-0.481	0.015	4.222	0.066	0.180	-0.253	4.148
Economies of scale (ΣBi) = 1.27		R^2 = 0.81	F = 51.11**						
Expected level of Y_2 = 37.71 kgs.									
Composite Output (Q)									
Intercept = 7.645									
Technical coefficients		0.811**	-0.191**	0.163**	0.099*	-0.031	0.049*	0.105	0.123*
t-value		7.24	-2.59	3.20	1.44	-1.05	2.21	1.41	1.97
Standard error		0.112	0.074	0.050	0.069	0.019	0.022	0.074	0.062
Composite marginal product (₱)		6677.70	-21.24	0.26	132.03	-2.08	4.94	8.63	122.59
Economies of scale (ΣBi) = 1.12		R^2 = 0.92	F = 149.39**						
Expected level of Q = ₱ 1893.80									
Input mean ($\bar{x}$)	GM	0.23	17.03	1170.89	1.42	28.13	18.78	23.03	1.90
	AM	0.53	47.22	2323.72	2.16	110.36	66.79	39.45	2.24
Average price of input			1.64	0.19	118.86			17.33	

** significant at 1%
 * significant at 10%

Intercepts are in natural log values

GM - geometric means
AM - arithmetic means

Table IV 11a Estimated production functions for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, Central Luzon and Bicol Region, Philippines, per hectare specification, wet-dry seasons average, 1982-83.

Inputs		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (Y_1)									
Intercept = 3.548									
Technical coefficients		-	-0.183*	0.069	0.124*	-0.042	0.017	0.208**	0.087
t-value		-	-2.03	1.23	2.20	-2.08	0.93	2.70	1.12
Standard error		-	0.090	0.056	0.056	0.020	0.019	0.077	0.077
Marginal product (cav.)		-	-0.207	0.001	2.225	-0.035	0.030	0.174	3.828
Economies of scale ($\Sigma\hat{B}i$) = 0.29 R^2 = 0.22 F = 3.74**									
Expected level of Y_1 = 83.62 cav.									
Fish (Y_2)									
Intercept = 1.342									
Technical coefficients		-	-0.220*	0.506**	0.121*	0.039	0.055*	-0.056	0.202*
t-value		-	-1.72	6.34	1.52	1.39	2.07	-0.51	1.83
Standard error		-	0.128	0.079	0.080	0.028	0.026	0.109	0.110
Marginal product (kgs.)		-	-0.519	0.017	4.528	0.069	0.206	-0.097	18.540
Economies of scale ($\Sigma\hat{B}i$) = 0.64 R^2 = 0.48 F = 12.49**									
Expected level of Y_2 = 174.39 kgs.									
Composite Output (Q)									
Intercept = 7.309									
Technical coefficients		-	-0.198**	0.184**	0.117*	-0.020	0.024	0.166**	0.125*
t-value		-	-2.69	4.01	2.54	-1.23	1.55	2.64	1.97
Standard error		-	0.073	0.045	0.046	0.016	0.015	0.063	0.063
Composite marginal product (₱)		-	-22.82	0.30	213.86	-1.73	4.40	14.15	560.40
Economies of scale ($\Sigma\hat{B}i$) = 0.40 R^2 = 0.38 F = 8.43**									
Expected level of Q = ₱ 8518.19									
Input mean ($\bar{x}$)	GM	1.00	73.90	5081.80	4.66	98.34	46.45	99.93	1.90
	AM	1.00	84.94	6987.52	7.18	367.64	235.23	118.68	2.24
Average price of input			1.64	0.19	118.86			17.33	

** significant at 1%
 * significant at 10%

Intercepts are in natural log values

marginal products of various inputs estimated at their respective geometric means.

IV.4.1 Estimated Optima of Input Application

Production functions are estimated not only for use in predicting total products but also as a guide in determining input application. In order to realize maximum net returns to production, a producer must find out the rates at which the various inputs are applied at the optimum level. Information on the productivities of the inputs, and the prevailing prices of inputs and outputs in the factor and product markets are needed to determine the optimum level of input application. With the use of the estimated relevant production function (in this case, the composite output production function), the input combinations can then be calculated. As already discussed in Chapter III, the optimum input combination will be that level of input application where the value of marginal products of inputs is equal to the respective input price. On the other hand, if the value of the marginal product is greater than the input price, i.e., $VMP_{xi} > P_{xi}$, the use of that input should be increased, and conversely, if the marginal product is less than the input price, the use of that input should be decreased.

Examples are provided below to show how the economic optima of the input levels are calculated with the use of the estimated composite production function. The usefulness of the composite output production function would only hold true as long as the output prices that were used in the estimation of the function still prevail. In the event that there are some changes in the output prices, the estimated composite output production function may become irrelevant, and the utility of the estimated individual components output production functions will be appreciated by using them in place of the composite output production function. The procedure for utilizing the individual components output production functions in determining the economic optima of input application are explicity dicussed in Chapter III. The input prices that are used in the following analyses are survey mean input prices.

Optimum stocking density

With the use of the estimated composite output production function, the optimum stocking density of tilapia fingerlings (X_3) in simultaneous rice-fish culture can be easily calculated, given the geometric means of all other inputs and the price of tilapia fingerlings. The optimum level of X_3 per farm for all study areas will be calculated as follows:

$$Q = 2090.16X_1^{0.811} \quad X_2^{-0.191} \quad X_3^{0.163} \quad X_4^{0.099} \quad X_5^{-0.031} \quad X_6^{0.049} \quad X_7^{0.105} \quad X_8^{0.123}.$$

Taking the partial derivatives of Q with respect to X_3 gives the composite marginal product of X_3:

$$\frac{\partial Q}{\partial X_3} = 0.163(2090.16)X_1^{0.811} \quad X_2^{-0.191} \quad X_3^{-0.837} \quad X_4^{0.099} \quad X_5^{-0.031} \quad X_6^{0.049} \quad X_7^{0.105} \quad X_8^{0.123}$$

Having obtained $\partial Q/\partial X_3$ or the composite marginal product of the tilapia fingerlings stocked, then equate the price ratio of input to output. Since composite product is a numeraire good, i.e., in monetary terms, and has a unit price equal to one (1), that is, the price of a peso is one peso, then $\partial Q/\partial X_3$ is basically equated with the input price (0.19). That is:

$$0.163(2090.16)X_1^{0.811} \quad X_2^{-0.191} \quad X_3^{-0.837} \quad X_4^{0.099} \quad X_5^{-0.031} \quad X_6^{0.049} \quad X_7^{0.105} \quad X_8^{0.123} = 0.19$$

Substituting the values of the geometric means of all the other inputs and solving for X_3 gives:

$$0.163(2090.16)(0.303)(0.582)(1.035)(0.901)(1.154)(1.390)(1.082)X_3^{-0.837} = 0.19$$

$$97.24X_3^{-0.837} = 0.19$$

$$X_3^{-0.837} = 0.19/97.24 = 0.00195$$

$$X_3 = 1729 \text{ tilapia fingerlings per farm}$$

From which, the optimum stocking rate for all study areas as a whole is 1729 tilapia fingerlings per farm per cropping season. The implicit assumption in this economically determined stocking density is that the survival rate and/or recovery rate of stocked tilapia fingerlings has already been taken into account in the input-output relationships through the raw data.

As surveyed, the arithmetic and geometric means stocking density of tilapia fingerlings is 2323 and 1170 respectively for all study areas average farm wet-dry seasons average. If the economically determined optimum rate of 1729 fingerlings is compared with the survey means rate of stocking, it is possible to recommend an increase or decrease in stocking rate per farm to achieve higher profits. Hence, the economically determined stocking rate of 1729 pieces of fingerlings is about 34.3 percent lower and 32.3 percent higher than the survey arithmetic and geometric means, respectively.

The use of the estimated per hectare specification composite output production function, however, seems to provide a more conclusive result. On the basis of the per hectare specification composite output production function, the optimum stocking density is estimated to be:

$$Q = 1493.68X_2^{-0.198} \quad X_3^{0.184} \quad X_4^{0.117} \quad X_5^{-0.020} \quad X_6^{0.024} \quad X_7^{0.166} \quad X_8^{0.125}$$

$$\frac{\partial Q}{\partial X_3} = 0.184(1493.68)X_2^{-0.198} \quad X_3^{-0.816} \quad X_4^{0.117} \quad X_5^{-0.020} \quad X_6^{0.024} \quad X_7^{0.166} \quad X_8^{0.125}$$

Substituting the per hectare geometic means of all other inputs in the composite marginal product of the X_3 equation and equating with the price of X_3 gives:

$$0.183(1493.68)(0.426)(1.197)(0.912)(1.096)(2.147)(1.083)X_3 = 0.19$$

and solving for X_3:

$$325.72X_3^{-0.816} = 0.19$$

$$X_3^{-0.816} = 0.19/325.72 = 0.00058$$

$$X_3 = 9{,}255 \text{ tilapia fingerlings per hectare}$$

If this optimum stocking rate of 9,255 fingerlings, with the average size of 1.90 to 2.24 cm. is compared with the per hectare arithmetic and geometric means of all study areas, fingerling stocking rates of 6,987 and 5,081 respectively, it is appears that the average all-study-area simultaneous rice-fish cultre farms can profitably increase the current stocking rate. This conclusion only holds true, as long as the output prices of ₱70.03 per cavan of rice, and ₱11.54 per kilogram of fish remains unchanged. These were used in estimating the composite ouput production function.

More importantly, the economically determined per hectare optimum stocking rate of 9,255 pieces of tilapia fingerlings for the average farm field conditions is higher (by about 85 percent) than what has been recommended (5,000 fingerlings) in the introduced technological package (see Table II.6 for more detail). The technological package was developed in the late 1970's using laboratory (field experiments) results. Many years have lasped since the package was formulated, the assumed prices have changed, and also, with the result of this present effort, it is apparent that the technological package that is being introduced must be extensively reviewed for relevance to the present and future conditions.

<u>Optimum quantity of inorganic fertilization</u>

Using a similar method as that used to determine the optimum stocking rate of fingerlings, and given the inorganic fertilizer price of ₱118.86 per bag, and the same product prices of ₱70.03 per cavan rice and ₱11.54 per kilogram fish, the optimum level of inorganic fertilization for the average farm is estimated to be 9.06 bags (or 453 kilograms) per hectare per cropping for all the areas under study. This is 2.08 bags (104.0 kilograms) more than the same average level of inorganic fertilization of 7.18 bags (359.0 kilograms) per hectare. Therefore, the total products of Y_1 and Y_2, gross returns (Q) and net return for the average simultaneous rice-fish culture farm can still be increased by increasing the quantity of inroganic fertilizer application, ceteris paribus.

Optimization in the use of all other inputs

With the use of the various estimated production functions, the marginal productivities of inputs, in terms of the physical product of the individual components output, as well as in term of the value aggregate of the outputs, are estimated at their respective geometric means. The marginal physical product of each of the inputs were estimated so that they can be used to verify the consistency (or reliability) of the inputs' composite marginal product estimates. Such a counter-check can be done by multiplying the estimated marginal physical products with the output prices and then, comparing the sum of the product with the composite marginal products, i.e., $\sum_{i=1}^{2} P_{yi}\ (dY_i/dX_i) = \partial Q/\partial X_i$. It can be seen from the various tables that in some cases the $\sum_{i=1}^{2} P_{yi}(dY_i/dX_i)$ will not be equal the estimated composite marginal product ($\partial Q/\partial X_i$). This could be explained by the estimation error encountered in any one of the production function regression estimates.

The estimated composite marginal product of each of the inputs compared with the respective input prices can be used in determining whether the levels of application of the inputs are at the economically optimum levels. In Table IV.12, are presented the results of the evaluation of the current levels of inputs application in the average simultaneous rice-fish culture farm in all the study areas taken as a whole. Some of the inputs are being used beyond the optimum level. The recommendations for optimum input application for the average simultaneous rice-fish culture farm are indicated in Table IV.12. The recommendations are formulated on the basis of survey mean input prices. Also the recommendation for a particular input assumes that all other inputs are at their respective geometric means. Furthermore, the opportunity cost of family labor is generally low, or even zero, thus, labor use in simultaneous rice-fish production could still be increased.

Table IV.12 Estimated composite marginal product at inputs' geometric means, inputs applications, price of input and recommendation for optimum input application in the average simultaneous rice-fish culture farm in all study areas, Philippines.

Variables	Level of Input use/ha.	$\partial Q/\partial X_i$ 1/	P_{xi} (pesos)	Recommendation for optimum input application
X_1	1.0	-	-	
X_2	84.94 (73.90)	-22.82	1.64	decrease
X_3	6987.52 (5081.80)	0.30	0.19	increase
X_4	7.18 (4.66)	213.86	118.86	increase
X_5	367.64 (98.34)	-1.73	1.00	decrease
X_6	235.23 (46.45)	4.40	1.00	increase
X_7	118.68 (99.93)	14.15	17.33	decrease / increase
X_8	2.24 (1.90)	560.40	-	increase sizes of stocked fingerlings

1/ Composite marginal product of input X_i is estimated at the inputs geometric means.

NOTE: Figures in parenthesis in the level of input column are the input geometric means.

IV.5 Summary and Implications of the Empircial Results

Actual farm field data were collected through farm survey, i.e., personal interviews of rice-fish culture operators in the Central Luzon and Bicol Region, Philippines. From the survey there were 75 useable questionnaires. In general, the farmers did not keep farm records, and thus, the data used in this study, are basically farmers' memory recalled information on rice-fish culture production during the wet season, 1982 and dry season, 1983. No intricate sampling procedures were followed, excepting the census type of sample identification and data collection.

A formal analysis of the potentials of simultaneous rice-fish culture was started with a demographic characterization of the technology. It was not surprising to learn that the rice farmers had only devoted about 20 percent on the average, of the total farm to rice-fish culture production. This implies that (a) the farmers under study were still in the process of adapting technology and (b) their opporutnity to expand their rice-fish culture production is still large.

The assessment of the farm level costs and returns of the production technology according to location and cropping seasons, suggest that the growing of fish (tilapia species) simultaneously with rice crops in the same paddy would be a profitable venture. On the average, the net return was estimated to be as high as ₱6,923.22 per hectare, per cropping of about 4 to 5 months duration. As much as 20 to 40 percent of the gross returns from simultaneous rice-fish culture was contributed by the fish component of the production system. The cost structure analyses indicate that fingerlings which are basic-specific fish production inputs, accounted for the largest share in the material cost of the production system. Thus, fingerlings or fish stocking material, are therefore one of the critical inputs in the simultaneous rice-fish culture system.

The survey mean farm field production of 85.30 cav. of rice and 163.85 kgs. of fish per hectare, are not significantly different from the production levels obtained from the experimental field conditions. These farm field production data along with the information on the profitability of simultaneous rice-fish culture, suggest that the concerned agencies have been heavily promoting the developed technology.

The technical input-output relationships of simultaneous rice-fish culture were estimated with a Cobb-Douglas production function model. Value aggregate or composite output production fuctions in the Cobb-Douglas logarithmic linear form were estimated for the different areas covered by the study. The standard reduced form input-output relationships, and the functional form input-output structural relationships, in simultaneous rice-fish culture were likewise, estimated in the Cobb-Douglas logarithmic linear form. The OLS and 2SLS regression estimation procedures were used in the various functions, the method(s) was (were)found to be relevant. In all cases, the Cobb-Douglas form fits the data well as revealed by the highly significant F-values and relatively high R^2.

The most intriguing results of the analysis, are the functional form input-output relationships. This analysis gave a "partial counter intuitive" result. It did not completely support the expected "symbiotic" production processes of rice and fish in the simultaneous culture system. The production of rice affects the total product of fish production, but conversely, total product of rice is not "statistically" affected by the fish production component of the system. From the management and technology development view points, the IRRI scientist's recommended that the culture practices/inputs of fish production be readjusted/modified in favor of rice crops, since rice is considered to be the major crop in simultaneous rice-fish culture (Singh, V.P., A.C. Early and T.H. Wickham, 1980). However, based upon these results it would be more reasonable to modify the standard cultural practices/inputs of production of rice, instead of fish, to achieve a more economically viable simultaneous rice-fish culture system.

The standard OLS production function regression analyses, revealed the following:

(1) Some of the inputs specific to rice production, do not only affect total product of rice, but also the total product of fish; and similarly the inputs specific to fish production, and the various overall output-specific inputs explain the composite output production variation;

(2) Land area, as one of the eight explanatory variables considered in the per farm specification models, appeared to be the most powerful variable in explaining the variation in total products of the simultaneous rice-fish culture system. The relatively large absolute value of the estimated coefficient of the variable (area harvested) suggest that total production can be significantly increased through the expansion of the farm area devoted to rice-fish culture;

(3) Palay seeds and fingerling are respectively basic-specific inputs of rice and fish production. Palay seeds (X_2) explains the variation in total

products of both rice and fish in a decreasing manner, given that technical coefficients of palay seeds is significant and negative. Fingerlings (X_3) application does not explain the variation in total product of rice, but influences fish production and because of the appreciable magnitude of the coefficient of fingerlings in the fish function, it explains the variation in total product composite output production;

(4) Supplemental feeds and pesticides, non-basic-specific inputs to fish and rice production, respectively, have larger impact on the individual components output functions than was expected. Supplemental feed application influences total rice output, but not the total fish output. Pesticides, on the other hand, positively influence total fish output, but not rice output. It supports the claim of E.A. Heinrichs. et. al. (1977) that rice-fish culture technology increases pesticide efficiency;

(5) The presence of scale economies, as revealed by increasing simultanous rice-fish production returns to scale implies that it is advantageous for the average rice-fish culture farm to expand the land area along with an increase of all simultaneous rice-fish culture inputs. In the per hectare specification, the estimated scale economies for other inputs other than land are decreased. This implies capital inputs restraint, if land area available for production is limited. One should take into account the land's maximum capacity to sustain, or accommodate all other inputs, in combination, for production.

With the assumed (sample means) input and output prices in this study, the estimated production function for the average simultaneous rice-fish culture farm implies that:

(a) The net returns to the average simultaneous rice-fish culture farm could still be increased via increasing the stocking density of fingerlings beyond the recommended rate of 5,000 to as much as 9,255 per hectare, ceteris paribus;

(b) The current levels of application of some of the inputs, particularly the palay seeds, supplemental feeds, and labor inputs, are beyond their optimum levels and thus, are recommended to be reduced;

(c) Inorganic fertilizer and pesticides which are generally considered to cause environmental hazards in simultaneous rice-fish culture, give positive marginal productivities at the current levels of application. The value of marginal products or the composite marginal products of these inputs are estimated to be much greater than their respective prices. Hence, the use of these inputs in simultaneous rice-fish production may still economically be increased. In response to this analysis, it is necessary to emphasize that the use of pesticides at the current level which are a specific input of rice, gave beneficial side-effects to the fish production component of the multi-output production system.

The data used in this study were obtained from individual farms (cross-sectional data) in two regions of the Philippines. Therefore, the reported production functions are interfarm, representing the average farm production functions for the industry. Each of the simultaneous rice-fish culture farms in the study area have their individual components output and composite output production functions. Thus, the estimated optimal production input values and the estimated technical production coefficients may be "over-" or "under" estimated for a particular farm. The production function analyses results are therefore not particularly useful in individual farm application. However, since the production function estimates represent the industry average, there is considerable value for policy making purposes.

Chapter V

PROPOSED RESEARCH FRAMEWORK FOR COMPREHENSIVE TECHNOLOGY ASSESSMENT OF RICE-FISH CULTURE[17]

Much research effort is needed before developing a truly comprehensive policy for rice-fish technology. Information gaps need elimination, and existing materials need organization into a form usable by policy-makers. Many other developing countries share the unfortunate predicament of the Philippines. They have very limited resources to allocate to research endeavors. A well-defined framework for future research initiatives would prevent duplication of efforts and can be a basis to maximize the effectiveness in both research spending and research management.

This chapter discusses the rationale of a comprehensive technology assessment; enumerates some of the general questions normally asked in technology

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[17]/The author based this chapter in great part on his (1983) paper on "Technology Assessment of Aquaculture: A Research Prospectus," Center for Policy and Development Studies, University of the Philippines at Los Banos, College, Laguna, Philippines.

assessment; explains the methodological problems confronted in undertaking comprehensive technology assessment; identifies and describes the linkages of various socio-economic variables or sectors that would affect or be affected by, the technology; and proposes an assessment framework in mapping-out the impacts of rice-fish culture technology. Primarily, the chapter was developed to identify a research agenda which has the greatest potential for contributing to problem solutions hindering further rice-fish culture technology development.

V.1 Objectives and Significance of Technology Assessment[18]/

There is no universally accepted definition of technology assessment (TA), but it can generally be thought of as a class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended, or modified (Coates, 1976). This general definition does not mean that the technology to be assessed is a "brand new" technology. The technology may have

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[18]/Technology is commonly taken to mean both the knowledge and the means of its utilization, that is a body of knowledge about techniques (Freeman, 1977). In this chapter, technology is broadly taken to mean the techniques and resources that are needed for the production of desired outputs.

already existed for generations, but is only now coming to play an important role in society.

Technology Assessment studies tend to be holistic, future-oriented and concerned with the more problematic factors underlying technological decision-making, particularly the anticipation of unintended, indirect and/or delayed effects, irreversibility and sustainability, values, goals and macro-alternatives. Thus, TA studies are not aimed at reducing uncertainty, as is often thought, but rather at clarifying and increasing awareness of the uncertainties and risks that may accompany technological change (Koppel, 1977). In other words, TA conforms to the law of common sense which prescribes thinking about what you are doing before you do it. Technology Assessment means looking ahead-not just letting the future happen. With these foregoing attributes of TA, one should not mistakenly consider it as a mere evaluation. Koppel asserts this point of view by making a detailed comparison and distinction between evaluation and assessment (Koppel, 1978, p. 26).

It thus follows that TA research should systematically examine the following: (a) the societal factors that may influence the rate and scope of the utilization of the technology in question; (b) the broad range of effects that may ensue, if and when, such a technology is introduced and widely adopted; and (c) the policy options implied for both government and private sectors, by all of the foregoing.

Finally, TA is normally undertaken to (a) illuminate the potential benefits of the technology, and thus, aid in publicizing them; and (b) generate advanced information or warning about any potential difficulties and possible risks. In both cases, TA can provide policy implications concerning the necessary policy options or actions necessary for obtaining the maximum benefits from the technology, while avoiding risks and minimizing technology's undesirable impacts.

V.2 Questions in TA and Methodological Difficulties in the Assessments of Technological Effects

V.2.1 Questions Normally Asked in TA Initiative

As in most TA studies (Porter, et. al., 1980), an assessment of the rice-fish culture technology should include questions like: What is the state-of-the-art of the technology? and; How is it evolving, being modified and/or improved? This question was addressed in Chapter II.

Rice-fish culture technology was developed to ultimately improve the nutrition of people in the inland areas. A pertinent assessment question to this goal would be: are there better micro or macro-alternatives to achieve the objective? Obviously, this calls for comparative evaluation of the available alternatives on the basis of well-specified goals or objectives which are to be achieved through the adoption of the technology in question.

What are the technology's potential second-and-higher-order impacts and consequences and how do these impacts and consequences interact with each other? In other words, one must consider the impacts of impacts.

The technology to be introduced would ultimately affect the society and therefore, the important TA questions should be concerned about who are the parties at interest and how will they be affected? Consequently, the question of who are the decision makers will be asked. And finally, what is the potential for public policy to enhance the technology's desirable impacts while minimizing undesirable ones?

The questions enumerated above are just a few of the many that need to be clarified and answered in a comprehensive TA research initiative. Usually, the specific policy questions are expected to emerge from the actual assessment work itself. A number of more specific policy questions requiring attention can be identified well in advance. These include various questions attendant to technology generation and transfer, technology support systems, policy levers and/or instruments, etc. Further details for these are presented in Section V.4.

V.2.2 Methodological Difficulties In Assessing Technological Impacts

People in general are aware of the importance of technology in their lives, but demand government protection from its possible negative side effects. To arrive at an efficient and effective public policy decision, a comprehensive assessment of the technology in question should be made. The need for more comprehensive assessments of alternatives, however, has been circumvented by preoccupation with the absence of satisfactory methodologies (Ulbricht, 1977; Crawford, 1977; Koppel, 1978).

Assessing social impacts might delay, and thereby, impede technological advancements. Thus, TA might become "Technology Arrestment" as suggested by Kranzberz (1979).

Assessing a given technology's effects is particularly difficult to pursue, when some impacts are long delayed, or are dependent upon scale of use. A good example is the long run deterioration of the agricultural environment as a result of the continued heavy farm use of agricultural chemicals (Carson, R., 1962; Bosch, R.V.D. 1978; Walter, E.M. and D.L. Schurter, 1970).

Even more difficult to evaluate are the consequences of the combination of technical developments interacting with other social forces. For instance, farm mechanization technology has done away with backbreaking labor but has also deprived unskilled farm workers of their livelihood. Consequently, the displaced workers have migrated to urban centers where they have added to existing urban problems.

Technological change can have both positive and negative impacts, i.e., trade-offs (Koppel, 1978). How can one decide if the social benefits of a new technology outweight the social costs? Generally, an individual demands that no new technology be introduced if he perceives the potential costs is greater than potential benefits. Is it possible or desirable then to create a cost-free society? How do we compare costs with benefits, for instance, when the costs only affect small groups of society?

Furthermore, how do we decide what constitutes a social benefit? How do we measure "the quality of life"? To this end, social scientists are developing appropriate indicators to measure social impacts (DAP, 1975). But is it possible to measure effects or items which really depend on "subjective judgements"?

This leads us to the question of what is really valued by the society.[19]/ For instance, do we really value the new breeds of fish, say "Miracle Fish" modern aquaculture technology provides us over the desire to prevent the extinction of naturally bred fish species as well as to preserve the environment and conserve raw materials for future generations? The society is emphasizing the value of conserving natural resources but do take actions that are inconsistent with this value. Even if the values can be agreed upon, there is little consensus on how to

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[19]/ Theoretically, in the capitalist economy, the market place determines values and what is desired in the economy. But in most developing countries, such as the Philippines where government intervention is common, the market may not reveal the true value of what is being desired by the society.

translate these into specific actions. This makes it difficult to start TA per se, since TA must begin with the attempt to specify the broad social goals. After such broad social goals are specified, TA must proceed with the evaluation of alternative development policies in terms of their contributions to those goals and the minimization of any unacceptable or undesirable trade-offs (Koppel, 1978).

The methodological difficulties of TA should, however, not blind us to its potential positive role in controlling undesirable ones. It is important to point out that TA also represents a democratic means for dealing with technological change. It is a way of educating the citizenry and their elected representatives to understand the potentialities and limitations of scientific-technological advances. Finally, TA insists that technology be used for the good of the whole society, not just for a few; it would leave decisions on technologies having major social impacts to the political process -- which is exactly where they belong in a democratic society.

V.3 Proposed Research Framework in Mapping-Out Technological Impacts

V.3.1 Taxonomy of Technology Assessment Related Studies

Researches such as feasibility studies, market research, cost-benefit studies, economic and environmental impact studies, etc., are all related to TA. The extent to which these research activities are normally carried-out is indicated by Table V.1. The analytical parameters, magnitude of analysis, and focus of study of these studies are indicated in Table V.1. There is also other TA-related research such as project input-output monitoring and evaluation (Nasol, 1983), that are normally done on a continuing basis. The scope through which TA initiatives may be designed and implemented can vary considerably, from micro-TA, which may be only undertaken at the laboratory and could perhaps be accomplished in a day, to macro-TA that usually takes much longer time and more resources.

Carrying-out different TA related studies independently, without regard to a comprehensive framework which establishes the linkages of such studies can lead to disconnected research initiative.

Table V.1 Taxonomy of technical studies[a]

TYPE OF STUDY	CENTRAL QUESTIONS TO BE ANSWERED	ANALYTICAL PARAMETERS: Technical efficacy	Economic feasibility	Safety risks	Public policy options	All relevant impact domains (e.g., economics, environment, social, psychological, political)	Only selected impact domains (e.g., economic)	Second- and higher-order effects (i.e., unintended, unanticipated, synergistic, cumulative)	Only first-order effects (i.e., intended impacts)	All key parties at interest (e.g., bankers, doctors, consumers, industry, youth, minorities)	Only particular parties at interest (e.g., doctors)	Effects on all relevant systems (e.g., health, transportation, communications, education, legal)	Only effects on particular system (e.g., health)
FEASIBILITY	Is it a workable and safe design? Can it be made with available resources and techniques? What will it cost to make?	1	1	1	4		X		X		X		X
MARKET RESEARCH	Who will use it? Who will pay for it? How much will they be willing to pay? How can demand be generated?	4	1	2	4		X		X		X		X
CLINICAL TRIAL	How well did it do what it was designed to do? Did it produce clinical side effects? Was the effect beneficial? What regimen is called for?	1	4	1	4		X	X			X		X
	What are the monetary costs?												

Note:

Magnitude of analysis:
1. Generally analyzed in depth
2. Generally included but analyzed only moderately
3. Generally included but analyzed superficially
4. Seldom or never included
5. Generally depthless

— Varies widely depending on objectives of the specific study

Focus of Study:
X Generally primary focus of study.
— Varies widely depending on objectives of the specific study.

Caveats:
[b]Some exceptional cost–benefit studies include nonmonetary values.
[c]Some exceptional environmental impact studies include social effects.

[a] Adopted from Porter, A., et. al., 1980 (with Arnstein, 1977:576, original source)

The possibility arises for information gaps to still exist, despite a number of specific studies on the technology in question having already been undertaken.

V.3.2 Impact Assessment Framework

The primary concern of TA is the socio-economic policy and institutional systems through which the technology must play out. It should be realized that a comprehensive TA task must deal with a very complex system. In its simplified form, the various interacting components of the system are indicated in Figure V.1.

The fish stocks and rice crops are an integral part of the system and clearly the growing of rice and fish in the paddy is the heart of the system. These growing crops are affected by the environment and also have impacts on the environment. The crops and the paddy environment are affected by the technology in use. The technology in use is determined by the technologies available - which - in turn is affected by the research and development (R & D) that is going on. Obviously, if no work is being done, technological improvement should not be expected. This is the core of the system, and assessment work

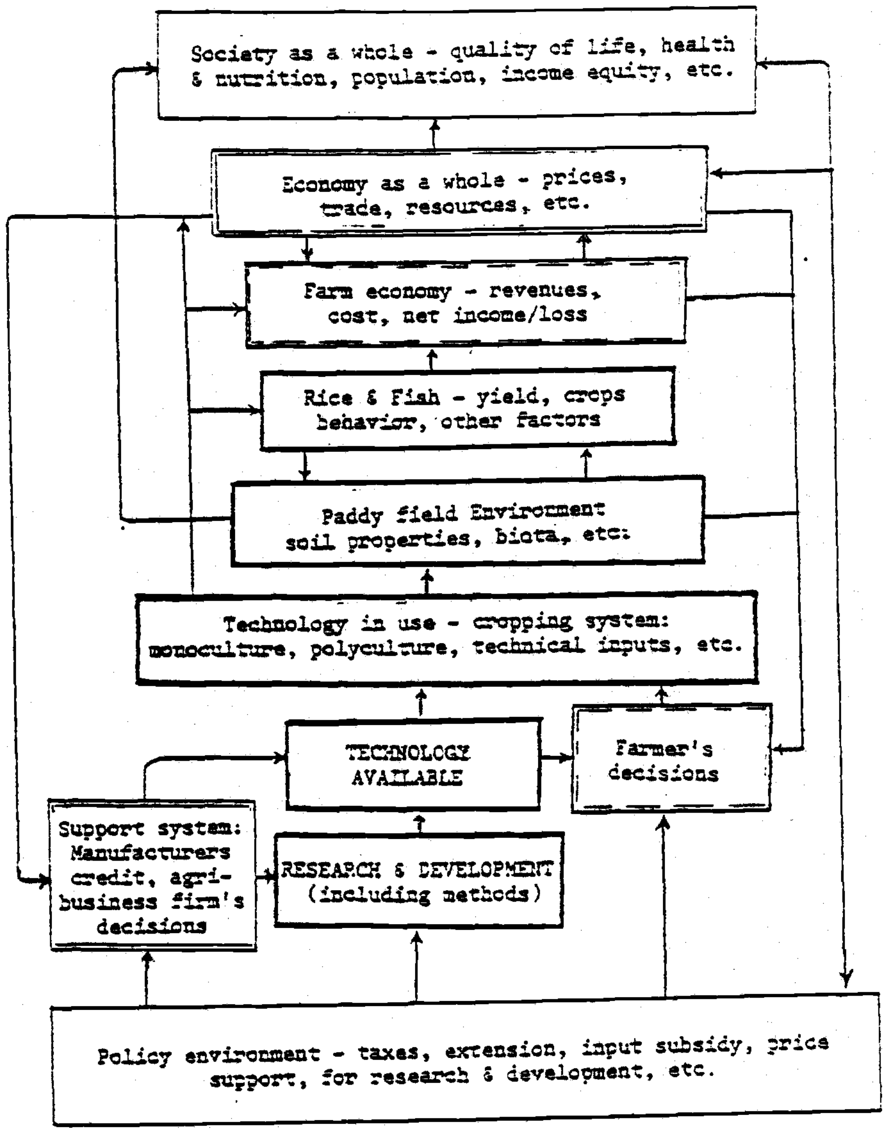

Figure V.1 TA of rice-fish culture: simplified assessment framework should not end at this point, because, of course, there are people involved.

The people involved are those who make the decisions. Farmer's decisions based on the technology available and on various external considerations determine what technology is in use. By the same token, what happens in the rice-fish paddy fields has impact on farm level economics -- gross revenue, cost, net income/loss, etc.

What happens at the farm level economy certainly affects the economy as a whole. The widescale adoption of appropriate technology would increase production. Unless there is a high demand for the output,the increases in production would lead to a decrease in output prices. If output prices go down, farm level economy will also be affected in ways such as the potential decrease in farm production in the succeeding period. The decline in output prices would also result in a potential decrease in quantity demand for production inputs such as fish fry, fertilizer, chemicals, etc.

There are many people involved. These are the people engaged in the whole support system such as the fish hatchery industry, palay seed industry, middleman, credit, etc. All are making decisions which will affect the technology in use which in turn will also be affected by it and so on.

The final components of the system are the society as a whole and the policy making body/environment. The society would certainly be affected in terms of quality of life, health, nutrition, income equity, etc. And finally, the policy making body will influence almost all the components of the system. This is done through the imposition of various policy instruments such as taxes, input subsidy, price and wage policies, support for R & D, etc.

It is very clear that each of the different components of the system will affect, and also be affected by, each other. In order to answer questions on how the components of the system are interacting with one another, one much have a thorough understanding of the value objectives and actions of the people involved. This understanding is necessary since it is the human factor that makes the system operate. From this point of view, it can be argued that the study of the human factors of technological developments which are basically policy and institutional analyses can form the core of a comprehensive technology assessment.

The obvious interested parties in rice-fish culture technology and the kind of flows and linkages that exist among these actors of the system are shown in Figure V.2. They make decisions on the various kinds of flows, such as money, commodities, information, controls, and regulations, etc., which would affect the technology in use. Tracing down the different kinds of flows and interactions that exist in the system is normally hard to accomplish, since the system is complex and dynamic.

Systematic linkages and methods of research are therefore essential for a complete understanding of the potential role of the technology. The framework illustrated above suggests that one should not simply line-up a list of technologies, and then, conclude that a particular technology in the list is the best. It is much more complex than that.

Finally, if the ultimate concern is the way in which policies to achieve the desired social objectives can be made effectively; then, the dynamic and complex system should be worked out, i.e., explored, scrutinized and analyzed in as much detail as possible. More specifically, the nature of linkages among actors of the system should be mapped out in at least an essential outline, to facilitate

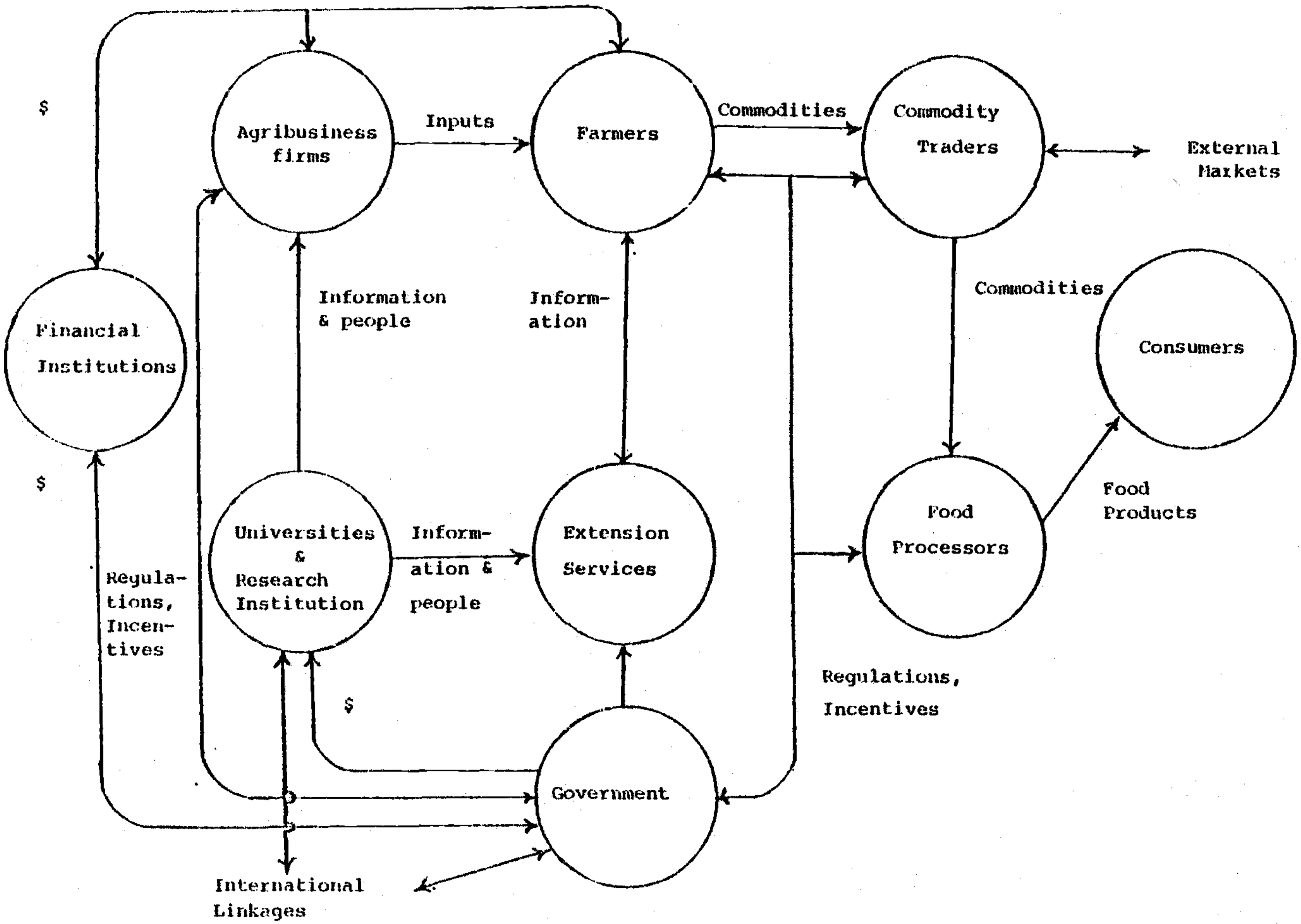

Figure V.2 Simplified structure of actors and linkages.

the determining action of all possible unexplained or unexploited technological consequences, and also as a way of identifying the most appropriate policy levers for achieving the desired social policy objectives.

V.4 Rice-Fish Culture Technology Development Policy Issues

There is an explicit link between a development program and supportive research (Smith, 1979). The objective of the nationwide implementation of rice-fish culture program was to increase income and improve the nutrition of rice farmers. The goal of supportive research should be to expand and clarify the alternative choices available to decision makers, be they the government policy makers, the private business managers, or the farmers themselves. TA initiative can be important supportive research, in the sense that it clarifies both the empirical and suppositional problems that are attendant to or likely to attend the development of the technology.

The empirical problems are those that are concerned with the needs of the rice farmers for increasing income and improving family nutrition as well. Suppositional problems, on the other hand, are those that relate to the assumptions decision-makers put forward regarding producers' behaviour, the socio-economic structure of the area in which production and distribution take place, the extent of available resources, and the likely effects of the development programs.

One of the important aspects of any comprehensive TA task is the examination of the available policy options in achieving the desired social objectives. A comprehensive assessment of the rice-fish culture technology must seek explanations to many policy questions.

Is there really a problem of insufficient supply of rice and fish? The country had already achieved its policy objective of self-sufficiency in rice production in the late 1970's (Palacpac, A., 1982). On the other hand, available statistics on fisheries production and consumption suggests an insufficient supply of fish (BFAR, 1982). Therefore, emphasis of increasing production through the improvement of technology should be made on fish production while at the same time fulfilling national policy objective of self-sufficiency in rice production. As pointed out in previous chapters, the quantity of fish available in the inland areas can be substantially increased through improvements in rice-fish culture technology. But what about the alternative means of meeting the country's consumption requirments for fish, such as through increasing the efficiency of fishing efforts on the high seas? Would it be a more appropriate policy decision to promote the use of new rice-fish culture technology over the available options? New technological innovation may be questioned from the view point of sustainability and stability. In this respect, would it, therefore, be more reasonable to adopt a policy that would maintain the balance between alternative solutions to the problem of fish inadequacy?

One of the important attributes of rice-fish culture technology which could be offered as justification for its widespread promotion is that it will maximize the use of, i.e., increase efficiency, of farm resources particularly land and water.
Fish production in the paddy fields has a great advantage over marine fisheries, as conditions are much more controllable (or predictable) by producers and less expensive for the government to manage. It should, however, be recognized that the technology would require other complementary inputs, such as fingerlings, fertilizer, feedstuffs, etc. More

specifically, the technology would tend to significantly increase farm demand for irrigation water and hence, could reduce available irrigation water for other farms' production. From this point of view policy decisions should also be concerned with whether the technology is sustainable and can be afforded by major groups in the farming community.

It is also important to emphasize that rice-fish culture technology is site specific to areas where there is adequate irrigation water. This does not mean that if you can grow irrigated rice you can also practice rice-fish culture, because even though water supply might be adequate, it may be contaminated with toxic pollutants. Therefore, policy decisions must also consider whether there would be enough suitable areas, or more specifically, would all of the irrigated rice fields, given the heavy farm use of agricultural chemicals, be suitable for rice-fish culture. Assuming that all these irrigated rice fields are still suitable, would it be desirable to use them all for rice-fish culture? What about the other farming system technologies which are now becoming more available to producers? With the promotion of rice-fish culture technology, what kind of complication may be added to the existing problematic tenancy arrangements or land tenure policy? And how do we go about dealing with the complication in tenancy problems? Indeed a review and analysis of the existing tenancy laws as they may affect technology adoption is itself an important component of TA initiative.

Supposing momentarily, that the available irrigated rice fields are too polluted, making fish culture a risky proposition, what sort of policy decisions and actions should be initiated? Given the risks, what form of incentives should be offered to prospective adoptors for them to assume such risks?

The effectiveness of the technology depends heavily on both environmental and socio-economic conditions. Let us suppose that the available form of rice-fish culture technology is appropriate under a given set of circumstances. Would there still be a need for government interventions? If so, what form of intervention? Where would the private sector support services step in? This question indicates the need to review or formulate a possible commercialization policy concerning control and property rights (or patents) on the use of new technology. There is reason for concern about the issue of property rights on new technology. If commercialization policy on new aquaculture technology is not well spelled-out, a distinct possibility exists that the new breeds of fish follow the path of hybrid poultry, as well as the Green Revolution corporate seeds (Balai Fellowship, 1984), and become a monopolized industry.

It is quite obvious that government intervention is desirable, since the new technology for food production would affect the people through their health, nutrition, income equity, etc. Government's role in technology development is indispensable most especially if there will be potential negative technological impacts. There are numerous important policy questions that can be put forward on the issue of the amelioration of negative technological impacts, such as differential benefits, rising land values, harm to agro-chemical industry, conflicts among policy institutions, etc. The government may want to make decisions on all of these questions. The decisions on various policy instruments such as R & D support, price support, subsidy on inputs, credit, environmental protection, crop insurance, etc., and on various issues about a broad range of support systems that influence the technology being assessed. Clearly, a variety of policy questions and problems emergent from this concern should be expected in the actual assessment work itself. Some of the specific questions can be stated in advance:

Technology Generation/Improvement

* Who is doing what specific research problems on rice-fish culture technology?

* In what direction is rice-fish culture research going? Would such technology improvement favor farmers or input suppliers or both?

* Where is the research support coming from? and what sort of arrangement for this research has been agreed upon?

* Is there enough manpower and interested people in this area of specialization? Is training still needed?

Technology Transfer

* How will support services, most of which have developed around specialized production systems such as Masagana 99, Masaganang Maisan, etc., be affected by the advent of rice-fish culture technology and other multi-output production technologies and related policies?

* How will the agro-chemical industry respond to the wide scale adoption of rice-fish culture technology?

* What are the likely patterns of commercialization, development of proprietary interests, legal and institutional mechanisms, impacts on receiving community or region and their policy responses?

Technology Support System

* What role in rice-fish culture technology developments will be played by multinational assistance agencies such as development banks, as well as business, trade, media, etc.?

* How will existing economic policies generally designed for other purposes (e.g., monetary policy, fertilizer and pesticides regulation, taxes, etc.) affect the rate and scope of new technology utilization?

* Are sufficient socio-economic and ecological data available for the evaluation of agricultural innovations such as rice-fish culture and other farming systems, and if not, how do the disadvantages of such an uncertainty compare with the drawbacks of institutional overload which might occur if more knowledge were sought?

* What role should the public sector play in facilitating or regulating private sector support services?

Resource-Use Policy

* If rice-fish culture technologies reduce the costs and economic risks of production on more marginal lands, in effect making such lands more valuable, who gains and who losses?

* Will the paddy lands themselves suffer long-term degradation through this more intensive short-term use?

* How would it complicate existing land reform or tenancy policies?

* What options are available to the public sector in coping with problems in these areas, such as the increase in demand for irrigation water?

V.5 Policy Implications of the Technology Assessment Prospectus

Many socio-economic as well as technical questions, such as those enumerated above, would need to be addressed to constitute full assessments of the rice-fish culture technology. It can be seen that significant research and information functions of a number of groups (e.g., research intitutions, extension agencies, farmers, etc.) will be needed and thus, would call for better, or more effective, research management.

The dilemma of contemporary research management is twofold. First, obtaining the broad spectrum of inputs needed may be difficult if not impossible. Second, managers of contemporary research in agriculture lack the necessary channels to those they intend to serve and are overwhelmed in some instances by excessive accountability to other audiences, with diverse, sometimes inconsistent, and often ill-defined goals (Koppel, B., 1978). It is precisely this situation that makes assessment an important component of research management.

Many scholars have concluded that the pitfalls of development programs, such as the Green Revolution, have been the failure to recognize that technological innovations operate within a complex set of economic, social, political, and cultural contexts (Umali, D.L., 1983; Pearse, A., 1980; Dumont, R. and N. Cohen, 1980; Lynch, F., 1978; Reinton, p., 1973, etc.). It can be seen that the above technology assessment prospectus aims to explain how rice-fish culture technology would operate within this complex set of contexts. It would thus be worthwhile to initiate TA, not only for rice-fish culture technology but also for other technologies.

Chapter VI

SUMMARY, POLICY IMPLICATIONS AND CONCLUSIONS

Because of (a) the increasing demand for food, (b) the inelastic supply of production resources, (c) the risks and uncertainties of single output oriented production technology, and (d) the people's nutritional requirements, there is a need for more appropriate technology in Philippine agriculture. While the rapidly developing technology on rice-fish culture offers important opportunities for meeting these problems and needs, much uncertainty, many problems and numerous policy questions that are attendant to, or likely to attend to, the widespread adoption and development of the technology *per se*, are yet to be clarified.

The main questions concern policy and technological decision-making. Specifically, (a) state-of-the-art rice-fish culture technology development is described; (b) theoretical and quantitative models are formulated for economic analysis of rice-fish culture system in the context of multi-output production technology; (c) the economics of the simultaneous rice-fish culture system is analyzed with reference to the costs and returns and the input-output relationships; (d) a research framework is proposed for the comprehensive assessment of the rice-fish culture technology; and (e) policy actions are identified for further development of rice-fish culture technology in the Philippines. The empirical results are followed by a discussion of the policy implications.

VI.1 Summary of Results

Filipino farmers are not unique in practicing fish culture in the lowland paddy fields. This practice is known world wide, particularly in the irrigated rice producing areas of the tropics. Indeed, it has a lengthy history, and is believed to be as old as irrigated rice production.

Rice-Fish Culture Technology Development: A Distilled Overview

Literature reviews revealed that before the advent of the heavy usage of agricultural chemicals in rice production, the Philippine lowland paddies teemed with many valuable fish, shellfish, and other aquatic fauna. The unanticiapted decline of the paddy field fishery resources may be associated with the widespread adoption of Green Revolution technology, in-as-much as the technology is dependent on agricultural chemical inputs which are generally detrimental to fishery resources.

Research and development of rice-fish culture technology did not begin until 1973 when an institutional rice-fish culture technology research and development program was implemented by the FAC-CLSU and UPCF. The program was designed to develop low-cost appropriate technology for the production of fish in rice farms and thus, to ultimately increase the fish supply as a cheap animal protein source for the nutritional improvement of people in landlocked areas. A variety of biological studies have been undertaken leading to technique (or methodology) development for simultaneous and rotationally, fish culturing with rice crops in the paddy fields.

The rice-fish culture technology package was introduced nationwide in the late 1970's and has become an important government policies on food and nutrition. The implementation of the rice-fish culture technology development program involved the participation of at least ten (10) national government agencies, and the provision of technical input recommendations and support services. Inter-agency collaboration was initiated as a strategy toward achieving program objectives.

Highlights of the Multi-Output Production System Model

With reference to the simultaneous rice-fish culture system, the concept of a multi-output production system has been formulated. It is a technique or method of production which would yield various types of outputs in one production period within the same production space. The various inputs in a multi-output production system may be classified into: "basic or non-basic output specific" inputs and "basic or non-basic non-output-specific" inputs of production.

An input is basic-specific (say, palay seeds) to a particular output (rice) when without such an input (palay seeds), the production of the particular output (rice) in the multi-output production system, would not take place. Therefore a multi-output production system is defined as follows:

> "The number of outputs to be produced should always be less than or equal to the number of basic-output-specific inputs needed in the multi-output production system."

Theoretically, various outputs do not directly depend on input applications, but instead, depend on the changes in the quality of the production environment, which is the intermediate product of input application in the over-all production process. Therefore, the various outputs of the production system are not "non-joint" in the over-all production process. Within the theoretical analysis of a multi-output production system model, the concept of multi-output "symbiotic maximum yield " was formulated, and found to be economically inefficient.

A Synthesis of the Empirical Economic Analysis Results

Actual farm field data on the wet and dry seasons, 1982-83, rice-fish culture operations of some 75 farmers in four, and two, provinces of Central Luzon and Bicol Region, respectively, were used in the empirical analyses. No intricate sampling procedure was used, except for the census type of sample identification and data collection. In general, the farmers did not keep farm records, thus, the data used in this study were at best limited to the farmers' memory-recalled information.

The average area devoted to rice-fish culture production was 0.53 ha. which is only about 20 percent of the total farm area operated by the average farmer in all the study areas. As surveyed, the mean farm production level of 85.30 cav. of rice and 163.85 kgs. of fish per hectare are not significantly different from the levels of production obtained under experimental field conditions. The farm level costs and returns analysis results suggest that the culture of fish (tilapia species) simultaneously with rice crops in the same paddy would be a profitable venture. On the average, the net return to production was estimated to be as high as ₱6,923.22 per hectare per cropping of about 4 to 5 months duration. The cost structure analysis results indicate that the cost (share) of fingerlings which is the basic-specific input of fish production, accounted for the largest share in the material cost of the production system. The contribution of fish production to the total gross returns from simultaneous rice-fish culture was as high as 40 percent.

Technical input-output relationships were analyzed with the use of the unconstrained Cobb-Douglas log linear production function model. Composite output production functions for simultaneous rice-fish production were estimated. The standard (reduced form) individual components output functions, and the functional form input-output structural relationships in simultaneous rice-fish production were likewise estimated in the Cobb-Douglas log linear model with the use of OLS and 2SLS regression estimation procedures. The technical input-output relationships were analyzed in both the per hectare and per farm specifications. In all cases, the Cobb-Douglas model fits the data well as revealed by the highly significant F-values and relatively high R^2.

Eight pre-determined, i.e., independent, variables were included in the standard OLS production function models. Palay seeds and pesticides, and fingerlings, supplemental feeds and sizes of stocked fingerlings were considered in the analyses to be the inputs specific to rice and fish production, respectively. Land or area harvested, inorganic fertilizer and labor services, were considered to be the non-output specific inputs of production. One limitation of the analysis was that the labor inputs were not disaggregated according to output. Among the most significant results of the input-output analyses are the following:

1. In general, the estimated technical coefficients of input-output relationships in simultaneous rice-fish production are consistent with the hypothesis;

2. Land or area harvested appeared to be the most powerful variable in explaining the variation in total production, in term of the physical product of

rice and fish, or in terms of the value aggregate of the outputs of the simultaneous rice-fish culture system. The elasticities of simultaneous rice-fish production were estimated to be from 0.681 to 0.862.

3. Some of the inputs specific to a particular output do not only significantly influence the total output but also the other output of the system, and vice versa;

4. Some of the non-basic-specific inputs, such as the supplemental feeds and pesticides, have been determined to be significant in the individual components output functions contrary to high expectations;

5. A particular variable input could significantly influence the variation of both outputs, without also significantly influencing the variation of the level of value aggregate or composite output;

6. The returns to scale of simultaneous rice-fish production were determined to be increasing in the per farm and decreasing in the per hectare specifications;

7. The functional form input-output structural relationships analyses gave intriguing "partial counter intuitive" results. They did not fully support the expectations of "symbiotic" rice-fish production processes in the simultaneous culture system. Rice production affects the total product of fish production but conversely, the total product of rice production is not statistically affected by the fish production components of the rice-fish culture system. The signs of the output-output technical coefficients are positive indicating complementarity of rice-fish production processes in multi-output production system;

8. The economic evaluation of input application in the average rice-fish culture farm, with the use of the estimated composite output production function revealed the following: (a) the net returns to the average farm could still be increased via increasing the stocking density of fingerlings beyond the recommended rate of 5,000 to as much as 9,255 per hectare, ceteris paribus; (b) the levels of

application of some of the inputs, particularly palay seeds, supplemental feeds, and labor services, were determined to be beyond the economically efficient levels; and (c) inorganic fertilizer and pesticides which are normally considered to pose a hazard to simultaneous rice-fish culture were determined to give positive marginal productivities at the current levels of inputs application.

Highlights of the Comprehensive Technology Assessment Prospectus

Since the above results are not sufficient for the formulation of a comprehensive policy on rice-fish culture development, a research framework for obtaining sufficient information is offered. Technology assessment has been broadly understood to mean a systematic way of examining the potential effects on society when a technology is introduced, extended or modified. Technology assessment has the anticipatory function of defining future outcomes, since it tends to be future-oriented, and thus, technology assessment can improve awareness of future uncertainties. It was also emphasized that technology assessment is not the mere evaluation of the performances of a given technology. Evaluation is, however, an integral component of assessment giving technology assessment a broader perspective.

An attempt has been made to conceptually demonstrate the potential role and relevance of technology assessment to policy decision-making. As described by Koppel (1978) the output of technology assessment can make suggestions for decisions involving planning, resource allocation, evaluation, and dissemination. It was also articulated that the analyses of the policy and institutional systems can form the core of a comprehensive technology assessment. Such an articulation was based on the recognition that it is the human input that makes the socio-economic system operate. It is really the problem of subjective judgement of the society's values and goals that makes a comprehensive technology assessment difficult to attain. The proposed research framework for mapping-out technological impacts would indicate that a comprehensive technology assessment is a multi-disciplinary task, and it is the difficulty of putting the perspective of these knowledgeable people into a common framework that makes a comprehensive technology assessment initiative much more difficult to implement.

VI.2 Policy Implications

The following policy questions are addressed: a) prospects for greater rice-fish production, b) relevance to production management decisions, c) technology improvement option, and d) technology transfer.

Prospects for Greater Rice-Fish Production

In general, production can be increased by opening new rice-fish lands (i.e., converting more rice land into rice-fish culture padies), or by production intensification (using more supplementary inputs).

Only a fairly small portion of each farm area was being used for rice-fish culture production. Analyses of the input-output relationships in production, indicate that the size or area harvested significantly influenced the increase of total products of both rice and fish production. It also indicated the presence of economies, as well as diseconomies, of scale of production when the input-output relationships were assessed on the per farm and per hectare specification, respectively. Intuitively, increasing production through the conversion of more rice paddies into rice-fish culture can be a reasonable strategy, as suggested by the empirical results. Increasing production via the intensification of supplementary inputs use should be implemented with some restraints, as there are decreasing returns to inputs application on a limited production area.

From the macro view point, the rice-fish culture program in the Philippines is basically aimed at increasing the supply of fish as a cheap source of animal protein, in the landlocked areas. Policy actions to achieve this objective via encouraging more farmers to adopt the rice-fish culture technology must take into account the availability of supplementary inputs and the need for more irrigation water. Irrigation water is a critical resource or input to rice-fish culture production. Hence, rice-fish culture can be considered a "site-specific technology", as it can only be practiced in areas where irrigation water supply is not a limiting factor. Thus, a policy that promotes an increase in the number of rice-fish culture farms would in effect tend to increase the demand for more irrigation water, and consequently, some policy action is necessary in order to address this increased water demand.

Relevance to Production Management Decision

The estimated production functions represent the industry functions as they portray the average input-output relationships for all the farms in the industry. These estimated functions may not represent the actual input-output relationships for a particular rice-fish culture farm. However, these estimated production function can be a useful guide to the individual rice-fish culture operator.

Technology Improvement Option

Despite the orientation of the empirical analyses having been mainly focused on economics, much of the analysis and findings can be of use to researchers in their endeavors to improve technological knowledge of rice-fish culture production. Results indicate that fish should not be treated as only a supplementary crop in the production system. The structural input-output relationships analyses indicate that rice production affects or influences the total product of fish production, while the converse does not hold true. These results suggest the necessity for the readjustment or modification of the specific cultural practices of rice production, if fish production from the simultaneous rice-fish culture system is to be increased. The study also examined the effects of the various output-specific and non-output-specific inputs in explaining the variation in the levels of total products of the simultaneous rice-fish culture. Some of the inputs specific to rice production also affect or influence the total product of fish, and conversely, some of the inputs specific to fish production also affect or influence the total product of rice production. These results can serve to pinpoint areas where further research can help improve the cultural practices of a simultaneous rice-fish culture system.

The identification or classification of the various inputs into output-specific, and non-output-specific, inputs does not only show the costs associated with the use of the inputs, but also the corresponding contribution of the inputs to total output that it was not specifically intended for. In other words, the external effects of an input, say fingerlings, on rice production is determined. The analysis of the cost structure, i.e., share of the total costs of an input in relation to the shares of the total costs of other inputs, along with the knowledge of the output responses to input application, can also help researchers to find ways to reduce further the cost of production.

Technology Transfer

A program development strategy that calls for the active participation of various support agencies and institutions may prove to be appropriate, but such a strategy will have to put forward the question of "accountability and credit" in cases of program failure and success. This would call for better, or more specific delineation of agency goals and functions at all levels of the hierarchy in the implementation of development program, i.e., the rice-fish culture technology transfer. A clear cut delineation of the roles and functions of the involved agencies and the basis for their collaboration should be properly specified and continuously be reviewed. This will strengthen coordination and help avoid duplication of functions in the execution of the development program.

It is necesary that the government adopt some alternative policy which would enhance this effective inter-agency collaboration. From the farmer's viewpoint, there is a need to further strengthen the existing policy to provide incentives for technology adoption.

Most of the commonly used agricultural chemicals in paddy field production are toxic to fish and other aquatic life. As pointed out in the review of literature, heavy farm usage of these toxic inputs would be a major constraint of the widespread adoption of the rice-fish culture technology. Fortunately however, new brands of agricultural chemicals that are compatible with the technology are beginning to be sold in the local markets. It is not unlikely that many more of those form of agricultural chemicals will be marketed by the multinational firms. While it is true that some of these agricultural chemical inputs will not kill the fish, they may accumulate in the flesh of the fish, and consequently lead to unknown health effects on the people. It would be necessary therefore, for the government to further improve and strengthen its regulatory power concerning the production and sales of agricultural chemicals in the country. Obviously, this is a necessary supportive policy to the widespread promotion and adoption of the rice-fish culture technology.

VI.3 Conclusions

The integration of fish culture with rice production was brought about by the need to maximize land use to produce more food and increase self-sufficiency, especially among the rice consuming peasants.

Marine fish are not as readily available in the inland areas as in the coastal areas. Also more than 50 percent of the marketed marine fish in the inland areas are poor in quality, yet they sell for even more than those in coastal areas (Sevilleja, R., 1979). Thus, the widespread adoption of the rice-fish culture technology would potentially serve to fill the quality and quantity gaps of the fish markets in the inland areas.

Fish is one of the most important basic food items of the Filipino diet. Substantial quantities of fish produced from rice paddies are likely to be consumed by the farm family. This would improve the diet of the farm family, and at the same time, would slightly reduce the demand for fish in the local markets. Further improvements of the rice-fish culture technology would mean substantial increases in fish production. Consequently, there would be an excess supply of fish which could be sold or traded to other farm families and hence, further reduces the demand in local markets.

Diversifying rice production through the application of the technology increases the fish supply in the inland areas. Rice-fish culture technology supports the government's shift in policy from grain production to protein food production (Lorico, B., 1981).

Simultaneous rice-fish culture production can be a profitable venture which rice farmers may logically adopt. However, the widespread adoption of rice-fish culture technology may be a slow process. Even if there are significant improvements in extension programs, the degree of acceptance of the technology will depend on the degree of conflict not only with the farmers' existing production system, but also with other production systems.

Except for some of the references included, there is no strong evidence that rice-fish culture technology is more economically advantageous, compared with the other forms of multi-output production system, as well as the single-output production system such as the monoculture of rice. With the recent emphasis of farming systems research in the Philippines (Integrated Agricultural Production and Marketing Project (IAPMP), 1981), it would not be unlikely that many alternative forms of agricultural production systems would become available to producers. In this respect, decision-makers, be they policy makers, agribusiness managers, or the farmers themselves, may face more complex production choices.

Comparative analyses of the economics of the various forms of the agricultural production system will then be needed, and should logically be initiated to form parts of a comprehensive technology assessment. A comprehensive technology assessment initiative for rice-fish culture is highly recommended not only in view of the need for more effective policy decisions on the technology *per se*, but also as a supportive activity to rural development programs, considering that comprehensive technology assessment can serve as a democratic means for dealing with technological change.

No one sample farmer had reported converting his entire irrigated rice fields into rice-fish culture production. While the government offers subsidy and other form of incentives for technology adoption, the sample farmers had only converted a fairly small portion of their respective total irrigated rice fields into rice-fish culture. Farmers' to some degree tend to avoid risk, and may only be in the process of technology adoption. Full acceptance of the technology, would also be determined by the success and failure of the technology in this adoptation stage. Hence, farmers respond to the relative economics of various production alternatives, given their available resources. This production economics study of simultaneous rice-fish culture system is only the first step in codifying the relative economics and farmers' responses. Similar studies of the alternative production systems are needed for complete understanding of the relative economics of and farmers' behaviour regarding the introduced rice-fish culture technology.

The reported technical input-output relationships in production were estimated with the use of interfarm data; and therefore, such technical input-output relationships estimates is an average for the industry and does not necessarily hold true to a particular rice-fish culture farm. These estimated parameters of the input-output relationships should only be used as a "guide", if one will have to advise individual farmers on optimum levels of input application. The estimated optimum input levels in this study may not be the optimum input levels to a particular farm. What is really needed is location-specific, i.e., on farm-specific, advice, because more than just ecological differences (soil, climate, etc.) are invloved. It is these location-specific differences that make technology packaging so very difficult and adaptation to locally prevailing conditions so expensive (Smith, I.R., 1981). However, progress can be made if biologists can determine the production response of different technologies and economists can evaluate the effect on producer profits. Thus, an interdisciplinary approaches to rice-fish culture technology research and development is a highly favorable strategy.

It is· important to emphasize that researchers should recognize the limited availability of financial resources for research and development. Because of this unfortunate situation, it would not be naive then to recommend that researchers should work or undertake technology improvement initiatives in areas that are representative of large areas so as to multiply the impact of the work done.

Implicitly, this study of the paddy field fishery resources and the potentials of rice-fish culture technology do suggest: a) the need for recognition of restraints in the use of new technologies so as to avoid the unintentional loss of nature-endowed resources that may be less valued now but may become extremely vaulable in the future,and b) the need to recognize that "mother-land" has a finite capacity for sustaining exploitation.

"Six years thou shalt sow thy field, and
Six years thou shalt prune thy vine yard,
and gather in the fruit thereof;

But in the seventh year shall be a sabbath
of rest unto the land.....
Thou shalt neither sow thy field, nor prune
thy vine yard,.....
And the sabbath of the land shall be meat for
you, for thee, and for the people....."

From the Third Book of Moses -
"Leviticus"

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VIII

APPENDIX

Appendix Table 1. The main fish species commonly grown or found in rice fields.

Common Name	Scientific Name	Occurrence	Original Source
1. Bhekti	Lates calcarifer	India	Pillay and Bose, 1957
2. Carps	Cypsinus carpio and other species	China, Hungary, Indonesia, Italy, Japan, Madagascar, Pakistan, Spain and some Southeast Asian countries	FAO, 1957; Coche, 1967; Grover, 1979; Arce, 1977
3. Catfish	Clarias spp.	Malaysia and other Southeast Asian	Gopinath, 1955; Soong, 1950; Tonoll, 1955
4. Crayfish	Cambarus clarkii	Japan	Yoshihiro et al., 1958
5. Eel	Anguilla japonica	Japan and India	Yoshihiro et.al., 1958 Anon., 1956
6. Goldfish	Carassius auratus	Japan	Yoshihiro et.al., 1958
7. Grey mullets	Mugil spp.	India and some isolated islands in Asia	Pillay and Bose, 1957
8. Milkfish	Chanos chanos	India and Indonesia	Menon, 1954; Djaingsastro, 1957
9. Mudfish	Ophicephalus striatus	Philippines, India Malaysia and Vietnam	Soong, 1954; Lemare, 1949; Wyatt, 1956
10. Tengra	Mystus gulio	India	Pillay & Bose, 1957
11. Tilapia	Sarotherodeon mossambicus	Indonesia, Taiwan Philippines and other Southeast Asian countries and Africa	FAO, 1957: Coche, 1967; Grover, 1979; Vincke, 1979; Arce, 1977

SOURCE: Adapted from Singh, V.P., A.C. Early, and T.H. Wickham, 1980 Rice Agronomy in Relation to Rice-Fish Culture. In Pullin, R.S.V. and Z.H. Shehadeh ed. Integrated agriculture-aquaculture farming systems. ICLARM Conference Proceeding 4. International Center for Living Aquatic Resources Management, Manila, and the Southeast Asian Center for Graduate Study and Research in Agriculture, College, Laguna, Philippines.

Appendix Table 2. Completed researches on rice-fish culture at the Freshwater Aquaculture Center Central Luzon State University, Nueva Ecija, Philippines, 1974-1980.

Subject of Completed Research	Number of Experiments Conducted	Major Findings and Conclusions
<u>Simultaneous Rice-Fish Culture System</u>		
1. Exploratory Research	1	Yield data for both rice and fish not impressive; better insights for more specific objectives and procedure for succeeding research work was generated.
2. Paddy field carrying capacity		
a. Fish stocking densities	4	Stocking denisty would affect the growth and yield of fish in the paddy fields. Studies indicate that 3,000 to 4,000 c. carp or 5,000 tilapia per ha. were most appropriate for mono-culture without supplemental feeding.
b. Fish stocking weights and size	2	Percentage of fish recovery is positively related with increasing size or weights of fish to be stocked. No conclusive indication that rice yields is affected by varying size or weights (5.0 to 29.0 g.) of fish to be stocked.
3. Polyculture studies	3	Polyculture of tilapia: carp (2:1) at stocking density of 6,000 fingerlings/ha. was considered best. Total fish harvest is affected by varying the ratio of tilapia and carp to be stocked at a constant stocking density of 6,000 fish/ha. stocking ratio of 3:1 give good total fish yield.
4. Paddy physical structure/layout (i.e., trench design)	3	Reduction of effective area for rice crop by as much as 10% did not significantly decrease rice yield. Trench design has effect on fish recovery and yield. Paddy with center trench of 1.0 m. wide and 0.4 to o.5 m. in depth give good fish production results.
5. Insecticides screening studies	6	Simultaneous rice-fish culture system can increase insecticides efficiency. Only Carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl N-methylcarbonate) systemic insecticides-nematicide is found safe for use in the system. Rootzone application method is recommended.
6. Supplemental feeding and fertilization studies	3	No feeding but with lamp give better production. Rice bran given as feed at rate of 5% body weight slightly increase fish production than unfed. No conclusive results is generated. No specific studies on the effect of chemical fertilization have been undertaken.
7. Fish species and rice varieties compatibility trials	0	No specific studies were undertaken to screen fish species and rice varieties for compatible use in simultaneous rice-fish culture system.

Appendix Table 2. continued.

Subject of Completed Research	Number of Experiments Completed	Major Findings and Conclusions
8. Cultural management studies		
a. Timing of stocking	1	No conclusive findings
b. Rice direct seeding	1	No conclusive results are made available.
Rotational Rice-Fish Culture System		
1. Development of fish paddy facility for rotational cropping	3	Paddy field dikes rasied to 0.6 m. to maintain 0.3 to 0.4 m. water depth is capable of supporting fish growth (stocked at 10,000 tilapia fingerlings/ha.). Growing of fish instead of rice during wet season seems justified since fish yield can break even or even more than rice yield in terms of peso value.
2. Evaluation of carrying capacity of fish paddy facility for rotational cropping	1	Results indicate that the paddy facility can sustain growth of 10,000 filapia/ha. without supplemental feeding would give yield which is more than half ton. Poly-culture (2:1) of tilapia and carp at 15,000 fish/ha. with supplemental feeding can be sustained by paddy facility and may yield as much as 0.8 ton.
3. Rice cropping in paddies after fish harvest	1	Growing of fish in rotation of rice crop can improve soil fertility due to residual fertilizer and supplemental feeds for fish. Savings in fertilizer cost of rice production may result from rotational cropping of rice and fish.
4. Culture of tilapia with taro (colocasia sp.) in rotational cropping	1	Results indicate that fish and taro enterprise will give better income than either purely rice or fish enterprise. Bigger portion of income may be contributed by taro crop.
Comparison of simultaneous and rotational rice-fish culture systems	1	Simultaneous rice-fish culture system is more beneficial than rotational system. Level of rice yield in simultaneous rice-fish culture system is not significantly different than the yield of rice when in monoculture system. Same is true to fish yield.

SOURCE: Condensed from a series of semi-annual Progress Reports (1975 to 1981) of NSDB Assisted Project No. 7103 of FAC-CLSU, Nueva Ecija, Philippines

Appendix Table 3. Effects of varying stocking density of fish fingerlings on yields of simultaneous rice-fish culture system under experimental condition at the FAC-CLSU, Philippines

STOCKING DENSITY	ESTIMATED PRODUCTION LEVEL PER HA. Rice (in cav.)	Fish (in kg.)	SPECIES/VARIETIES AND OTHER INPUTS APPLIED INTO THE SYSTEM
		Production Trial 1	
2,000	106.2	56.2	Tilapia nilotica - 1.0 g. ave. wt. at stocking
3,000	113.1	87.2	IR-38 - transplanted at 20 x 25 cm. distance between hills of 2-3 plants/hill
4,000	115.7	109.0	83 days culture period
			16-20-0 at 75 kg./ha.
5,000	112.6	104.6	45-0-0 at 150 kg./ha.
6,000	110.9	106.5	6 to 10 cm. water depth
		Production Trial 2	
4,000	60.7	37.5	Tilapia aurea s. - 1.8 to 10.0 g. ave. wt. at stocking
5,000	62.2	71.6	IR-40 - transplanted at 20 x 20 cm distance between hills at 2-3 plants/hill
6,000	62.8	92.0	70 days culture period
7,000	73.7	104.8	14-14-14 - at 150 kg./ha. (2x)
			45-0-0 - at 75 kg./ha.
			6 to 10 cm. water depth
		Production Trial 3	
2,000	93.4	139.6	Cyprinus carpio - 58.8 g. ave. wt. at stocking
3,000	91.0	188.3	IR-32 - transplanted at 20 x 20 cm. distance between hills at 2-3 plants/hill
4,000	87.4	198.9	82 days culture period
			16-20-0 at 150 kg./ha. (2x)
			45-0-0 at 75 kg./ha. (2x)
			10 cm. water depth

Note: 2x would mean two times application of the same quantity as indicated above.

SOURCE: Condensed from Central Luzon State University, Fresh Water Aquaculture Center, NSDB Assisted Project No. 7103 Ag. Tech. Reports 10:134-137 (1976); 11:14-17, 21-25 (1977); and 14:34-43 (1978), CLSU, Nueva Ecija, Philippines.

Appendix Table 4. Average prices of output and input of wet and dry seasons simultaneous rice-fish culture production as surveyed in Central Luzon and Bicol Region, Philippines, 1982-83.

Particulars		Study Area					
		Central Luzon		Bicol Region		All Study Areas	
		WS, 1982	DS, 1983	WS, 1982	DS, 1983	WS, 1982	DS, 1983
Rice (cav.)	Py_1	70.75 (25.38)	70.00 (14.73)	66.96 (16.16)	73.00 (17.39)	69.28 (21.81)	71.65 (16.19)
Fish (kgs.)	Py_2	12.87 (2.43)	13.11 (1.86)	9.42 (2.00)	10.28 (2.32)	11.53 (2.26)	11.55 (2.11)
Palay seeds	Px_2	1.56 (0.48)	1.62 (0.38)	1.64 (0.64)	1.77 (0.62)	1.59 (0.54)	1.70 (0.51)
Fingerlings (pcs.)	Px_3	0.22 (0.09)	0.18 (0.07)	0.19 (0.10)	0.17 (0.04)	0.21 (0.09)	0.17 (0.05)
Inorganic Fertilizer (bgs.)	Px_4	113.88 (21.86)	123.24 (25.14)	121.16 (21.70)	123.24 (20.51)	116.70 (21.79)	123.24 (22.59)
Labor services (man-hours)	Px_7	18.82 (5.85)	18.02 (5.99)	15.77 (3.81)	18.02 (2.98)	17.64 (5.06)	18.02 (4.33)

Note: Figures within parenthesis are the standard deviations. WS and DS would mean wet-season and dry-season, respectively.

Appendix Table 5. Itemized input share in simultaneous rice-fish culture production cost (pesos/ha.) as surveyed in Central Luzon and Bicol Region, Philippines, wet season (WS), 1982 and dry season (DS), 1983.

Input Item	Central Luzon				Bicol Region				All Study Areas			
	WS, 1982		DS, 1983		WS, 1982		DS, 1983		WS, 1982		DS, 1983	
	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
1. Material	(1773.90)	(52.36)	(1146.97)	(42.61)	(2728.60)	(63.95)	(2170.77)	(54.66)	(2045.96)	(56.07)	(1664.49)	(49.91)
a. Palay seeds	138.79	4.10	192.97	7.17	135.44	3.17	197.53	4.97	138.76	3.80	194.69	5.84
b. Fingerlings	1024.65	30.25	510.70	18.97	1174.06	27.52	728.20	18.34	1071.94	29.37	619.79	18.58
c. Inorganic fertilizer	328.54	9.70	233.45	8.67	948.97	22.24	767.43	19.32	500.14	13.71	504.52	15.13
d. Supplemental feeds	210.38	6.21	108.92	4.05	234.94	5.51	291.39	7.34	218.41	5.99	201.46	6.04
e. Pesticides	71.54	2.10	100.93	3.75	235.19	5.51	186.22	4.69	116.71	3.20	144.03	4.32
2. Labor	(1247.36)	(36.82)	(1163.77)	(43.23)	(1223.78)	(26.68)	(1390.28)	(35.00)	(1248.80)	(34.22)	(1275.39)	(38.24)
a. Hired	887.90	26.21	748.80	27.82	904.50	21.20	1080.14	27.19	898.05	24.61	915.09	27.44
b. O & F	359.46	10.61	414.97	15.41	319.28	7.48	310.14	7.81	350.75	9.61	360.30	10.80
3. Miscellaneous operating cost[1/]	(366.31)	(10.82)	(381.29)	(14.16)	(314.43)	(7.37)	(410.64)	(10.34)	(354.47)	(9.71)	(395.03)	(11.85)
Total Production Cost/ha.	3387.57	100.00	2692.03	100.00	4266.81	100.00	3971.69	100.00	3649.23	100.00	3334.91	100.00

[1/] Includes all other costs and incidental operating expenses such as food served to farm workers, transportation expenses, etc.

Figures in parenthesis are sub-total of each input category.

Appendix Table 6. Survey means of the explanatory variables of simultaneous rice-fish culture production in Central Luzon and Bicol Region, Philippines, wet season and dry season, 1982-83.

Variables	Symbol	Central Luzon		Bicol Region		All Study Areas	
		WS, 1982	DS, 1983	WS, 1982	DS, 1983	WS, 1982	DS, 1983
Farms Reporting	(n)	38	18	24	23	62	41
Area harvested (ha.)	X_1	0.61 (0.92)	0.60 (1.17)	0.36 (0.39)	0.49 (0.63)	0.51 (0.76)	0.55 (0.90)
Palay seeds (kgs.)	X_2	49.57 (88.94)	63.41 (118.98)	28.44 (29.82)	50.26 (77.45)	41.39 (72.39)	56.02 (95.97)
Fish fingerlings (pcs.)	X_3	3015.08 (3782.19)	1730.27 (1917.84)	2043.12 (1943.65)	1913.18 (1469.29)	2638.84 (3218.88)	1847.20 (1647.96)
Inorganic fertilizer (bgs.)	X_4	1.74 (2.09)	1.16 (1.31)	2.76 (2.90)	3.02 (4.64)	2.13 (2.46)	2.21 (3.59)
Supplemental feeds (pesos)	X_5	128.33 (195.60)	65.35 (90.24)	84.58 (168.70)	149.27 (346.23)	111.39 (185.47)	108.79 (261.62)
Pesticides (pesos)	X_6	43.63 (61.60)	60.57 (91.22)	84.68 (91.52)	89.04 (100.32)	59.52 (76.59)	77.78 (95.50)
Labor inputs (man-days)	X_7	42.90 (42.95)	40.08 (53.75)	28.82 (22.24)	43.82 (45.85)	37.45 (36.79)	42.47 (48.37)
Ave. size of stocked fingerlings (cm.)	X_8	2.34 (1.31)	2.18 (1.29)	2.45 (1.28)	1.93 (1.16)	2.38 (1.28)	2.04 (1.21)

Note: WS and DS would mean wet season and dry season, respectively.

Figures within parenthesis are standard deviations.

Appendix Table 7. Production data for rice and fish grown and harvested undet the multi-output and single-output production systems

Production System	Estimated Yield Per ha. Rice (cav.)	Fish (kgs.)	Technical Inputs
<u>Multi-output Production System</u>			
1. Rice-fish culture without supplemental feeding	138.17	110.35	*Tilapia nilotica* fingerlings ave. weight of 17.5 g. stocked at 5,000/ha.
2. Rice-fish culture with supplemental feeding	115.47	194.50	IR-36 seedlings transplanted at 20 x 20 cm. distance between hills and 2-3 seedlings/hill.
<u>Single-output Production System</u>			
1. Rice monoculture	122.35		Fertilization: 75 kg./ha. 45-0-0 150 kg./ha. 16-20-0
2. Fish monoculture;			
a. with fertilization only		163.90	Furadan 2F insecticides applied by rootzone soil injection method
b. with fertilization and feeding		246.90	Fine rice bran used as supplemental feeds given at the rate of 5% fish body weight.
			94 days culture period for fish grown.

SOURCE: Central Luzon State University, Fresh Water Aquaculture Center; NSDB Assisted Project No. 7103. Ag. Technical Report 11:32-38 (1977), FAC-CLSU, Nueva Ecija, Philippines.

Appendix Table 7a. Effect of supplemental feeding on rice-fish culture yields at various fish stocking densities.[1]

Fingerling Stocking Density (pcs.per ha.)	Fish Yield (Kgs.) Per Ha. Supplemental Feeding[1] Without	With	(Inc./Dec.)	Rice Yield (Cav.) Per Ha. Supplemental Feeding[1] Without	With	(Inc./Dec.)
2000	110.1	147.1	+ 37.1	92.4	101.4	+ 9.1
4000	159.4	258.5	+ 99.1	118.3	103.1	- 15.3
5000	89.0	112.9	+ 23.9	74.4	64.8	- 9.6
6000	127.4	172.4	+ 45.0	80.8	75.0	- 5.8
7000	104.8	89.7	- 15.2	73.7	65.8	- 7.8
All stocking densities	118.1	156.1	+ 38.0	87.9	82.0	- 5.9

1/ Fine rice bran was used as supplemental feed supplied at the rate of 5 per cent of fish body weight given daily. Fish specie grown is tilapia nilotica.

Source: Central Luzon State University, Fresh Water Aquaculture Center, NSDB Assisted Project No. 7103 Ag. Tech. Reports 12:20-24 (1977); 15:43-50 (1978); 17:59-64 (1980). CLSU Munoz, N.E. Philippines.

Appendix Table 8. Effect of different fish stocking weight (size) in yields of simultaneous rice-fish culture system under experimental condition at the FAC-CLSU, Philippines.

Ave. Size of Finglerings stocked		Estimated Production Level Per ha.		Species/Varieties and Other Inputs Applied in the system
wt. in gms.	length in cm.	Rice (cav.)	Fish (kgs.)	
			Production Trial 1	
8.0	> 1.0	90.2	79.87	*Tilapia nilotica* - at constant stocking density of 5,000 finglerlings/ha.
14.5	1.4	87.9	132.62	72 days of culture period
20.5	2.0	88.5	176.25	IR-40 - transplanted at 25 x 25 cm. distance between hills of 3-4 plants/hill
26.6	2.6	95.7	211.25	16-20-0 at 150 kg./ha.
				45-0-0 at 75 kg./ha.
				Furadan 3G - 50 kg. (a.i.)/ha.
				10-15 cm. water depth
			Production Trial 2	
5.0	> 1.0	66.2	67.50	*Tilapia nilotica* - at constant stocking denisty of 5,000 fingerlings/ha.
13.0	1.3	71.9	187.79	69 days of culture period
19.0	1.9	84.4	199.52	IR-36 transplanted at 25 x 25 cm. distance between hills of 3-4 plants/hill
29.0	2.9	76.5	219.81	16-20-0 at 150 kg./ha.
				45-0-0 at 75 kg./ha.
				Furadan 3G - 50 kg. (a.i.)/ha.
				10-15 cm. water depth

SOURCE: Central Luzon State University, Fresh Water Aquaculture Center, NSDB Assisted Project No. 8103 Ag. Tech. Reports 12: 25-28 (1977) and 13: 17-21 (1978), CLSU, Nueva Ecija, Philippines.

Appendix Table 9. Correlation matrix of variables in simultaneous rice-fish culture production in Central Luzon and Bicol Region, Philippines, per farm specification wet-dry seasons average, 1982-83.

Variables	Y_1	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y_1	1.0									
Y_2	0.77	1.0								
X_1	0.94	0.82	1.0							
X_2	0.87	0.76	0.94	1.0						
X_3	0.76	0.85	0.80	0.76	1.0					
X_4	0.61	0.62	0.60	0.59	0.59	1.0				
X_5	0.21	0.37	0.28	0.26	0.34	0.31	1.0			
X_6	0.52	0.54	0.51	0.56	0.50	0.49	0.08	1.0		
X_7	0.87	0.68	0.91	0.85	0.65	0.56	0.26	0.48	1.0	
X_8	0.09	0.20	0.07	0.01	0.12	0.06	0.21	-0.03	0.01	1.0

N = 103 sample observations; 62 and 41 observations for the wet and dry seasons, respectively

Appendix Table 9a. Correlation matrix of variables in simultaneous rice-fish culture production in Central Luzon and Bicol Region, Philippines, per hectare specification, wet-dry seasons average, 1982-83.

Variables	Y_1	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y_1	1.0									
Y_2	0.13	1.0								
X_1	-	-	-							
X_2	-0.19	-0.12	-	1.0						
X_3	0.17	0.63	-	-0.02	1.0					
X_4	0.28	0.35	-	0.01	0.34	1.0				
X_5	-0.05	0.31	-	-0.10	0.26	0.18	1.0			
X_6	0.09	0.19	-	0.31	0.13	0.19	-0.10	1.0		
X_7	0.27	-0.03	-	-0.10	-0.03	0.17	0.09	-0.001	1.0	
X_8	0.03	0.23	-	-0.12	0.07	-0.04	0.22	-0.08	-0.14	1.0

n = 103 sample observations: 62 and 41 observations for the wet and dry seasons, respectively.

Appendix Table 10. Second stage least squares estimate of the technical coefficients of individual components output and composite output production functions for simultaneous rice-fish culture system, Central Luzon and Bicol Region, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Variable and Description	Central Luzon			Bicol Region			All Study Areas		
	y_1	y_2	Q	y_1	y_2	Q	y_1	y_2	Q
Intercept (constant)	4.392	2.667	8.674	3.903	-1.015	8.151	4.091	2.878	8.855
X_1	1.015	0.788	0.979	0.829	0.412	0.777	0.924	0.877	0.917
X_2	-0.251	-0.216	-0.245	-0.068	0.025	-0.056	-0.182	-0.296	-0.198
X_3	-0.010	0.340	0.044	0.008	0.704	0.093	0.007	0.373	0.058
X_4	-0.099	-0.093	-0.098	0.241	-0.255	0.179	0.097	0.155	0.105
X_5	-0.005	0.172	0.022	0.0006	0.046	0.006	0.002	0.146	0.022
X_6	0.049	0.042	0.047	0.012	0.004	0.011	0.043	0.071	0.046
X_7	0.230	-0.147	0.171	0.072	0.018	0.065	0.150	-0.238	0.095
X_8	0.001	-0.046	-0.006	0.008	0.641	0.086	0.003	0.158	0.024
$\Sigma\beta_i$	0.93	0.84	0.91	1.10	1.59	1.16	1.04	1.25	1.07
<u>ACT FIT tests</u>									
R	0.92	0.89	0.96	0.97	0.89	0.97	0.94	0.88	0.96
R^2	0.86	0.81	0.92	0.94	0.81	0.94	0.88	0.77	0.91
Root-mean squared error	0.534	0.975	0.371	0.305	0.531	0.451	0.445	0.804	0.377
Mean absolute value	0.366	0.809	0.304	0.230	0.430	0.397	0.304	0.637	0.294
Reg. coeff. actual on predict.	1.011	0.780	0.980	1.000	0.971	0.973	1.007	0.833	0.976
Theil's inequality coeff.	0.081	0.119	0.005	0.046	0.062	0.028	0.067	0.096	0.024

Appendix Table 10a. Second stage least squares estimate of the technical coefficients of individual components output and composite output production function for simultaneous rice-fish culture system. Central Luzon and Bicol Region, Philippines, per hectare specification wet-dry seasons average, 1982-83.

Variable and Description	Central Luzon			Bicol Region			All Study Areas		
	Y_1	Y_2	Q	Y_1	Y_2	Q	Y_1	Y_2	Q
Intercept (constant)	4.013	1.224	8.274	3.719	-0.311	7.968	3.839	0.634	8.094
X_1	-	-	-	-	-	-	-	-	-
X_2	-0.248	-0.174	-0.236	-0.036	-0.031	-0.035	-0.163	-0.184	-0.165
X_3	0.012	0.430	0.077	0.031	0.593	0.100	0.022	0.493	0.088
X_4	0.006	-0.040	-0.001	0.154	0.031	0.138	0.117	0.089	0.113
X_5	0.003	-0.123	0.021	0.004	0.084	0.013	0.006	0.132	0.024
X_6	0.032	0.022	0.030	-0.0004	-0.0003	-0.00038	0.018	0.020	0.018
X_7	0.257	0.047	0.224	0.078	-0.009	0.067	0.175	0.026	0.153
X_8	0.002	-0.065	0.008	0.024	0.458	0.077	0.002	0.047	0.008
$\Sigma\beta_1$	0.06	0.34	0.10	0.25	1.13	0.36	0.26	0.36	0.27
ACT FIT Tests									
R	0.26	0.54	0.43	0.48	0.67	0.68	0.37	0.59	0.55
R^2	0.07	0.30	0.19	0.23	0.44	0.46	0.13	0.36	0.31
Root-mean-sq. error	0.531	1.350	0.426	0.307	1.023	0.420	0.443	1.212	0.395
Mean absolute error	0.358	1.121	0.344	0.230	0.859	0.370	0.299	1.002	0.306
Reg. coeff. actual on predict.	0.870	0.428	0.819	0.959	0.509	0.973	0.995	0.495	1.054
Theil's inequality coeffi.	0.059	0.122	0.023	0.033	0.086	0.022	0.049	0.106	0.021

Appendix Table 11. Estimated technical coefficients of some alternative structural equations of input-output relationship in simultaneous rice-fish culture system for all study areas, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Variable and description	Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Intercept (constant)	4.034 (1.040)	3.88	-1.777 (0.429)	-4.14	4.173 (0.597)	6.98	-1.800 (0.426)	-4.23
X_1	0.906** (0.193)	4.68	-	-	0.930** (0.126)	7.35	-	-
X_2	-0.176* (0.096)	-1.82	-	-	-0.181* (0.091)	1.98	-	-
X_3	-	-	0.505** (0.085)	5.92	-	-	0.515** (0.083)	6.17
X_4	0.094 (0.093)	1.01	-	-	0.1005 (0.083)	1.20	-	-
X_5	-	-	0.069* (0.034)	1.99	-	-	0.040 (0.034)	1.16
X_6	0.042 (0.030)	1.36	-	-	0.044* (0.027)	1.60	-	-
X_7	0.155 (0.112)	1.38	-	-	0.147 (0.100)	1.40	-	-
X_8	-	-	0.301* (0.164)	1.83	-	-	0.337* (0.164)	2.05
$\hat{Y}_1$	-	-	0.449** (0.085)	5.26	-	-	0.453** (0.085)	5.30
$\hat{Y}_2$	0.019 (0.120)	0.16	-	-	-	-	-	-
F-value	132.89**		95.79**		161.08**		96.29**	
Standard error of regression	0.44		0.62		0.44		0.62	

** significant at 1%
 * significant at 10%

Appendix Table 11a. Estimated technical coefficients of some alternative structural equations of input-output relationships in simultaneous rice-fish culture system for all study areas, Philippines, per hectare specification, wet-dry seasons average, 1982-83.

Variable and description	Rice (Y_1)		Fish (Y_2)		Rice (Y_1)		Fish (Y_2)	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Intercept (constant)	3.811 (0.781)	4.87	-3.262 (1.330)	-2.45	4.138 (0.542)	7.63	-1.779 (1.947)	-0.91
X_1	-	-	-	-	-	-	-	-
X_2	-0.155 (0.106)	-1.45	-	-	-0.188* (0.090)	-2.08	-	-
X_3	-	-	0.495** (0.080)	6.14	-	-	0.504** (0.087)	5.77
X_4	0.113* (0.056)	2.02	-	-	0.123* (0.053)	2.31	-	-
X_5	-	-	0.094** (0.034)	2.76	-	-	0.039 (0.028)	1.35
X_6	0.017 (0.021)	0.78	-	-	0.023 (0.018)	1.22	-	-
X_7	0.174* (0.077)	2.24	-	-	0.178* (0.077)	2.30	-	-
X_8	-	-	0.155 (0.172)	0.89	-	-	0.044 (0.062)	0.71
$\hat{Y}_1$	-	-	0.798** (0.306)	2.61	-	-	0.528 (0.476)	1.11
$\hat{Y}_2$	0.044 (0.076)	0.58	-	-	-	-	-	-
F-value	4.07		21.31**		5.03**		18.25**	
Standard error of regression	0.44		o.61		o.43		0.63	

** significant at 1%
* significant at 10%

Appenidx Table 12. Estimated production functions (Cobb-Douglas) for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, Central Luzon, Philippines, per farm specification, wet-dry season average, 1982-83.

Inputs		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (y_1)									
Intercept[a/] =3.895									
Technical coefficients		0.981**	-0.285*	0.091	-0.026	-0.116**	0.034	0.275*	0.061
t-value		4.69	-2.20	1.05	-0.19	-3.10	0.86	1.77	0.53
Standard error		0.208	0.129	0.086	0.135	0.037	0.039	0.155	0.113
Marginal product (cav.)		78.071	-0.321	0.0016	-0.459	-0.078	0.055	0.205	0.600
Economics of scale (ΣB_i) = 1.01 R^2 = 0.90 F = 53.59**									
Expected level of $\hat{y}_1$ = 19.10 cav.									
Fish (y_2)									
Intercept = 2.129									
Technical coefficients		0.635*	-0.069	0.365**	0.166	0.088*	0.084*	-0.242	0.109
t-value		2.47	-0.44	3.43	0.99	1.90	1.73	-1.26	0.78
Standard error		0.257	0.159	0.106	0.166	0.046	0.048	0.191	0.139
Marginal product (kgs.)		77.152	-0.118	0.010	4.482	0.090	0.210	-0.276	1.638
Economics of scale (ΣB_i) = 1.13 R^2 = 0.86 F = 35.43**									
Expected level of $\hat{y}_2$ = 29.16 kgs.									
Composite output (Q)									
Intercept = 7.997									
Technical coefficients		0.882**	-0.207*	0.141*	-0.014	-0.069*	0.041**	0.152	0.073
t-value		5.67	-2.15	2.19	-0.14	-2.49	1.41	1.31	0.87
Standard error		0.155	0.096	0.064	0.100	0.027	0.029	0.115	0.084
Composite marginal product (₱)		6950.52	-23.14	0.25	-24.52	-4.63	6.67	11.27	71.17
Economics of scale (ΣB_i) = 1.01 R^2 = 0.94 F = 90.25**									
Expected level of $\hat{Q}$ = ₱ 1891.30									
Input mean ($\bar{x}$)	GM[b/]	0.24	16.92	1063.21	1.08	28.21	11.62	25.50	1.94
	AM	0.61	54.02	2602.11	1.55	108.09	49.07	41.99	2.29
Average price of input (₱)			1.58	0.21	116.76			18.56	

a/ Intercepts are in natural log values b/ GM = geometric means; AM = arithmetic means

* significant at 10%

** significant at 1%

Appendix Table 12a. Estimated production function (Cobb-Douglas) for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, Central Luzon, Philippines, per hectare specification, wet-dry season average, 1982-83.

Inputs		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (Y_1)									
Intercept = 3.745									
Technical coefficients		-	-0.311**	0.091	0.019	-0.087**	0.024	0.302**	0.108
t-value		-	-2.36	1.12	0.21	-2.77	0.84	2.73	0.90
Standard error		-	0.132	0.080	0.092	0.031	0.029	0.110	0.120
Marginal product (cav.)		-	-0.340	0.0015	0.433	-0.071	0.077	0.228	4.360
Economies of scale ($\Sigma \hat{B}_i$) = 0.13 R^2 = 0.30 F = 2.88*									
Expected level of $\hat{Y}_1$ = 78.33 cav.									
Fish (Y_2)									
Intercept = 0.923									
Technical coefficients		-	-0.076	0.447**	0.044	0.078*	0.061*	-0.025	0.065
t-value		-	-0.45	4.38	0.37	1.95	1.66	-0.17	0.42
Standard error		-	0.166	0.102	0.117	0.039	0.036	0.139	0.152
Marginal product (kgs.)		-	-0.140	0.013	1.693	0.107	3.315	-0.031	4.422
Economies of scale ($\Sigma \hat{B}_i$) = 0.59 R^2 = 0.39 F = 4.32**									
Expected level of $\hat{Y}_2$ = 131.98 kgs.									
Composite Output (Q)									
Intercept = 7.428									
Technical coefficient		-	-0.226**	0.017**	0.016	-0.050*	0.025	0.245**	0.094
t-value		-	-2.25	2.75	0.24	-2.09	1.11	2.90	1.02
Standard error		-	0.100	0.062	0.070	0.024	0.022	0.084	0.092
Composite marginal product (₱)		-	-21.66	0.025	31.97	-3.58	7.05	16.19	332.08
Economies of scale ($\Sigma \hat{B}_i$) = 0.26 R^2 = 0.32 F = 3.26**									
Expected level of $\hat{Q}$ = ₱ 6,853.73									
Input mean ($\bar{x}$)	GM	1.00	71.51	4492.48	3.43	95.71	24.28	103.68	1.94
	AM	1.00	84.44	6089.94	4.86	346.11	172.85	127.62	2.29
Average price of input (₱)			1.58	0.21	116.76			18.56	

Intercepts are in natural log values

** significant at 1%
* significant at 10%

Appendix Table 13. Estimated production functions (Cobb-Douglas) for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, Bicol Region, Philippines, per farm specification, wet-dry seasons average, 1982-83.

Inputs	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (y_1)								
Intercept[a/] 4.037								
Technical coefficients	0.835**	-0.055	-0.018	0.237*	0.001	0.020	0.061	0.064
t-value	4.73	-0.45	-0.18	2.11	0.05	0.48	0.44	0.66
Standard error	0.176	0.121	0.101	0.112	0.028	0.041	0.138	0.097
Marginal product (cav.)	64.484	-0.054	-0.0002	3.355	0.0006	0.010	0.046	0.584
Economics of scale (ΣB_i) = 1.15 R^2 = 0.94 F = 69.47**								
Expected level of $\hat{y}_1$ = 16.99 cav.								
Fish (y_2)								
Intercept[a/] -0.157								
Technical coefficients	0.618*	-0.321*	0.782**	-0.209*	0.011	-0.055	0.172	0.391*
t-value	2.23	-1.68	4.91	-1.19	0.25	-0.84	0.79	2.56
Standard error	0.277	0.190	0.159	0.175	0.045	0.065	0.216	0.152
Marginal product (kgs.)	186.214	-1.240	0.039	-11.545	0.026	-0.111	0.509	13.935
Economics of scale (ΣB_i) = 1.39 R^2 = 0.84 F = 24.15**								
Expected level of $\hat{y}_2$ = 66.29 kgs.								
Composite output (Q)								
Intercept[a/] 7.207								
Technical coefficients	0.795**	-0.152	0.214**	0.074	0.017	0.0004	0.105	0.154*
t-value	5.36	-1.49	2.52	0.78	0.71	0.01	0.91	1.88
Standard error	0.148	0.102	0.085	0.094	0.024	0.035	0.116	0.081
Composit marginal product (₱)	7230.88	-17.73	0.33	123.39	1.21	0.02	9.38	165.67
Economics of scale (ΣB_i) = 1.21 R^2 = 0.95 F = 90.46**								
Expected level of $\hat{Q}$ = ₱ 2,001.00								
Input mean ($\bar{x}$) GM	0.22	17.15	1313.51	1.20	28.04	32.78	22.39	1.86
AM	0.44	39.11	1992.02	2.89	113.06	87.89	36.42	2.19
Average price of inputs (₱)	-	1.71	0.18	121.41			15.84	

a/ Intercepts are in natural log values.
* significant at 10%
** significant at 1%

Appendix Table 13a. Estimated production functions (Cobb-Douglas) for individual components output and composite output, marginal productivity of input and expected level of production of simultaneous rice-fish culture system, Bicol Region, Philippines, per hectare specification, wet-dry seasons average, 1982-83.

Inputs		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Rice (y_1)									
Intercept[a/] = 3.731									
Technical coefficients		-	-0.049	0.030	0.151*	-0.001	0.007	0.089	0.059
t-value		-	-0.42	0.40	2.06	-0.04	0.29	0.81	0.62
Standard error		-	0.117	0.075	0.073	0.023	0.024	0.110	0.095
Economics of scale (ΣB_i) =		0.29	R^2 = 0.24	F = 1.73					
Expected level of $\hat{y}_1$ = 93.15 cav.									
Marginal product (cav.)		-	-0.059	0.0004	2.137	-0.0009	0.006	0.086	2.954
Fish (y_2)									
Intercept[a/] 1.207									
Technical coefficients		-	-0.351*	0.612**	-0.026	0.012	-0.014	0.079	0.359*
t-value		-	-1.86	5.04	-0.22	0.32	-0.35	0.45	2.33
Standard error		-	0.188	0.121	0.117	0.036	0.039	0.177	0.154
Economics of scale (ΣB_i) =		0.68	R^2 = 0.62	F = 9.13**					
Expected level of $\hat{y}_2$ = 249.87 kgs.									
Marginal product (kgs)		-	-1.141	0.025	-0.987	0.029	-0.035	0.205	48.227
Composit output (Q)									
Intercept[a/] 7.406									
Technical coefficients		-	-0.149*	0.194**	0.079	0.012	0.0008	0.096	0.144*
t-value		-	-1.55	3.13	1.33	0.64	0.04	1.06	1.83
Standard error		-	0.096	0.061	0.060	0.018	0.019	0.090	0.078
Economics of scale (ΣB_i) =		0.36	R^2 = 0.55	F = 5.88**					
Expected level of $\hat{Q}$ = 9661.80									
Composite marginal product (₱)		-	-18.73	0.32	116.00	1.14	0.07	9.66	748.01
Input mean ($\bar{x}$)	GM	1.00	76.86	5885.69	6.58	101.56	99.48	95.99	1.86
	AM	1.00	85.53	8056.98	9.95	393.29	309.56	108.04	2.19
Average price of input (₱)			1.71	0.18	121.41			15.84	

[a/] Intercepts are in natural log values

* significant at 10%
** significant at 1%