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**A COMPARATIVE STUDY ON COST-BENEFIT OF RICE-FISH  
CULTURE UNDER DIFFERENT RATES OF CHEMICAL  
FERTILIZER APPLICATION IN BANGPLAMA DISTRICT  
SUPHANBURI PROVINCE**

**LAKKANA KAEWVICHIT**

อธิพนธ์นทนาการ

จาก

มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT  
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LAKKANA KAEWVICHIT: A COMPARATIVE STUDY ON COST - BENEFIT OF RICE - FISH CULTURE UNDER DIFFERENT RATES OF CHEMICAL FERTILIZER APPLICATION IN BANGPLAMA DISTRICT SUPHANBURI PROVINCE. THESIS ADVISORS: SANSANEE CHOOWAEW, Ph.D., PIROM CHANTHAWORN, Ph.D., ARTHIT NAMASONDHI, M.Sc. 163 P. ISBN 974-664-074-7

A comparative study on cost and benefit of rice culture and rice-fish culture under different rates of chemical fertilizer application was carried out in a farmer's field at Bangplama district, Suphanburi province. The experiment was done during the second crop, transplanting rice cultivation. Mixed chemical fertilizer 16-20-0 was applied at the rate of 30 kg/rai on day 7 after transplanting and urea fertilizer 46-0-0 was applied at 15 kg/rai, 60 days after seedling, as recommended by the Department of Agriculture. There were 5 treatments: rice culture with 100% fertilizer application and rice-fish culture with 100, 75, 50 and 25% chemical fertilizer application, with three replications, 5x5 m<sup>2</sup> (25 m<sup>2</sup>) per plot. Sex reversed *Oreochromis niloticus*, 11 cm in length and 25-30 gm in weight, were stocked at 4 fish/m<sup>2</sup> and KLG 83055-1-1-1-2-1-4 rice variety was grown at the rate of 6 kg/rai. Rice bran was used as fish food at the rate of 5% of fish body weight once a day and neem extract 100 cc/40 litres of water/rai, was used as pesticides. The production cost and benefit were recorded. Cost-benefit analysis, net present value, benefit-cost ratio, internal rate of return and sensitivity were analysed for 1 rai in 10 years period and 12% of discount rate.

The results indicated that there was no difference between rice farming of farmer who owned and who rented the land. Rice-fish culture with 100% chemical fertilizer application gave the highest return (8,764.75 baht/rai). The return decreased when the chemical fertilizer application rate decreased. Rice culture without fish gave the return 4,959.44 baht /rai. The production cost of rice culture without fish was the lowest (3,025.21 baht/rai) and tended to increase when the chemical fertilizer application rate increased. The cost-benefit analysis calculated in 10 years at 12% of discount rate indicated that all treatments provided a profit. The profit from rice-fish culture with 100% chemical fertilizer application was the highest (38,161.13 baht/rai of NPV, 1.63 times B/C ratio and 36.43% of IRR). The profit decreased when the chemical fertilizer application decreased. The profit of rice-fish culture under 25% chemical fertilizer application was the lowest (8,488.60 baht/rai of NPV, 1.15 times of B/C ratio and 33.83% of IRR). The profit from rice culture without fish was in the same range as the profit from rice-fish culture with 75% and 50% fertilizer application. When the production factors changed, the profit of rice culture without fish and rice-fish culture under 50 and 25% chemical fertilizer application tended to decrease dramatically to nonprofit, While the profit of rice-fish culture under 100 and 75% chemical fertilizer application changed but still profitable. The economic analysis indicated that the chemical fertilizer application could be reduced by 25% (or 75% of normal rate) in rice-fish culture and still, the profit was higher than rice culture without fish.

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(สาขาเทคโนโลยีที่เหมาะสมเพื่อการพัฒนาทรัพยากร)

ลักษณะ แก้ววิชิต : การศึกษาเปรียบเทียบต้นทุนและผลตอบแทนของการเลี้ยงปลาในนาข้าวภายใต้เงื่อนไขการใช้ปุ๋ยเคมีในอัตราที่แตกต่างกัน : กรณีศึกษาอำเภอบางปลาม้า จังหวัดสุพรรณบุรี (A COMPARATIVE STUDY ON COST- BENEFIT OF RICE FISH CULTURE UNDER DIFFERENT RATES OF CHEMICAL FERTILIZER APPLICATION IN BANGPLAMA DISTRICT SUPHANBURI PROVINCE). คณะกรรมการควบคุมวิทยานิพนธ์ : ศันสนีย์ ชูแหว, Ph.D. กิรมย์ จันทาร, Ph.D. อาทิตย์ นามะสนธิ, วท.ม. 163 หน้า ISBN 974-664-074-7

การศึกษาเปรียบเทียบต้นทุนและผลตอบแทนของการทำนาข้าวและการเลี้ยงปลาในนาข้าวภายใต้เงื่อนไขการใช้ปุ๋ยเคมีในอัตราที่แตกต่างกัน ทำการทดลองในแปลงนาเกษตรกรอำเภอบางปลาม้า จังหวัดสุพรรณบุรี ในฤดูนาปรัง ระบบการทำนาแบบปักดำ ใส่ปุ๋ยเคมีตามคำแนะนำของกรมวิชาการเกษตร คือปุ๋ยเคมีเชิงผสม สูตร 16-20-0 อัตรา 30 กิโลกรัม/ไร่ ในระยะ 7 วันหลังจากปักดำ และครั้งที่ 2 ใส่ปุ๋ยยูเรียสูตร 46-0-0 อัตรา 15 กิโลกรัม/ไร่ ในระยะ 60 วันหลังจากตกกล้า ในแปลงนาข้าวปกติและแปลงนาข้าวที่มีการเลี้ยงปลา ซึ่งทดลองผันแปรอัตราการใส่ปุ๋ยเคมี โดยลดปริมาณการใส่ปุ๋ยเคมีให้เหลือร้อยละ 75, 50 และ 25 ของอัตราที่กรมวิชาการเกษตรแนะนำ ดังนั้นจะได้กลุ่มทดลอง 5 กลุ่ม ทำการทดลอง 3 ซ้ำ ในพื้นที่แปลงทดลองขนาด 25 ตารางเมตร ปล่อยปลาชนิดปลานิลแปลงเพศขนาด 11 เซนติเมตร น้ำหนัก 25-30 กรัม ในอัตรา 4 ตัวต่อตารางเมตร ใช้พันธุ์ข้าวเจ้าหอมคลองหลวง 1 ในอัตรา 6 กิโลกรัมต่อไร่ ใช้รำข้าวเป็นอาหารปลาในอัตราร้อยละ 5 ของน้ำหนักตัวปลา วันละ 1 ครั้ง และใช้สารสกัดสะเดาในอัตรา 400 ซีซี ต่อน้ำ 40 ลิตร ต่อ 1 ไร่ เก็บรวบรวมข้อมูลต้นทุนการผลิต และผลตอบแทน นำมาวิเคราะห์ต้นทุน ผลตอบแทน มูลค่าปัจจุบันสุทธิ อัตราส่วนผลตอบแทนต่อต้นทุน อัตราผลตอบแทนภายใน และวิเคราะห์ความอ่อนไหวของการลงทุนในทางเศรษฐศาสตร์ ในขนาดพื้นที่ 1 ไร่ ในระยะเวลา 10 ปี ที่อัตราส่วนลดร้อยละ 12

ผลการศึกษาพบว่า การทำนาในพื้นที่ของตนเองและในพื้นที่เช่า ผลการวิเคราะห์ทางเศรษฐศาสตร์ไม่มีความแตกต่างกัน แปลงนาที่เลี้ยงปลาซึ่งใช้ปุ๋ยเคมีในอัตราปกติให้ผลตอบแทนสูงสุด คือ 8,764.75 บาทต่อไร่ และให้ผลตอบแทนลดลงเมื่อลดอัตราการใส่ปุ๋ยเคมี ส่วนแปลงนาปลูกข้าวอย่างเดียวให้ผลตอบแทน 4,959.44 บาทต่อไร่ แปลงนาปลูกข้าวอย่างเดียวมีต้นทุนการผลิตต่ำสุดคือ 3,025.21 บาทต่อไร่ และมีต้นทุนเพิ่มขึ้นเมื่อใส่ปุ๋ยเคมีเพิ่มขึ้น การวิเคราะห์ต้นทุนผลตอบแทนในระยะเวลา 10 ปี ที่อัตราคิดลดร้อยละ 12 พบว่า ทุกการทดลองให้ผลตอบแทนทางเศรษฐศาสตร์ที่ได้ผลกำไร โดยแปลงนาเลี้ยงปลาอัตราการใส่ปุ๋ยเคมีร้อยละ 100 ให้ผลกำไรสูงสุดคือ มีมูลค่าปัจจุบันสุทธิ 38,161.13 บาทต่อไร่ อัตราส่วนผลตอบแทนต่อต้นทุน 1.63 เท่า และอัตราผลตอบแทนภายใน 36.43% และให้ผลกำไรลดลงเมื่อลดอัตราการใส่ปุ๋ยเคมี โดยแปลงนาเลี้ยงปลาที่ใช้ปุ๋ยเคมีร้อยละ 25 ให้ผลกำไรต่ำสุดคือ มีมูลค่าปัจจุบันสุทธิ 8,488.60 บาทต่อไร่ อัตราส่วนผลตอบแทนต่อต้นทุน 1.15 เท่า และอัตราผลตอบแทนภายใน 33.83% ผลกำไรที่ได้จากแปลงนาปลูกข้าวอย่างเดียวจะอยู่ในช่วงเดียวกับผลกำไรที่ได้จากแปลงนาเลี้ยงปลาที่ใช้ปุ๋ยเคมีร้อยละ 75 กับ 50 เมื่อมีการเปลี่ยนแปลงปัจจัยการผลิตแปลงนาปลูกข้าวอย่างเดียวและแปลงนาเลี้ยงปลาที่ใช้ปุ๋ยเคมีร้อยละ 50 และ 25 มีแนวโน้มที่จะให้ผลกำไรลดลงจนถึงขาดทุนมากที่สุด ในขณะที่แปลงนาเลี้ยงปลาที่ใช้ปุ๋ยเคมี ร้อยละ 100 และ 75 มีแนวโน้มให้ผลกำไรเปลี่ยนแปลงแต่เป็นการเปลี่ยนแปลงที่ยังคงให้ผลกำไร การพิจารณาทางเศรษฐศาสตร์ พบว่า การลดการใช้ปุ๋ยเคมีร้อยละ 25 (หรือใช้ปุ๋ยร้อยละ 75 ของอัตราเดิม) ร่วมกับการเลี้ยงปลาในนาข้าว สามารถให้ผลตอบแทนที่สูงกว่าการปลูกข้าวอย่างเดียว

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## CHAPTER I

### INTRODUCTION

#### 1.1 Background and problems

For the past 3-4 decades, rice monoculture has been the major production system in the Central Plain of Thailand. Heavy machineries, high yield varieties of rice and chemical pesticides have been used along with chemical fertilizers to increase rice yield. According to the Office of Agricultural Economics (1995) (1), the central region had higher rate of using modern technology but much less planted area than the other regions (Table 1-1).

Modern technology has led to the higher cost of production. In 1995, the central region had the total cost of rice production of 3,311.02 baht/rai, which was higher than of the other regions (Table 1-1). The value of importation of chemical fertilizers and pesticides of Thailand had also higher rate from 2,736.5 million baht in 1977 to 19,433.10 million baht in 1995 or 12.56% increased per year on average (Table 1-2) (2,3,4,5,6,7&8).

**Table 1-1 : Rice planted area, productivity and cost by region in 1995.**

<b>Items</b>	<b>northeast</b>	<b>north</b>	<b>central<sup>1/</sup></b>	<b>south</b>
<b>Total land area (Rais)</b>	<b>105,533,963</b>	<b>106,027,680</b>	<b>64,196,992</b>	<b>44,196,992</b>
<b>Farm holding land (Rais)</b>	<b>57,615,984</b>	<b>28,904,863</b>	<b>27,547,973</b>	<b>17,202,073</b>
• <b>Planted area (Rais)</b>	<b>32,359,069</b>	<b>14,516,384</b>	<b>13,515,044</b>	<b>2,962,506</b>
- Major rice	32,024,711	12,772,740	9,762,606	2,846,934
- Second rice	334,358	1,743,644	3,752,438	115,572
• <b>Production (Tons)</b>	<b>8,587,022</b>	<b>5,857,289</b>	<b>6,610,299</b>	<b>960,871</b>
- Major rice	8,435,539	4,586,988	3,790,644	915,446
- Second rice	151,483	1,270,301	2,819,655	45,425
• <b>Yield per rai (Kgs)</b>	<b>740</b>	<b>1,189</b>	<b>1,220</b>	<b>730</b>
- Major rice	281	453	465	337
- Second rice	459	736	755	393
• <b>Total cost of rice production (Baht/rai)</b>	<b>2,543.78</b>	<b>3,176.94</b>	<b>3,311.02</b>	<b>2,952.52</b>
- Variable cost	2,199.81	2,748.95	2,870.62	2,546.64
- Fixed cost	343.97	427.99	440.4	405.88
• <b>Two wheel walking tractors (Units)</b>	<b>202,769</b>	<b>696,905</b>	<b>376,039</b>	<b>239,980</b>
• <b>Big tractors (Units)</b>	<b>17,418</b>	<b>39,457</b>	<b>87,721</b>	<b>4,245</b>
• <b>Water pump (Units)</b>	<b>310,160</b>	<b>504,438</b>	<b>1,123,937</b>	<b>99,779</b>
• <b>Sprayers with machine operated (Units)</b>	<b>20,563</b>	<b>57,701</b>	<b>304,120</b>	<b>7,795</b>
• <b>Sprayers with hand operated (Units)</b>	<b>2,602,406</b>	<b>3,670,717</b>	<b>2,328,417</b>	<b>1,289,088</b>
• <b>Threshing equipment (Units)</b>	<b>6,365</b>	<b>22,463</b>	<b>36,682</b>	<b>3,017</b>
• <b>Chemical fertilizer (Tons)</b>	<b>80,648</b>	<b>36,635.45</b>	<b>56,951.30</b>	<b>33,259.20</b>

Source : Agricultural Statistics of Thailand, Crop Year 1995/1996. Office of  
Agricultural Economics. Ministry of Agriculture & Co-operatives.

Note : 1/ The Central = central and eastern regions

**Table 1-2 : Value of chemical fertilizers and pesticides imported to Thailand, 1977-1995.**

year	Value (Million baht)	% increasing per year <sup>1/</sup>
1977	2,736.50	-
1978	2,937.50	7.35
1979	3,972.00	35.22
1980	4,224.70	6.36
1981	5,180.50	22.62
1982	4,724.60	-8.80
1983	6,232.50	31.92
1984	6,162.60	-1.12
1985	6,748.50	9.51
1986	6,678.61	-1.04
1987	6,698.52	0.30
1988	10,073.96	50.39
1989	13,034.20	29.39
1990	14,351.80	10.11
1991	13,138.20	-8.46
1992	15,862.50	20.74
1993	16,740.60	5.54
1994	16,752.90	0.07
1995	19,433.10	16.00
<b>Average</b>		<b>12.56</b>

Source : Department of Business Economics. Trade Statistic and Economic Indicators of Thailand 1981-1996.

Note : 1/ Calculation

There has been a significant increase of chemical fertilizer application in rice production between 1977 to 1995, from 370,000 to 1,501,896 tons or 4% increased per year on average (Table 1-3) (9).

**Table 1-3 : Quantity of chemical fertilizers used in rice production of Thailand during 1977-1995.**

Year	Dry season (Tons)	Wet season(Tons)	Total(Tons)
1977	265,662	104,338	370,000
1978	291,365	128,635	420,000
1979	300,000	178,500	478,500
1980	320,000	100,940	420,940
1981	340,055	154,092	494,147
1982	373,851	169,453	543,304
1983	466,454	202,490	668,944
1984	443,808	204,125	647,933
1985	413,929	196,071	610,000
1986	447,857	212,143	660,000
1987	459,240	180,760	640,000
1988	611,000	241,000	852,000
1989	857,820	252,980	1,110,800
1990	739,400	260,600	1,000,000
1991	720,800	130,400	851,000
1992	709,000	279,000	988,000
1993	1,133,073	228,364	1,361,437
1994	1,233,943	161,909	1,395,852
1995	1,270,867	231,029	1,501,896

Source : Office of Agricultural Economics, 1996.

In spite of using higher quantity of chemical inputs, rice yield of Thailand did not show a dramatic increase. In fact, rice yield per a million ton of chemical fertilizer application has decreased obviously. Moreover, using more chemical inputs has also deteriorated soil fertility and other physical properties. Consequently, farmers needed to apply more and more chemical inputs and increase their total production cost (Table 1-4) (10&11). The present economic crisis of Thailand does not allow farmers to cope with high expenses on high yielding rice varieties, chemical fertilizers, pesticides and

other heavy machineries. Rice monoculture is no longer a sustainable production system. Other alternatives need to be sought of. In order to reduce the application rates of chemical fertilizers and pesticides in ricefield, rice-fish culture is viewed as one of possible alternatives.

**Table 1-4 : Rice yield of Thailand and the rate of chemical fertilizer application in paddy field during 1979-1995.**

Year	Quantity of chemical fertilizer used in paddy field (million tons) <sup>1/</sup>	Rice yield (million tons) <sup>2/</sup>	Rice yield/ 1 million ton of chemical fertilizer (million tons) <sup>3/</sup>
1979	0.48	17.50	36.46
1980	0.42	15.80	37.62
1981	0.50	17.40	34.80
1982	0.54	17.80	32.96
1983	0.67	16.90	25.22
1984	0.65	19.50	30.00
1985	0.61	19.90	32.62
1986	0.66	20.26	30.70
1987	0.64	18.87	29.48
1988	0.85	18.04	21.22
1989	1.11	21.26	19.15
1990	1.00	20.60	20.60
1991	0.85	17.19	20.22
1992	0.99	20.40	20.61
1993	1.36	19.92	14.65
1994	1.40	18.92	13.51
1995	1.50	19.88	13.25

Source : 1/. Office of Agricultural Economics,1996.

2/. Office of Agricultural Economics,1996.

3/. Calculation.

Rice-fish culture has been promoted in Thailand by the Department of Fisheries since 1948 (12). This has been practiced in Ubonratchatani since 1984 (13). In 1991, it has been promoted throughout the northeastern region, e.g., Tung Kula Ronghai Project, Rainfed Agricultural Development Project, Northeastern Fisheries Project and National Inland Fisheries Project (14). The technique has also been practiced in the north and the central areas including Suphanburi province at Suphanburi Rice Experiment Station in 1989. The experiment was undertaken in 4.5 rai of rice cultivated area and 0.75 rai of ditch area. Various rice varieties, e.g., RD.15, Dok Mali 105 and Pathumthani 60 and three species of fish, i.e., *Oreochromis niloticus*, *Cyprinus carpio* and *Puntius gonionotus* were selected for the experiment. In the initial study, number of fish released was 1,000 fish/rai. The chemical fertilizer was used at the minimum quantity while there was no use of chemical pesticide. The primary result showed an increase of both rice and fish yields (15). Fish was able to help control plant diseases and eliminate pests. The movement of fish also stirred water and soil which helped add dissolved oxygen needed for the development of the root system of rice. Besides, fish feces were rich of nitrogen and organic nutrients which were essential for rice growth (12). A long period of rice-fish culture definitely increases soil fertility continuously and also improves the physical characteristics of soils (16). However, rice-fish culture has not been widely practiced among Suphanburi farmers because the data on rice and fish yields were not available for comparison.

For this reason, this study focuses on the comparison of cost and benefit of rice-fish culture under different application rates of chemical fertilizer and neem extract used as natural pesticides. The study tends to determine whether rice-fish culture can help reduce chemical fertilizer application without decreasing rice yield as well as farmers' income.

The expected outcome will be useful for promoting rice-fish culture in the central region of Thailand. In addition, this example of integrated farming practice, if economically feasible, will help decrease farmers' production cost and improve the overall environmental quality.

## 1.2 Objective of the study

To compare the cost-benefit of rice-fish culture under different rates of chemical fertilizer application.

## 1.3 Scope of the study

### 1.3.1 Conditions of experiment

The experiment was conducted in Bangplama district, Suphanburi province, Thailand. The experimental plots were on Ayuthaya soil series, plain area, clayey soil with moderate fertility. Rice was transplanted on the experimental plots, with 20x20 cm spacing, during March-June, 1998.

### 1.3.2 Controlled variables

1. Sex reversed *Oreochromis niloticus* was used for the experiment. The fish were stocked at the rate of 4 fish/m<sup>2</sup>. The fish were 11 cm in length, 25-30 gm in weight, and 2 months old. Fish were procured from the Genetic Fisheries Division, Department of Fisheries.

2. KLG 83055-1-1-2-1-4 rice variety derived from Suphanburi Rice Experiment Station was used for the experiment. The maturity period was about 120 days.

3. Neem extract purchased from commercial source was used for the experiment at the rate of 100 cc/40 litres of water/rai.

4. The experiment period was about 4 months in second rice cropping period (March to June).

5. The experimental plots were irrigated and water was maintained at 30 cm deep.

6. Rice bran was used for fish feeding at the rate of 5% of fish body weight.

### 1.3.3 Factor variables

Rice and rice-fish culture were comparatively investigated using the amount of chemical fertilizer recommended by the Department of Agriculture. Two types of chemical fertilizer were applied to all experimental plots : 16-20-0 and 46-0-0. Chemical fertilizer application rates were varied from 100, 75, 50 and 25%.

### 1.3.4 Cost-benefit analysis included :

#### 1. Cost

Total costs = Fixed costs(cash + non cash) + Variable costs(cash + non cash)

Fixed costs = Land taxes, land rent, opportunity cost and depreciation cost

Variable costs = Labor cost for land preparation until harvesting and material costs

#### 2. Benefit

Total benefits = Total yield x Price/unit

Total yield = Productivity of rice and fish

Net profits = Total benefit - Total cost

Economic analysis included:

1. Net Present Value (NPV)
2. Benefit Cost Ratio (B/C ratio)
3. Internal Rate of Return (IRR)
4. Sensitivity Analysis

#### **1.4 Expected outcome**

1. To provide the basic estimation on the cost-benefit of rice-fish culture in the central region of Thailand under different rates of chemical fertilizer application.
2. To provide the decision supporting data for farmers on the reduction of chemical fertilizer application by rice-fish culture.
3. To provide the information for the agricultural extension offices for rice-fish culture promotion in order to reduce the quantity of chemical fertilizer application.
4. To promote the rice-fish culture as the appropriate technology for agricultural and environmental management.

## CHAPTER II

### LITERATURE REVIEW

#### 2.1 Rice production system in the central region of Thailand

The central region of Thailand has been almost completely under the irrigation system development. Rice cultivation characteristics are generally transplanting and broadcasting cultivation. Rice yield can be successfully increased because factors of production can be easily controlled (17).

In transplanting cultivation, rice sprouts are sown in mud field. They are then transplanted in prepared field. Water is the main physical factor that is necessary for rice root development.

In broadcasting cultivation, rice seeds are broadcasted in the field. This cultivation practice depends on both rainfall and irrigation.

1. For rainfed crops, rice seeds are broadcasted in dry field and then developed to be seedlings after the rain falls.

2. For irrigated crops, rice seeds are broadcasted in prepared mud field. Water supply is controlled.

Under complete irrigation system, rice is cultivated twice a year in the Central : wet season (May - November) and dry season (November - April).

## 2.2 Rice production factors

Each step of rice production depends on several factors and costs (18). In 1996, the Suphanburi Rice Experiment Station (19) studied the second rice production cost of farmers in Suphanburi province. The result of this study is shown in Table 2-1.

**Table 2-1 : Activities and costs of second rice production in Suphanburi province, 1996.**

Activities	Costs (Baht/rai)
1. Land preparation	
1.1 Burning straw	5
1.2 Ploughing	120
1.3 Harrowing	100
1.4 Grading ground of surface soil	150
2. Seedling preparation	169.50
3. Labor cost for sowing	35
4. Labor cost for rice repairing	5
5. Chemical pesticide spraying	
5.1 Chemical pesticide	203
5.2 Labor	245
6. Prevention of snail	
6.1 Francydran chemical	36
6.2 Labor	5
7. Prevention of rat	
7.1 Sing phosphile chemical	1.00
7.2 Labor	2.50
8. Water pumping management	226
9. 1 <sup>st</sup> application of chemical fertilizer	
9.1 16-20-0	110
9.2 46-0-0	35
9.3 Labor	15
10. 2 <sup>nd</sup> application of chemical fertilizer	
10.1 16-20-0	233.75
10.2 46-0-0	43.75
10.3 Labor	29.25
11. Threshing	420
12. Land rent	630
14. Interest rate(12%)	42.30
<b>Total costs</b>	<b>2,862.05</b>

Source : Jittaldakorn et al.,1996.

The total costs of second rice production was 2,862.05 baht/rai. Major items were for land preparation, chemical pesticide spraying, chemical fertilizer application, threshing and land rent. Especially, the production cost of chemical fertilizer and pesticide management was 914.75 baht/rai or 32% of total production cost. Income derived from rice selling was 4,200 baht/rai and the farmer's net profit was 1,337.95 baht/rai.

According to the Agricultural Economics Office (1996) (20), the production cost for second rice was 2,081.24 baht/rai. The production cost of chemical fertilizer and pesticide management was 482.63 baht/rai or 23% of total production cost, income was 3,303.81 baht/rai and the farmer's profit was 1,222.57 baht/rai. However, Sinthanaporn (1998) (21) reported the farmer have not gained profit from rice farming activities. In Chachoengsao province, the farmer had debt as equal as 2,076 baht/rai.

## **2.3 Chemical fertilizers and pesticides application in paddy field**

### **2.3.1 Chemical fertilizer application**

Most of chemical fertilizers applied into ricefields are of 2 types (22) :

1. Single fertilizer consists of one major element, i.e. nitrogen (N), phosphorus (P) and potassium(K) (18). Especially, 45% nitrogen urea fertilizer is popularly used in paddy field. The amount of 100 kg of urea fertilizer gives 45 kg of nitrogen element (N) (23).
2. Mixed fertilizers, such as 16-20-0 and 18-22-0, provide nitrogen and phosphorus elements (23).

In addition, organic fertilizer is used for soil improvement such as blue-green algae which can be used as substitutes of nitrogen fertilizer. However, this technology is still limitedly used (24).

### 2.3.2 Chemical pesticide application

Diseases and pests of rice plant are major causes affecting about 15-20% of rice productivity. At present, many types of chemical pesticides are applied (Table 2-2).

**Table 2-2 : Chemical pesticides applied in paddy field.**

No.	Common name	Commercial name	Type of diseases and pests
1.	Kasugamycin	Kasumin 2% WP	Blast diseases
2.	Maneb	Manzate D 80% WP or Maneb 80% WP	Sheath roof disease
3.	Validamycin	Validacin 3% EC	Sheath Blight disease
4.	Carbofuran	Furadan 3% G	Rice stem borer, Brown planthopper, Whitebacked planthopper, Rice green leafhopper, Rice gall midge and Golden Apple Snail
5.	Cartap	Padan 4 G	Rice stem borer and Golden Apple Snail
6.	Carbaryl	Seven 85%	Rice thrips, Rice green leafhopper, Rice hisba, Rice caseworm and Rice leaf folder
7.	Malathion	Malathion 57 EC	Rice thrips, Rice swarming caterpillar, Rice hispa, Rice caseworm and common armyworm
8.	Metaldehyde	Anglo slug 5% granular bait	Golden Apple Snail

Source : Tongdeetae, 1996 (25).

### 2.3.3 Consequences of chemical fertilizer and chemical pesticide application

In 1995, Bangplama district, Suphanburi province has faced with soil fertility depletion because of double cropping (26). Also, there has been frequent use of chemical pesticides. Rice productivity dropped. Especially in 1990 (January to July), the brown planthopper epidemic destroyed a total area of 52,529 rai, 28% of paddy field area in Bangplama district. Moreover, the occurrence of toxic accumulation affected both farmer's health and environment quality. Accordingly, effects of toxic chemicals on aquatic animals in paddy field were reported in Suphanburi province (27).

Sangwanit (1988) (27) collected examples of aquatic animals including fish, crab and snail for investigating toxic substances. The result showed a high quantity of chemical pesticide residues in aquatic animals which is Organochlorine chemical pesticide group, e.g., Heptachlor, Dieldrin, Endrin and DDT. This chemical pesticide group is highly toxic, slowly dissolvable and increasingly accumulated in aquatic animals in a long period. Moreover, aquatic animals will increasingly receive toxic substances from food chain in ecosystem (Table 2-3).

**Table 2-3 : Pesticide residues found in aquatic animals in paddy field Suphanburi province, 1988.**

Aquatic animal Samples	Finding species	Toxic substance	Quantity accumulated in aquatic animals (ppm)
Fish	<i>Anabas testudineus</i>	Heptachlor	ND-0.009
	<i>Notopterus notopterus</i>	Aldrin, Endrin	ND-0.002, ND-0.026
	<i>Trichogaster microlepis</i>	DDT	ND-0.009
Crab	<i>Paralaubuca riveroi</i>	Dieldrin, DDE, TDE	ND-0.061, ND-0.050, ND-0.045
Snail	<i>Sinotaia ingallsiana</i>	BHC, Heptachlor expoxide	ND-0.018, ND-0.004

Source : Sangwanit, 1988.

Note : ND = Non Detectable

A comparison of various pesticides toxicity on *Oreochromis niloticus* after exposure for 48 hr was reported (28). Table 2-4 shows a comparison on various pesticides' toxicity. The LC<sub>50</sub> value on *Oreochromis niloticus* indicates the toxicity of each substance. In comparison among pesticides, neem seed extract, a natural pesticide is less toxic than the others since its LC<sub>50</sub> value is highest (1,040.5 mg/litre). That means neem seed extract can be used at a concentration of 1,040.5 mg/litre in order to kill half of the amount of *Oreochromis niloticus* after 48 hr exposure. The toxicity of other chemical pesticides is very high even at a low concentration.

**Table 2-4 : Comparison of various pesticides' toxicity on *Oreochromis niloticus* after 48 hr exposure.**

Toxicity series	Common name	Target	LC <sub>50</sub> value (mg/ 1 litre of water)	Maximum rate of application (mg/ 1 litre of water)
1	Cyfluthrin	insect	0.010	50.00
2	Fenvalerate	"	0.058	200.00
3	Cypermethrin	"	0.150	250.00
4	Cabophenothion	"	0.217	718.50
5	Mevinphos	"	0.777	480.00
6	Chlofuzuron	"	0.799	100.00
7	Mancozeb	fungi	1.436	1,200.00
8	Phomothion	insect	5.926	1,237.50
9	Thephubenzuron	"	7.031	100.00
10	Methyl parathion	"	8.531	1,000.00
11	Dimethoate	"	43.660	200.00
12	Diflubenzuron	"	66.511	500.00
13	Monocrotophos	"	251.574	600.00
14	neem seed extract	"	1,040.500	33,000.00

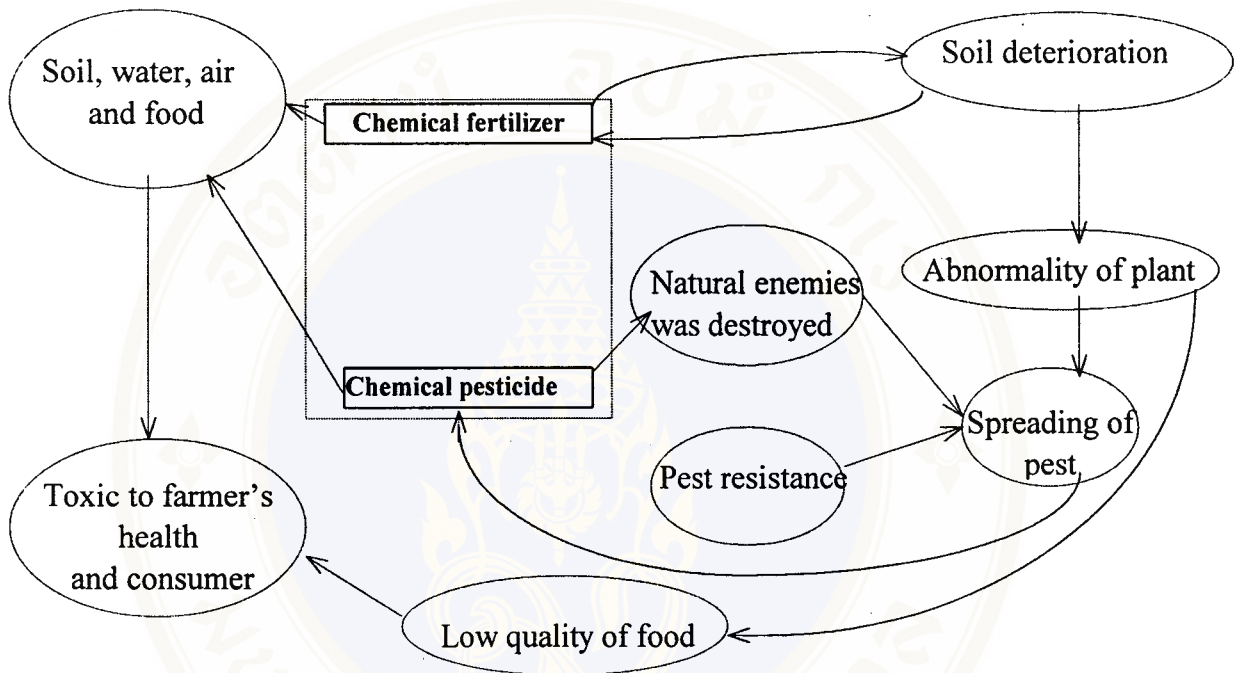
Source : Agricultural Toxic Substance Division, 1995.

Note : LC<sub>50</sub> = Median Lethal Concentration

Not only misuse and overuse of chemical fertilizer have no benefit for ricefield but also lead to high cost of production. Only 30-50% of nitrogen and 20-30% of phosphorus can be absorbed by rice plant for growth (29). The rest of chemical fertilizer may leach in the soil or is absorbed by weeds. So the overuse of chemical fertilizer is not beneficial to rice culture (23).

Disadvantages of overuse of chemical fertilizers and pesticides are increase of farmers' debt, harmful effects on farmers' health, pest resistance and plant disease

epidemic, deterioration of natural resources and ecosystems, toxic residues in aquatic organisms, and low quality of agricultural products (Fig.2-1).



**Fig. 2-1 : Effects of chemical fertilizer and pesticide application for monoculture (30).**

Source : Non-government organization of the central and northern regions, 1992.

Application of chemical fertilizer and pesticides can be reduced to an appropriate quantity and substituted by natural products ,e.g., neem seed extract which is cheap and safe for farmers, environment, natural enemies (31).

## 2.4 Rice-fish culture system

Rice-fish culture has been introduced to many countries of Asia such as Indonesia, Philippines, China and Thailand since 1948 (12). The system was practiced for the first time in Ubonratchathani province in 1984 (13). Soil characteristics of the northeastern region are saline, silty-sand or laterite, low fertility, and the irrigation system is inadequate, agriculture in most areas is rain dependent. Shortage of rainfall occasionally causes the decreased yield and increase of farmer's debt. In order to solve these problems and to increase the protein food source, the Department of Fisheries promotes rice-fish culture. In 1985, rice-fish culture has been introduced to the area of 14,902.76 rai of 3,733 farmers in the northeastern region (32). Rice yield was 8,069.80 tons, the value was 21.6 million bahts. Rice-fish culture has been practiced in Khonkaen, Mahasarakham, Ubonratchathani, Sisaket and Kalasin provinces. At present, it has been more widely spread in the northern and the central areas. The experiments of the Department of Fisheries and Department of Agriculture have suggested patterns, methods and techniques for rice-fish culture system that farmers can adopt as follows.

### 2.4.1 Site selection for rice-fish culture

Criteria for selecting appropriate sites (12&33) are as follows.

1. The site should have or should be near the water source such as reservoir, swamp, canal, for convenient water supply. In case of rainfed area, water should be stored in the field for at least 90 days during the period of rice-fish culture.
2. The site should be safe from flood and the water level should be controlled at least 30 cm in height.
3. Soil properties should be clay and extra absorption.
4. The site should locate near the farmer's residence.

#### 2.4.2 Pattern of rice-fish culture

##### Size of field

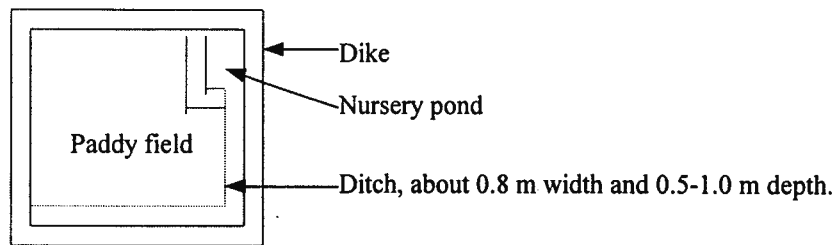
Normally, an appropriate size of the rainfed rice growing plot is about 5 rai or larger in order to gain a high net return (12&34). Therefore, farmers should start with a smaller plots at the beginning of rice-fish farming and extend to larger areas when they have adequate experience (35&36).

##### Paddy field preparation

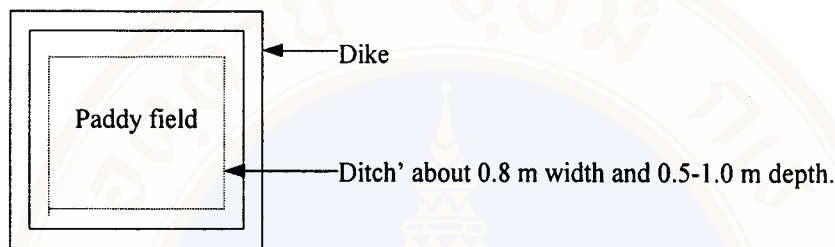
Sripitakkiat (37) divided rice-fish field preparation into 3 categories.

1. Three sided dikes and 1 highest side is open, which is appropriate for the mountainous slope and rainfed rice area.
2. Four sided dikes. This pattern is usually found in the central area and many irrigated areas.
3. Refuge pond, dug about 50-100 m in depth at the lowest part of the field. This pond is a refuge for fish.

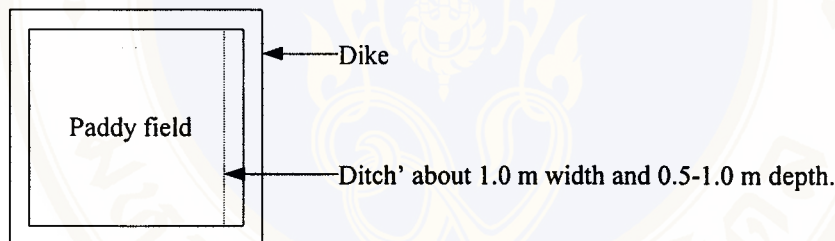
Ratanawaraha and Sangpeth (34) reported that four patterns have been used for land preparation in rice-fish farming (Fig. 2-2).



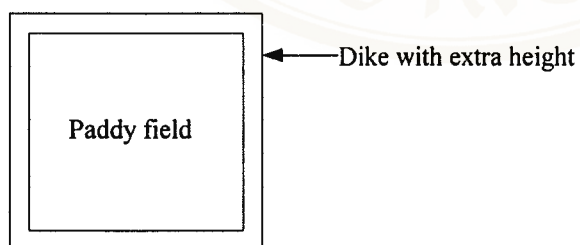
**Pattern 1.** Rice plot with 4 sided dikes, 2 ditches and 1 nursery pond.



**Pattern 2.** Rice plot with 4 side surrounded dikes and surrounded ditch.



**Pattern 3.** Rice plot with 4 sided dikes and 1 ditch.



**Pattern 4.** Rice plot with 4 sided dikes with extra height.

**Fig. 2-2 : Patterns of rice-fish farming.**

Pattern 1 with a nursery pond is popular in the northeastern region because it is easy to catch fish and water is maintained throughout the dry season. However, for the

central area where there is complete and sufficient irrigation system, this pattern is too expensive. Patterns 2 and 3 are appropriate but ditching cost is very high. Pattern 4 which has no ditch in the field, is suitable for the flooded area, but not appropriate for the Central which is plain area.

Most of the central area is paddy field and is suitable for rice-fish farming. Four sided dikes pattern is the most popular, providing that the height of dikes should be added to 50 cm in order to prevent seepage of water. Ditch is dug about 80 cm wide and 50-80 cm deep near the edge of the dike. At the corner, a compile pond is dug near the inlet or farmer's home (33). Bamboo screens or plastic nets should be installed to prevent fish escape through irrigation and drainage holes (37).

#### 2.4.3 Fish species

Fish species appropriate for rice-fish culture should have some characteristics (12,33&37) as follows.

1. tolerate to shallow and turbid water,
2. tolerate to high or varied temperatures throughout the day,
3. tolerate to the fluctuation of dissolved oxygen,
4. have rapid growth rate and compatible to short period of rice growth (about 120 days),
5. feed on natural food and supplementary food available locally,
6. have least damage on dikes and rice seedlings,
7. widely distribute in many agricultural areas,
8. edible and locally acceptable as local protein food source with good taste.

Fish species recommended for rice-fish culture are such as *Oreochromis niloticus*, *Cyprinus carpio*, *Puntius gonionotus*, *Aristichthys nobilis* and *Hypophthalmichthys*

*molitrix* (12&37). These fish species feed on natural food, both phytoplankton and zooplankton. Each fish species has its own characteristics and there are advantages and limitations in each fish species (33&37).

### ***Oreochromis niloticus***

Advantages: Widely distributed, able to inhabit both freshwater and brackish water. *Oreochromis niloticus* shows rapid growth rate, tolerate to wide range of environmental conditions and easily breed.

Limitations: Fully mature at the age of 4 months, breed and give great number of fingerlings, causing high density. This problem can be solved, if farmers use the sex-reversed *Oreochromis niloticus*, their size would be appropriate by the catching time.

### ***Cyprinus carpio***

Advantages: Its stirring behavior helps add dissolved oxygen for the growth and development of rice plant. And also, it helps reduce diseases, pests and caterpillars of crabs and shells.

Limitations: Its stirring behavior, destroys the dikes, causing fish escape and water leakage, damage to rice plant's roots and water turbidity. This affects the decrease in the photosynthesis of phytoplankton and decrease of natural food for fish.

### ***Puntius gonionotus***

Advantages: The fingerlings feed on both phytoplankton and zooplankton. Adulted fish feed on larger plants and animals such as algae and weed.

Limitations: The fish destroy rice stems, leaves, ears.

### ***Aristichthys nobilis* and *Hypophthalmichthys molitrix***

Advantages: Feed on both phytoplankton and zooplankton.

Limitations: Heavy-eating habits, supplement food required.

Among the recommended fish species, *Oreochromis niloticus* is widely accepted due to the following reasons:

1. tolerant to shallow water (as to 30 cm deep), varied temperatures, turbid water and the fluctuation of oxygen,
2. easy to raise with natural food available in ricefield,
3. causing least damage to rice plants,
4. rapid growth rate, short generation time and compatible to rice growing period,
5. local fish species and easily breed.

#### 2.4.3.1 Sizes, stocked density and releasing period

Normally, fish are released at about 5-7 cm in size when they are able to feed on natural food and escape from predators. Stocking density is 400-800 fish/rai at which the growth rate of fish is highest (12&37). Mang-umphan and Promya (38) investigated various rates of *Oreochromis niloticus* released into ricefield of about 25 m<sup>2</sup>. The results revealed that the releasing rate of 4 fish/m<sup>2</sup> (6,400 fish/rai) gave the maximum rice yield at 4.53 kg/25 m<sup>2</sup> (289.92 kg/rai). The stocking density of 4 fish/m<sup>2</sup> is an appropriate rate and fingerlings are normally released after 15-20 days of rice transplanting to allow the root of rice seedlings fully develop (12).

#### 2.4.3.2 Fish food and feeding method

Natural food is generally available in the field but it may not be enough for fish feeding. So supplementary food can be chosen as follows (12,37&39).

1. Locally available food given at the edge of dike are such as rice bran, termites, chopped vegetables, weeds, algae and bean.

2. Compost which contain layers of the stack, dry weed, farmyard manure, is heaped at the compilation pond in the field corner. This was confined by bamboo screen. Occasionally, excrement of animal is also broadcasted into ricefield.

3. Fish are fed with commercial pellet food once a day at the rate of 3-5% of body weight.

This experiment used rice bran for fish feeding once a day at the rate of 5% of body weight.

#### 2.4.4 Rice varieties for rice-fish culture

Rice varieties recommended by the Department of Agricultural Extension vary with localities. Each rice variety has different characteristics that suit each environment. Rice stem should be strenuous and high. The maturity period should be at least 120 days (12).

In rice-fish culture, rice can be both transplanted and broadcasted, but transplanting is more acceptable because it is easier for fish to search for food. If farmer chooses broadcasting cultivation, a channel in ricefield should be provided for fish movement or the fish stocking rate should be decreased.

#### 2.4.5 Additional care and maintenance

The Department of Fisheries (12) recommended that rice-fish culture should be maintained as follows.

1. Before fish release into the field, the enemies of fish such as striped snake, snake, frog, and rat should be eradicated.
2. Level of water should be controlled at least at about 30 cm until harvesting.
3. The height and strength of rice plot dike should be increased and continuously examined.
4. Chemical pesticides should not be used in rice-fish culture. Natural substances, e.g. neem extract, which are not toxic to fish should be used as replacement.

5. Chemical fertilizer, if necessary should be applied with caution. Prior to use, it should be dissolved in water and then sprayed into the field.

6. Before rice-fish cultivation about 1-2 weeks, the ditch which is dug should be exposed to the sunlight in order to eliminate disease. Lime could be used for soil improvement.

7. The morning or evening is an appropriate time for releasing fish. Fish's bag should be floated in the water in the field for thirty minutes to allow fish to adjust to the field temperature.

#### 2.4.6 Advantages of rice-fish culture (12)

1. Farmers can use their land for the maximum benefit from both rice and fish production. The economic efficiency of ricefield as well as farmers' income can be increased.

2. Farmers can save both material and labor cost because fish help eradicate pests and weeds in the field.

3. The movement of fish stirs water and enhances the development of root system of rice.

4. Fish feces are full of nitrogen, organic matter and essential minerals which are useful and important for rice growth and can replace or reduce the amount of chemical fertilizer applied in ricefield.

5. In the long term, rice-fish culture can help increase rice productivity by improving soil properties and fertility.

## 2.5 Effects of rice-fish culture on ricefield ecosystem

The intensive use of technology in paddy field of the central area has adverse effects on ricefield ecosystem and the overall environment (40). Rice-fish culture can help decrease the use of synthetic pesticides and fertilizers and provide advantages including changes in soil properties and farmer's good health (40&41).

### 2.5.1 Changes in soil properties

The Department of Fisheries (12) suggested that rice-fish culture in a long continuously period could help increase soil fertility.

Changes in soil properties after rice-fish culture were observed in China (42). The results of soil analysis in many periods were shown in Table 2-5.

**Table 2-5 : The soil properties after rice-fish culture in China during 1983-1986.**

Season	Soil sampling	Activities	O.M. (%)	Total N (%)	Total P P <sub>2</sub> O <sub>5</sub> (%)	K (ppm)
Major rice	Surface	Rice only	3.748	0.219	1.20	91
		Rice with fish	3.896	0.226	1.19	86
Major rice	Ditch	Rice only	3.928	0.228	1.29	172
		Rice with fish	4.272	0.272	1.53	334
Second rice	Surface	Rice only	3.677	0.205	0.12	88
		Rice with fish	3.849	0.198	0.14	172
Second rice	Ditch	Rice only	4.107	0.239	0.13	157
		Rice with fish	4.825	0.289	0.15	192

Source : Central Laboratory ,Fujian Academy of Agricultural Sciences, 1995.

Note : O.M. = Organic Matter, Total N = Total Nitrogen , Total P = Total Phosphorus, K = Potassium

Table 2-5 shows that the soils under rice-fish culture have higher organic matter content than normal rice cultivation. Similarly, 3 major nutrients (N,P and K) of rice-

fish culture are higher than the rice cultivation. An increase of soil fertility in rice-fish culture will lead to an increase of rice productivity.

Chen Huarong (43) studied the organic matter in rice-fish culture in China during 1984-1987 and indicated that rice-fish culture was an efficient way to enhance organic matter enrichment (Table 2- 6).

**Table 2-6 : Organic matter in experimented rice-fish culture in China during 1984-1987.**

Year	Treatment	% O.M.
1984	Control (before fish stocking)	4.101
1985	1 <sup>st</sup> year of rice-fish culture	4.848
1986	2 <sup>nd</sup> year of rice-fish culture	5.014
1987	3 <sup>rd</sup> year of rice-fish culture	5.269

Source : Chen Huarong, Yunnan Academy of Agricultural Sciences, 1995.

Li Xieping, Wu Huaixun and Zhang Yongtai (44) observed the significant improvement of soil fertility in the rice-fish culture from 1985 to 1987. The percentage of organic matter in soil increased from 2.0 to 2.4% while the total nitrogen increased from 0.14 to 0.16%. Wu Langhu (45) carried out the comparative studies on organic matter and nitrogen content in ricefield and rice-fish culture during 1982 to 1985. This study demonstrated that the organic matter and nitrogen mineral of rice-fish culture were higher than the rice cultivation. Wang Zaide, Wang Pu and Jie Zengshun (46) reported that there was an increase in the content of organic matter and nitrogen mineral. The soil fertility of ricefield could be increased by rice-fish culture and finally resulted in an increase of rice productivity.

### 2.5.2 Change in farmer's health

In rice-fish culture, chemical pesticides are substituted by natural pesticides such as neem and lemon grass extracts. Various reports confirm that these extracts are able to drive pests, stop growing rates of caterpillars and decrease the percentage of egg hatchability (47&48). Furthermore, there is no side-effect on natural enemies of pests, farmer's health and environment. Total production cost is also lowered. In Thailand, a survey of 250 government hospitals and health centers revealed that some 5,500 people were admitted because of pesticide poisoning in 1985 alone. Among those, 384 people died (49). The symptoms of those who suffered from the toxicity of chemical pesticides were shown in Table 2-7.

**Table 2-7 : The effects of pesticides on human after chronic exposure.**

System	Effects	Critical signs and symptoms/laboratory findings	Source
Eye	Pterygium	Vascular membrane on eye, decreased visual acuity	-
Skin	Eczema Nail destruction	Lichenification and fissuring	Morgan(1982)& WHO(1982) EPA findings & Hock(1987)
Respiratory (pulmonary tract)	Bronchial asthma	Wheezing cough, bronchospasm dyspnea	Morgan(1982) & Nemery(1987)
Cardiovascular	Electrocardiograph (EKG) changes, high blood pressure	-	Morgan(1982)
Gastrointestinal tract	Chronic gastritis	Epigastric pain, nausea, vomiting	WHO(1982)
Kidneys	Asymptomatic urinary abnormalities	Albuminuria, hematuria, elevated blood, urea nitrogen(BUN), creatinine	WHO(1982) & Hock(1987)

Source : Rola and Pingali,1993(50).

Rola and Pingali (1993), cited by Pretty (49) calculated the costs of health problems, caused by pesticide exposure in order to examine the economics of various pest control strategies. From this calculation, the cost of health for normal ricefield was higher than the natural pest controlled in ricefield that has no cost of health. The results indicated that the natural pest control was the best choice for farmers.

### 2.5.3 Change in the ricefield practice

In Bangladesh (49), rice yield increased when farmers practically combined rice-integrated pest management with fish culture (10 - 24% increased from natural practice). Moreover, farmers were able to increase net returns from fish harvesting. See also Table 2-8.

**Table 2-8 : Change of rice yield in various rice farming in Bangladesh, 1993.**

Farmer trained in:	Change in pesticide use(as % of normal practice)	Rice yields (as % of normal practice)	Food and income from fish
Normal practice	100%	100%	No
IPM only	24%	110%	No
Rice-fish culture	0	117%	Yes
IPM and rice-fish culture	0	124%	Yes

Source : Kamp et al(1993), cited by Pretty, 1995.

The combination of integrated pest management (IPM) with rice-fish culture was able to reduce chemical pesticide uses and could have further beneficial impacts on human health and wild fish populations. Similarly, the aim of this research focused on a comparative study on cost-benefit of rice-fish culture under the different chemical fertilizer rates using neem extract as pest controlling agent.

## 2.6 Theory of production

Because of limited natural resources, production factors must be appropriately managed. The entrepreneur aims at the maximum profit or the minimum cost. They generally face with several questions involved the basic economic system. Those questions (51&52) are as follows.

*What?* For resource allocation, a producer needs to determine what to produce and how much to produce.

*How?* Most goods can be produced by using different production processes. The suitability of production methods is considered at first. Not only technical methods (material management) are used, but also organization methods (labor, capital management) are considered.

*For whom?* Each productivity must be specific for each consumer group.

For this study, rice-fish culture must use appropriate resources and methods because farmer also aims at the maximum profit or the minimum cost.

### 2.6.1 The concept of production theory

The production economics is clarified according to the concepts of costs and outputs that response to inputs. The production factors must be used to maximize profit and/or to minimize costs. The production factors can be changed as well as productivity (53&54). Therefore, the principles of production economics should be extremely useful for the farm manager who is seeking profit and efficiency. This is an input-output relationship that is written as a symbol of production function(51&55).

$$Q = f(x_1, x_2, x_3, \dots, x_n)$$

where  $Q$  is output and  $x_1, \dots, x_n$  are different inputs that take part in the production of  $Q$ . The functional symbol "f" signifies the form of the relationship that transforms inputs into output.

Production function shows an input-output relationship, many inputs, e.g., labor, materials, land and capital are served to produce an output (rice and fish yields). For each input, it is used in an appropriate ratio for process of production. If one input factor is overused, outputs are still constant or declining but production cost is increasing. Rice-fish culture must use an appropriate ratio of production factors. There are many production factors which can be classified as follows.

#### 2.6.2 The factors of production

The factors of production can be classified into four groups (51,56&57):

1. Land is a natural resource that includes inside and outside properties of soil. Because of the difference of soil properties including fertility, the differences of quantity and type of soil. The return of land uses is land rent.
2. Labor is an important factor that is necessary for land preparation until harvesting. The return of labor is hired labor.
3. Capital is a major factor for purchase of materials and farm management (land preparation until harvesting). The return of capital is interest.
4. Entrepreneur is an initiator, owner of enterprise or manager. Entrepreneur will make the decision about the use of appropriate resources and method for production process. The return is profit.

All four factors are used for rice-fish culture. The details are as follows:

#### 2.6.3 Cost of production

The cost of production can be classified into two categories:

1. Fixed costs : occur instantaneously and constantly over the production period, whether goods are produced or not. Farmers must pay fixed costs during the production period (58). In rice-fish culture, fixed costs are :

1. Land taxes (for land owner),
2. Interest,
3. Depreciation of machines and equipments,
4. Opportunity cost or land rent.

2. Variable costs : occur when farmers start the production process.

1. labor costs for land preparation until harvesting, including both hired labor and in-house labor.
2. Material costs e.g., plant and animal varieties, chemical fertilizers and pesticides, and fuels.

Rice-fish culture must consider production factors that are appropriately used among land, labor, capital and entrepreneur. The reason can be discussed as follows.

#### 2.6.4 Law of Diminishing Returns

The law states that:

“If increasing amounts of one input are added to a production process while all other inputs are held constant, the amount of output added per unit of variable input will eventually decrease” (51).

When the variable input is used with all other inputs are held constant (fixed inputs), marginal product ( $MP_L$ )<sup>1</sup> increases with the first application of the variable input until MP reaches its maximum and is decreasing. When MP is decreasing, there

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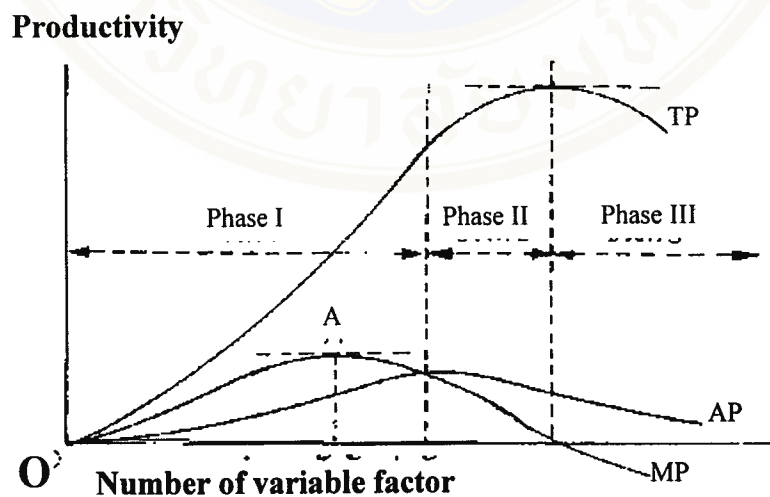
<sup>1</sup>  $MP_L = \Delta TP / \Delta L$

will be one point that MP equals average product (AP)<sup>2</sup> which AP is maximum. When MP is equal to zero, there will be point that total production (TP) is maximum.

If one rai of paddy field (fixed input) is appropriately used with one level of chemical fertilizer application (variable input), when chemical fertilizer is increased while paddy area is still constant, MP (rice yield) will be decreased. Because chemical fertilizer application (variable input) is overused. The proportion of application is not appropriate. At present, the overuse of chemical fertilizer in ricefield is widely spread in the central area. The reason can be discussed in stages of production (59).

### 2.6.5 Stages of Production

There are relationships between total product (TP), marginal product (MP) and average product (AP) that can be divided into three regions or stages. Each is important from the standpoint of efficient resource use. The three stages are shown in Fig. 2-3.



**Fig. 2-3 : Geometric relationship between TP, AP and MP and stages of production.**

Source : Mingmneenakin, 1992 (59).

<sup>2</sup> AP = TP/L when MP = Marginal Product, TP = Total Product, AP = Average Product and L = Number of variable cost

**Phase I** : Increasing returns. Variable input is increasingly transformed into product until AP reaches its maximum at the end of Phase I. MP is greater than AP. AP is increasing throughout Phase I. So an entrepreneur should greatly increase the variable input since MP is increasing and does not equal to zero.

**Phase II** : Diminishing Returns. MP is decreasing and is less than AP until MP reaches its equal zero at the end of Phase II. The efficiency of the fixed input is greatest at the end of Phase II. So an entrepreneur usually produces at this Phase. However, they do not know the suitable variable input until the cost and benefits of production are analyzed.

**Phase III** : Decreasing returns. Excessive quantities of the variable input are combined with the fixed input. The total output begins to decrease. Entrepreneur should not produce in this phase because total output is decreasing.

Within the rice production system the chemical fertilizer is applied in Phase II. Farmers increase the use of chemical fertilizer in ricefield while rice productivity is declining (Table 1-4). So the rice-fish culture technology must be used in order to reduced the chemical fertilizer use which could be explained in the law of substitution.

#### 2.6.6 Law of Substitution

The law states that:

“ Many factors that can be substituted by low price factor until the production is the minimum cost. At this point, the substitute proportion is as equal as the converse of factor price” (60).

Because of the high cost of chemical fertilizer, it can be substituted by fish's feces in rice-fish culture. The proportion between the fish manure and the chemical fertilizer application was examined in this study.

### 2.6.7 Project Analysis

Project analysis is one of solutions to problems of choice. Project analysis will show clearly the appraisal of all benefits and costs of each project. If the benefits are much higher than costs, the costs of the project will be covered. The project analysis is most valuable for decision making in resources management. The analysis of the project's cost and benefits can be divided into 2 types (61).

#### *Financial analysis*

In case of a rice-fish farmer, the cash flow is the main interest. The cash inflow and outflow is calculated in order to find out the financial viability of rice-fish farming. Consequently, shadow price is not applied and the opportunity costs of land and family labor are not considered.

#### *Economic analysis*

The main interest is to investigate the contribution of each farming option to society. Hence, the opportunity cost of land and family labor are considered in the process of calculation, and the shadow price is applied instead of the market price.

##### 2.6.7.1 The major distinctions between financial and economic analysis

There are three major distinctions between financial and economic analysis (41&61).

1. In economic analysis, certain prices may be changed to reflect better, true social or economic values. So the shadow prices are used. In financial analysis, market prices including taxes and subsidies are normally used.

2. In economic analysis, taxes and subsidies are treated as transfer payments. In financial analysis, taxes are treated simply as a cost and subsidies as a benefit.

3. In economic analysis, interest on capital is not separated and deducted from the gross returns since it is part of the total return to capital available to the whole society. In financial analysis, interest paid to outside money suppliers was treated as a cost and repayment of money borrowed from outside suppliers was deducted before arriving at the benefit stream. Interest paid to the entity from whose point of view the financial analysis was not being conducted to add into a cost.

Since the objective of this study was to investigate the costs and benefits of rice-fish culture, the opportunity costs of land and family labor, and the shadow prices were applied instead of the market prices. The project analysis was an economic analysis.

#### 2.6.7.2 The criteria for decision on investment

Three criteria are usually used for decision making in resources management. They are compound Net Present Value (NPV), Benefit Cost Ratio (B/C Ratio ) and Internal Rate of Return (IRR) (62).

1. Net Present Value (NPV) is defined as the comparison between the present value of project benefits and the present value of project costs.

$$NPV = \sum_{t=1}^N B_t / (1+i)^t - \sum_{t=1}^N C_t / (1+i)^t$$

$$\text{or} \quad = \sum_{t=1}^N \frac{B_t - C_t}{(1+i)^t}$$

If the NPV has a positive value, the project is considered profitable.

2. Benefit Cost Ratio (B/C Ratio) is defined as the ratio between the present value of project benefits and the present value of project costs.

$$\text{B/C Ratio} = \frac{\sum_{t=1}^N B_t / (1+i)^t}{\sum_{t=1}^N C_t / (1+i)^t}$$

If the value of B/C Ratio is higher than one, the project is considered profitable.

3. Internal Rate of Return (IRR) is defined as the rate of discount which equals to the present value of costs and benefits.

$$\sum_{t=1}^N C_t / (1+i)^t = \sum_{t=1}^N B_t / (1+i)^t$$

or

$$\text{NPV} = \sum_{t=1}^N \frac{B_t - C_t}{(1+i)^t} = 0$$

Notes :  $B_t$  = Benefits of project in year t

$C_t$  = Costs of project in year t

t = Year of project

N = Age of project

$\Sigma$  = Summation

I (IRR) = Internal rate of return

The project is considered acceptable if the IRR exceeds pre-determined rate, otherwise the project is rejected.

#### 2.6.7.3 Discount rate

In this study, all estimated costs and benefits were based on the figures of 1998. All prices were assumed constant throughout the period of the project. Choosing proper discount rate was one of the most important in the cost-benefit analysis. However, the interest of the government bonds was 12% for agriculture which was the minimum rate. This discount rate was used in this study.

#### 2.6.7.4 The project duration

Because the life span of machineries was 10 years. Therefore, the project duration was determined at 10 years in this study.

Risk factors influence on farmer, thus these factors are used to analyse sensitivity. It is often advantageous to investigate the effect of the change in some parameters on the solutions.

## 2.7 Relevant researches on rice-fish culture

During 1984 to 1993 the Department of Agriculture (13) reported on rice-fish culture in 7 provinces in the northeastern, northern and central regions. Experiments were carried out in Rice Experiment Station of each province. The productivity of rice and fish are compared in Table 2-9.

**Table 2-9 : The productivity of rice-fish culture in many provinces during 1984 to 1993.**

No.	Province	Rice/fish culture		Total		Net income (baht/rai)
		Rice/fish yield(kg/rai)	income (baht/rai)	income (baht/rai)	cost (baht/rai)	
1	Ubonratchathani	340/19	1,258/475	1,733	720	1,013
2	Nakhonpathom	439/33	1,624/825	2,449	750	1,699
3	Chainat	435/41	1,610/1,025	2,635	1,309	1,611
4	Suphanburi	675/30	2,498/750	3,248	1,039	2,209
5	Phitsanulok	695/19	2,442/517	2,959	1,799	1,160
6	Phichit	537/29	1,910/804	2,714	1,668	1,046
7	Uttaradit	645/25	2,192/682	2,874	1,944	930
<b>Average</b>		538/28	1,933/725	2,658	1,278	1,380

Source : The Department of Agriculture, 1995.

Notes : 1. Price of rice 3.41-3.70 baht/kg.

2. Price of fish 25.0-27.0 baht/kg.

3. Price of rice and fish are average price during 1984 to 1993.

From the Table 2-9 the average yields of rice and fish in rice-fish culture were 538 and 28 kg/rai, respectively. Farmers earned 1,933 and 725 baht/rai from selling rice and fish, respectively. Farmers had a net profit of 1,380 baht/rai on average. Especially, Suphanburi province had the highest net income from 675 kg/rai of rice yield and 30 kg/rai of fish yield, which were quite high compared to other provinces. Due to many advantageous factors for agriculture, Suphanburi province has high potential for promoting rice-fish culture.

Comparative studies on rice culture and rice-fish culture at 5 Rice Experiment Stations in the central and northeastern regions, namely Suphanburi, Kogsamrong,

Sakonnakhon, Surin and Pimai Rice Experiment Stations (15). The average area of ricefield and rice-fish culture was 4.97 rai. Rice varieties including RD.15, Dok Mali 105, RD.6 and Pathumthani 60 and three species of fish, i.e. *Oreochromis niloticus*, *Cyprinus carpio* and *Puntius gonionotus* were selected for experiment. The fish were released at the ratio of 1:2:2 and the total density was 1,000 fish per rai. Fish were released after 15-20 days of rice transplanting. Rice bran was used for feeding fish at 5% of fish body weight. Chemical fertilizer was used at the minimum quantity while there was no use of chemical pesticide in rice-fish culture. The experiment was done with three replications. The results showed that rice yield per unit area of rice-fish culture tended to be higher than rice yield of the ricefield at every Rice Experiment Station. The average fish yield was 37.2 kg/rai (Table 2-10).

**Table 2-10 : Comparison on the total fish weight and rice productivity from rice-fish culture at 5 Rice Experiment Stations, 1989.**

Stations	Total fish weight (kg/rai)	Rice productivity(kg/rai)							
		RD.15		Dok Mali 105		Phathumthani 60		RD.6	
		Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control
Suphanburi	24.7	246.1	181.6	263.5	175.5	356.7	339.4	-	-
Kogsamrong	51	472	497	618	621	593	589	-	-
Sakonnakhon	40.5	*	*	*	*	*	*	*	*
Surin	12.71	564.4	550.4	607.68	645.62	-	-	558.31	548.5
Pimai	57	537	537	562	547	-	-	704	681
Average	37.2	454.9	441.5	512.8	455.7	474.9	464.2	631.2	614.8
Net gain (kg/rai)		13.4		57.1		10.7		16.4	

Source : Sodto, 1989.

Note : \* Error data.

Table 2-10 also showed the comparison between yields of various rice varieties. The net profit derived at each Station was considerably high although the chemical fertilizer was used at the minimum quantity. Hence, farmers should be able to reduce the quantity of chemical fertilizer used while maintaining the same or increasing their rice yield. Furthermore, they could have additional fish productivity.

In 1985, the Department of Fisheries (34) reported that there were 3,733 farmers practicing rice-fish culture in the total area of 14,902.76 rai in the northeastern region. The quantity of rice productivity was 808.80 tons (54.27 kg/rai) and valued at 21.6 million baht (1,449.39 baht/rai). Rice productivity increased from 5 to 19% of rice productivity in rice culture. Average fish productivity was 36.75 kg/rai (63).

In 1987, the Department of Fisheries (34) made a comparison on the total income and the total costs of rice-fish culture and rice culture experimented at Khonkaen Rice Experiment Station (Table 2-11).

**Table 2-11 : Total income and total costs of rice-fish culture and rice culture at Khonkaen Rice Experiment Station, 1987.**

<b>Items</b>	<b>Rice-fish culture(Baht/rai)</b>	<b>Rice culture(Baht/rai)</b>
<b>Total Costs</b>	<b>1,080</b>	<b>640</b>
1. Ditching	240	-
2. 1,000 fish	250	-
3. Chemical fertilizer	210	210
4. Fish feeding	50	-
5. Land preparation	180	180
6. Transplanting	150	150
7. Weed elimination	-	100
<b>Total Income</b>	<b>2,547</b>	<b>1,071</b>
1. Rice	1,281	1,071
2. Fish	1,266	-
<b>Net profit</b>	<b>1,467</b>	<b>431</b>

Source : Ratanavaraha,1989.

Table 2-11 showed that, although the production cost of rice-fish culture was higher than of rice culture, the income from rice-fish culture was higher than from normal rice culture. Also, the net profit was approximately 3.5 times. It was also possible to reduce the use of chemical fertilizer while maintaining the same level of rice yield. The fish released into ricefield helped add organic manure and farmers gained additional yield and income from fish productivity.

In the same period, rice-fish culture was studied by Sugpong et al. (64) at Khonkaen Rice Experiment Station. The experiment was undertaken under the randomized complete block design (RCBD), consisting of 4 treatments with 4 replications as follows,

Treatment1. Rice cultivation (control).

Treatment2. Rice-fish culture, fish were stocked at 800 fish/rai.

Treatment3. Rice-fish culture, fish were stocked at 1,000 fish/rai.

Treatment4. Rice-fish culture, fish were stocked at 1,200 fish/rai.

There was a total of 16 experimental plots. The area of each plot was 400 m<sup>2</sup>. The rice-fish culture treatment had a ditch of 0.5 m wide and 0.3 m deep. The released fish were 3-5 cm in size. Three species of fish were selected for experiment. They were *Oreochromis niloticus*, *Cyprinus carpio* and *Puntius gonionotus*. The ratio of 3 species of fish released was 1:6:3. Dok Mali 105 rice variety was transplanted with the spacing of 25x33.3 cm and 3 seedlings per hill. In every treatment, chemical fertilizer was applied at the rate recommended by the Department of Agriculture for the northeastern area (16-16-8, 25 kg/rai of basal fertilizer and 15 kg/rai of ammoniumsulphate fertilizer as top up fertilizer). Rice bran, broken milled rice and bean residue were used as fish food at the rate of 5% of fish body weight, twice a week. Fish were raised in ricefield for 103 days. The results showed that rice yield tended to increase when the rate of fish stocked increased. The rate of fish stocking of 1,200 fish/rai gave the maximum rice yield at 405 kg/rai, compared with the controlled plot, 306 kg/rai. The fish yield from rice-fish culture, with rate of fish stocking of 1,200 fish/rai was 70 kg/rai, compared with 47 and 35 kg/rai from rice-fish culture with 800 and 1,000 fish/rai, respectively. Minimum survival rate of *Cyprinus carpio* was found in rice-fish culture with the stocking rate of 1,000 fish/rai (16%). The *Oreochromis niloticus* had the maximum fish growth rate at 1.61 g/day, compared with 1.2 and 0.93 g/day of *Puntius gonionotus* and *Cyprinus carpio*, respectively. Rice yield in rice-fish culture tended to increase while the chemical fertilizer was applied. It was possible that if farmers reduced the chemical fertilizer used in rice-fish culture, the productivity of rice may still remain the same or increase.

The socio-economic status of farmers practicing rice-fish culture at Tung Kula Ronghai Development Project Area in crop year 1986/1987 was surveyed by Leenanond et al.(65). 38 farmers in three provinces (Roi Et, Mahasarakham and Surin) were interviewed 6 times during December 1986 to March 1988. The result showed that the appropriate size of rice-fish culture was 5 rai. The depth of ditch was 1-1.5 m and the width was 1-2.5 m. A compile pond was dug 0.02-1.13 rai area and depth was 1.5-3 m. Fish species popularly used were *Puntius gonionotus*, *Labeo rohita*, *Oreochromis niloticus* and *Cirrhina microlepis*. Average density of fish stocking was 985 fish/rai. Fish released was 2-3 cm in size. Dok Mali 105 and Sanpatong rice varieties were grown. Chemical pesticide was applied from the minimum rate to non-use. After transplanting, farmers applied the chemical fertilizer, 16-16-18 at the rate of 10-20 kg/rai. The farmyard manure was applied for natural fish feeds. The production cost was 847.66 baht/rai. Fixed costs were 101.68 baht/rai while variable costs were 745.98 baht/rai. The farmers gained 220.22 kg/rai of rice yield which equaled to 836.84 baht/rai. Moreover, the farmers received 336.42 baht/rai from selling fish. The total income was 1,173.26 baht/rai and the net profit was 325.6 baht/rai.

Tongphan et al. (63) examined the rice-fish farming technology in rainfed and irrigated areas in Ubonratchathani during wet season in 1987 and 1988. The experiment was done in three districts representing different geographical characteristics of ricefield in terrace area (Amnatcharoen district), in plain area (Khuang-nai district) and plateau area (Dej-udom district).

There were 52 farmers participating in this program. The average size of paddy field associated with rice-fish culture was 2.4 rai. RD.6, RD.8, Dok Mali 105 and Sanpatong rice varieties and *Oreochromis niloticus*, *Cyprinus carpio* and *Puntius*

*gonionotus* were cultured in farmer's field. The ratio of 3 fish species released was 1:2:2 and the average density was 600 fish/rai. The fingerlings were stocked in 20-60 m<sup>2</sup> nursery pond and were released when they reached 3-5 cm in size. Chemical fertilizer was used in ricefield but no pesticide was used. Dok Mali 105 gave the highest rice yield in all cases. The average rice yield increased by 15% in rice-fish plots, compared with controlled plots. Cash return was not affected by the size of paddy field. However, higher investment on inputs was required for larger scale rice-fish farming system. The highest cash return was obtained from the investment of less than 300-400 baht/rai which was appropriate for farmers of the Northeast. The greatest proportion of labor input went into the management and improvement of land for rice-fish culture.

The rice-fish culture technology was transferred to farmer's field in Huay-thalang district, Nakhonratchasima province during 1988 to 1990 (66). There were 10 farmers with a total area of 17.53 rai participating in rice-fish farming. There were 2 treatments in this observation, rice culture and rice-fish culture. Dok Mali 105 was transplanted and 3-5 cm in size of *Oreochromis niloticus*, *Cyprinus carpio* and *Puntius gonionotus* were released at the ratio of 1:2:2 and the average density was 600 fish per rai. Four sided dikes were added and a ditch (1 m wide and 0.75 m deep) was dug. At the corner, there was a nursery pond (10 m wide, 10 m long and 1.5 m deep). At 15 days after transplanting, the fish was released in the field. The results showed that rice yields in rice-fish culture was 419 kg/rai on average while rice yields without fish raising was 361 kg/rai on average. There was an increase of rice yield in rice-fish culture by 17% per year on average. An average of fish yield was 20 kg/rai or 19% per year. The net profit in rice-fish culture was 1,683 baht/rai per year on average while

net profit from rice culture was 1,266 baht/rai per year on average. The net profit from rice-fish culture was higher by 35% per year on average (Table 2-12).

**Table 2-12 : Productivity and net profit of rice and rice-fish culture in Nakhonratchasima province during 1988 to 1990.**

Year	Rice culture		Rice-fish culture			
	Rice yield (Kg/rai)	Net profit (Baht/rai)	Rice yield (Kg/rai)	Fish yield (Kg/rai)	Net profit (Baht/rai)	% increasing of net profit
1988	271	949	320	14	1,245	31
1989	488	1,706	525	14	2,000	17
1990	325	1,138	411	26	1,804	58
Avg.	361	1,266	419	20	1,683	35

The Department of Agriculture (67) conducted the experiment on rice-fish culture. There were 10 farmers in a total area of 57 rai associated with this experiment in Samngam district, Phichit province in 1989. There were 3 treatments as follows:

Treatment1. ricefield, chemical fertilizer was used (16-16-8, 20 kg/rai as basal fertilizer and 21-0-0, 10 kg/rai as top up fertilizer).

Treatment2. rice-fish culture, chemical fertilizer was not used .

Treatment3. rice-fish culture, chemical fertilizer was applied exactly the same as in Treatment1.

Before land preparation, compost or farmyard manure and lime were applied at the rate of 1,000 kg/rai and 50 kg/rai, respectively. Fish were stocked in a nursery pond until they reached 5-7 cm in size. Fish species, *Cyprinus carpio*, *Labeo rohita* and *Puntius gonionotus* were released at the rate of 1:1:1 and the total density was 2,000

fish/rai. RD. 27 was transplanted in space of 25x25 cm and 3-5 seedlings per hill. The results were presented in Table 2-13.

**Table 2-13 : Productivity, income and net profit of rice and rice-fish culture in Phichit, 1989.**

Treatment	Productivity		Income		Net profit (baht/rai)
	Rice(kg/rai)	Fish(kg/rai)	Rice(kg/rai)	Fish(kg/rai)	
1	355.0	-	1,129.0	-	641.5
2	375.6	35.4	1,194.5	708.2	732.4
3	482.8	41.1	1,535.5	822.4	1,025.6

Note : Price of rice 3.78 baht/kg and fish 20 baht/kg

Fish productivity = Fish stocking + Natural fish

The results showed that rice-fish culture with and without chemical fertilizer application gave higher rice yield than rice monoculture. Without chemical fertilizer application, rice-fish culture also gave higher rice yield than rice monoculture. Fish yield was 35.4 kg/rai. If the chemical fertilizer was applied in rice-fish culture (treatment3), rice yield increased. Hence, farmers were able to reduce cost of production for chemical fertilizer application by rice-fish culture.

Mang-umphan and Promya (38) studied various stocking rates of sex-reversed *Oreochromis niloticus* in rice-fish culture at Chiangmai province. The randomized complete block design (RCBD) with 4 treatments and 3 replications was used for this experiment.

Treatment1. Rice culture (Control).

Treatment2. Rice-fish culture, fish released at 2 fish/m<sup>2</sup>(3,200 fish/rai).

Treatment3. Rice-fish culture, fish released at 3 fish/m<sup>2</sup>(4,800 fish/rai).

Treatment4. Rice-fish culture, fish released at 4 fish/m<sup>2</sup>(6,400 fish/rai).

The area of each plot was 5x5 m<sup>2</sup>. At four sides of each plot, ditch was dug for 0.4 m wide and 0.4 m deep. Fish reached 20-25 g in size and 15% protein commercial pellet food was used for fish feeding at the rate of 2% of body weight. RD.6 was transplanted in space of 20x20 cm. Farmyard manure was used at 5 kg/25 m<sup>2</sup> (320 kg/rai) as basal fertilizer and urea fertilizer was used as top up fertilizer at the rate of 0.5 kg/25 m<sup>2</sup>(32 kg/rai). Fish was raised in ricefield for 64 days. The results showed that rice-fish culture with the fish stocking density of 2 fish/m<sup>2</sup>(3,200 per rai) gave the maximum fish weight (38.2 g/fish). Whereas, rice-fish culture with the fish stocking density of 4 fish/m<sup>2</sup>(6,400 per rai) gave the maximum rice yield at 4.53 kg/25 m<sup>2</sup> (289.92 kg/rai). Meanwhile rice monoculture gave the lowest rice yield at 2.6 kg/25 m<sup>2</sup> (166.4 kg/rai). Rice-fish culture gave total rice yield increase by 15-74% of total yield in monoculture. Rice-fish culture technology could give the highest rice yield if the suitable rate of fish stocked in ricefield was chosen.

The rice-fish culture was also examined at the Asian Institute of Technology (AIT) by Begam and Setboonsarng (1994) (68). NPV and BCR of rice-fish culture was studied under the following conditions.

Treatment1. Rice-fish culture with 0% open ditch for fish in the field.

Treatment2. Rice-fish culture with 25% open ditch for fish in the field.

Treatment3. Rice-fish culture with 50% open ditch for fish in the field.

Treatment4. Rice-fish culture with 75% open ditch for fish in the field.

Treatment5. Zero % rice field area with 100% fish pond.

For each treatment, there were three replications. The plot size was 5x5 m<sup>2</sup>. RD.23 rice variety was transplanted and chemical pesticide was not used but chemical fertilizer was normally used at the rate recommended by the Department of Agriculture (16-20-0 spread over the plot by hand as a basal fertilizer and 21-0-0 spread as a top up fertilizer). In every treatment, the *Oreochromis niloticus* 5-7 cm in size were released at a density of 4 fish/m<sup>2</sup>. Fish were raised in the field for 93 days. The interest rate of 12% per year was used and the project life was considered at 15 cycles. The results were shown in Table 2-14.

**Table 2-14 : Cost-benefit analysis of rice-fish culture under different percentages of open water area.**

Items	Open water fish culture area (%)				
	0	25	50	75	100
<b>Total Costs(Baht/rai)</b>	27,417.60	39,241.60	51,312.64	63,356.80	75,401.60
Fixed costs	9,318.40	22,550.40	35,772.80	49,001.60	62,230.40
Variable Costs	18,099.20	16,691.20	15,539.84	14,355.20	13,171.20
<b>Total Income(Baht/rai)</b>	22,528.00	21,603.84	20,078.08	18,400.64	16,864.00
Rice	7,845.12	5,731.84	4,007.68	2,061.44	0
Fish	14,682.88	15,872.00	16,070.40	16,339.20	16,864.00
<b>Net Profit(Baht/rai)</b>	-4,889.60	-17,637.76	-31,234.56	-44,956.16	-58,537.60
<b>Net Present Value (NPV)(Baht/rai)</b>	43,536.64	36,096.64	19,144.96	820.48	-18,145.92
<b>Benefit Cost Ratio (B/C Ratio)(%)</b>	1.19	1.16	1.09	1.00	0.92

Source : Begam and Setboonsarng, 1994.

The fish culture with 100% pond (Treatment 5) had the highest production cost (75,401.6 baht/rai). The fixed cost under this condition was also highest. The variable cost in rice-fish culture without ditch (Treatment 1) was highest. The B/C Ratio of

rice-fish culture without ditch was highest while fish culture with 100% pond (Treatment 5) was lowest and not profitable. The NPV decreased as the percentage of open ditch increased. The maximum profit was gained from treatment 1 (43,536.64 baht/rai) while the minimum profit was gained from treatment 5 (-18,145.92 baht/rai). The derived profit varied with the ditch area.

In Southeast Asia, especially in the Philippines and Indonesia, there were many reports during 1979-1985 (69&70).

Mang-umphan (71) studied the performance of *Oreochromis niloticus* in rice-fish culture using different levels of chemical and commercial organic fertilizers at the Central Luason State of the Philippines. The experiment consisted of 4 treatments with 3 replications as follows.

Treatment 1. Rice-fish culture with 100% chemical fertilizer.

Treatment 2. Rice-fish culture with 50% chemical fertilizer and 50% commercial organic fertilizer.

Treatment 3. Rice-fish culture with 25% chemical fertilizer and 75% commercial organic fertilizer.

Treatment 4. Rice-fish culture with 100% commercial organic fertilizer.

The experimental plot was 200 m<sup>2</sup>. Ditch was dug at the middle of the plot, having the size of 50 cm deep, 20 cm long and 80 cm wide. The dike was 50 cm high. Chemical fertilizer 16-20-0, 46-0-0 and 0-0-60 and commercial organic fertilizer purchased from commercial sources were used at the rate recommended by the Agricultural Department of the Philippines. RD.64 rice variety was transplanted and *Oreochromis niloticus* was released at the rate of 800 fish/rai. The fish were raised for

126 days in the field. The results revealed that the highest net profit was obtained in treatment 2 (1,829.22 baht/rai) followed by treatment 1 (1,811.23 baht/rai), treatment 3 (1,581.62 baht/rai) and treatment 4 (1,568.42 baht/rai), respectively. The ratio of 1:1 of chemical to commercial organic fertilizer application achieved the highest net profit.

Torres et al. (72) studied rice-fish culture with different rates of chemical and organic fertilizer applications at Guimba and Nueva Ecija of the Philippines in 1988 (June-October), 1989 (January-May and June-October). A total of 36 farmers were involved in the trials. There were 4 treatments with 3 replications. Experimental plots area was 300 m<sup>2</sup>. Peripheral trench refuges were dug with a width of 1 m and a depth of 0.3-0.4 m. Fingerlings of *Oreochromis niloticus* were stocked at 800 fish/rai in 1988 (June-October) and 1989 (January-May) and 900 fish/rai in 1989 (June-October). Culture period of *O. niloticus* for all experiments was 60-70 days. In each treatment, application of chemical and organic fertilizer was shown in Table 2-15.

**Table 2-15 : Types and quantity of fertilizer were applied in experimental treatment at Guimba and Nueva Ecija , the Philippines in 1988-1989.**

Treatment	Fertilizer types	Method of application	Experiment 1 (Jun-Oct) 1988 Wet season (kg/rai)	Experiment 2 (Jan-May) 1989 Dry season (kg/rai)	Experiment 3 (Jun-Oct) 1989 Wet season (kg/rai)
1 (Control)	16-20-0	Basal	32	32	32
	45-0-0	Basal	8	8	8
	45-0-0	Top dress	8	16	8
2	16-20-0	Basal	48	48	48
	45-0-0	Basal	8	8	8
	45-0-0	Top dress	8	16	8
3	16-20-0	Basal	32	32	32
	45-0-0	Basal	8	8	8
	45-0-0	Top dress	8	16	8
	+organic	Basal	800	800	800
4	16-20-0	Basal	32	32	32
	45-0-0	Basal	8	8	8
	45-0-0	Top dress	8	16	8
	+organic	50% basal	600	600	600
	+organic	50% top dress	600	600	600

Source : Torres et al., 1992.

Fish yields were low in all three experiments and lowest in the dry season (Experiment 2), because only 2 g fingerlings were stocked. Survival rate was slightly low. Rice yield varied between 864 and 1,088 kg/rai (Table 2-16).

**Table 2-16 : Productivity of rice and fish in rice-fish culture on varied condition of fertilizer application, the Philippines (1988 and 1989).**

Production parameter	Experiment 1				Experiment 2				Experiment 3			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Mean stocking weight(g)	16.4	16.1	14.8	15.1	2.3	2.4	2.3	2.4	10.5	10.2	10.9	11.8
Mean harvest weight(g)	32.6	32.7	32.4	31.4	13.0	13.1	11.9	14.2	34.6	38.5	40.5	41.2
Survival rate(%)	80.0	78.0	82.0	83.0	67	67	78	81	74	77	78	82
Fish yield(kg/rai)	20.85	20.32	21.23	20.75	6.99	7.04	7.41	9.55	23.63	27.04	28.8	32
Rice yield(kg/rai)	1,040	1,056	976	976	1,056	1,088	928	992	944	960	960	864

From the table, effects of fertilizer on each treatment were insignificant. Rice yields tended to be slightly lower in organic fertilizer treatments.

The study of various chemical fertilizer application in rice-fish culture was compared with ricefield only in Indonesia (73). The Triple Super Phosphate fertilizer, 0-46-0 was normally used in ricefield as 16 kg/rai and rice-fish culture experiments were variedly used rate as 0, 4, 8, 12, 16, 20 and 24 kg/rai, respectively. The results of rice and fish yields are shown in Table 2-17.

**Table 2-17 : Rice and fish yields of rice-fish culture systems as affected by TSP (0-46-0) levels at the Sukamundi in the Indonesia, 1989.**

TSP level(kg/rai)	Rice yield (kg/rai)	Fish yield(kg/rai)
1. Rice-fish culture		
0	1,065.6	22.24
4	1,059.2	20.16
8	1,064	21.76
12	1,142.4	22.72
16	1,177.6	24
20	1,153.6	25.28
24	1,052.8	21.12
2. Ordinary rice cultivation		
16	969.6	-

Source : Fagi et al,1990

Note : TSP = Triple Super Phosphate (0-46-0)

All ratio of chemical fertilizer application in rice-fish culture gave higher rice yield than the ordinary rice cultivation. The inclusion of fish in rice cultivation increased efficiency of fertilizer use.

The results of literature review confirmed that rice-fish culture could give higher rice yield than normal rice culture by 5-19% on average (34). In the central area of Thailand, the appropriate rates of chemical fertilizer application in rice-fish culture have not been clearly determined. This study intended to perform the economic analysis on rice-fish culture in order to help farmers in the central area decide on the possibility to reduce their rice production factor. Possibility to reduce chemical fertilizer application and the appropriate rate of chemical fertilizer to be applied in rice-fish culture were explored. Furthermore, this would help make decision on how to

use rice-fish farming as an appropriate technology for resource and environmental management in ricefields.



## CHAPTER III

### MATERIALS AND METHODS

#### 3.1 Experimental design

A randomized completely block design : RCB (74) was used for the experiment. There were five treatments with three replications. The treatments were as follows.

Treatment 1: Rice culture (Control), with 30 kg/rai of 16-20-0 fertilizer and 15 kg/rai of 46-0-0 urea fertilizer (100% chemical fertilizer application rate recommended by the Department of Agriculture).

Treatment 2: Rice-fish culture, with the same rates of chemical fertilizer application as Treatment 1.

Treatment 3: Rice-fish culture, with 22.5 kg/rai of 16-20-0 fertilizer and 11.25 kg/rai of 46-0-0 urea fertilizer (75% chemical fertilizer application rate recommended by the Department of Agriculture).

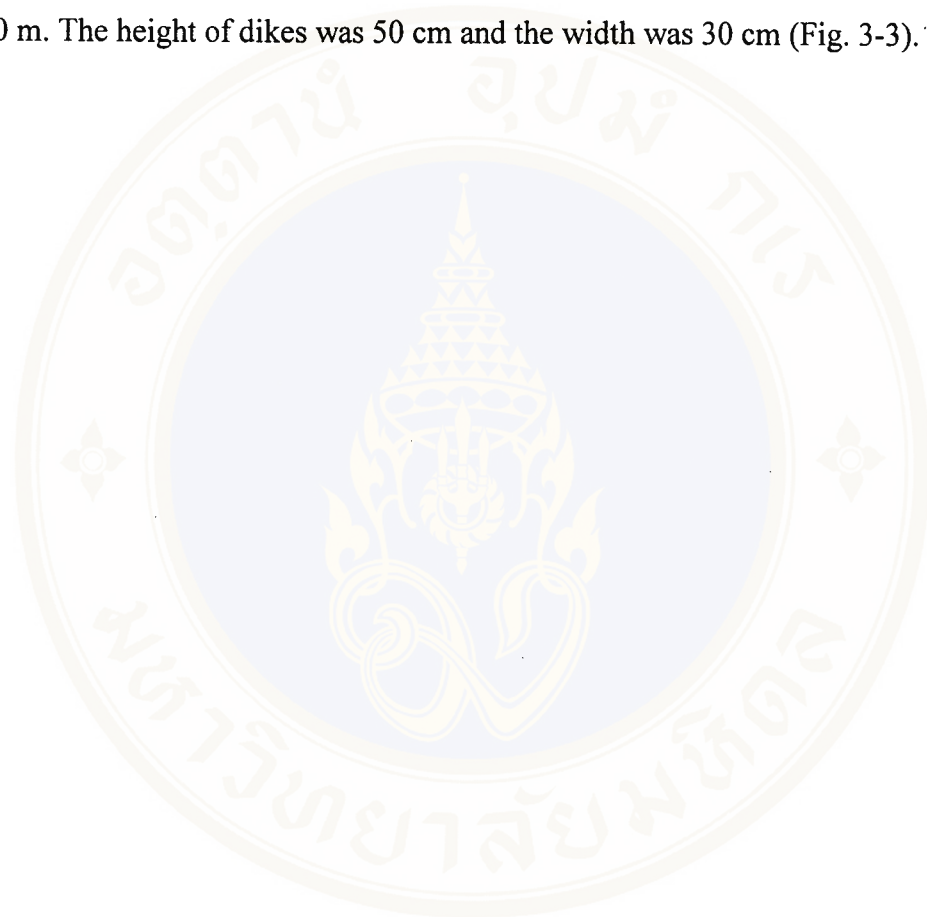
Treatment 4: Rice-fish culture, with 15 kg/rai of 16-20-0 fertilizer and 7.5 kg/rai of 46-0-0 urea fertilizer (50% chemical fertilizer application rate recommended by the Department of Agriculture).

Treatment 5: Rice-fish culture, with 7.5 kg/rai of 16-20-0 fertilizer and 3.75 kg/rai of 46-0-0 urea fertilizer (25% chemical fertilizer application rate recommended by the Department of Agriculture).

There was a total of 15 plots. The area of each plot was 5x5 m<sup>2</sup> and the total experimental area was 375 m<sup>2</sup>. The experimental layout was shown in Fig.3-1.

For rice culture without fish, the height of the dikes was 50 cm and the width was 30 cm (Fig. 3-2).

For rice-fish culture, there was a total area of 4.2x5 m<sup>2</sup> for rice growing and 0.8x5 m<sup>2</sup> for *Oreochromis niloticus* culture (16% of experimental area) with the ditch depth 1.0 m. The height of dikes was 50 cm and the width was 30 cm (Fig. 3-3).



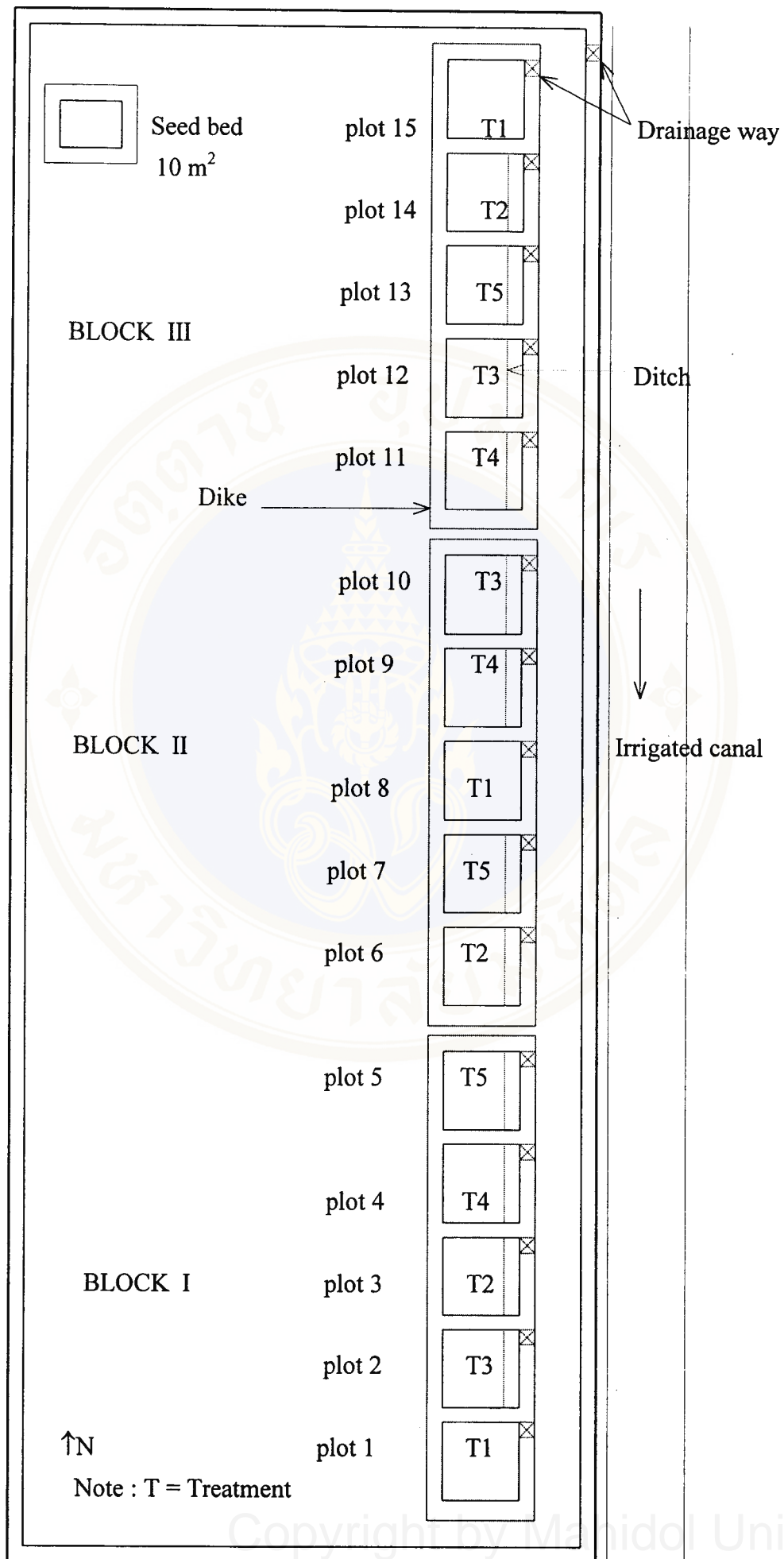
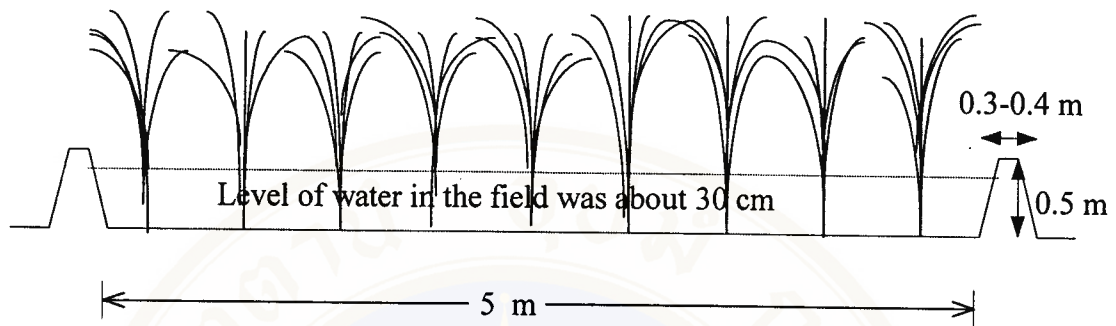
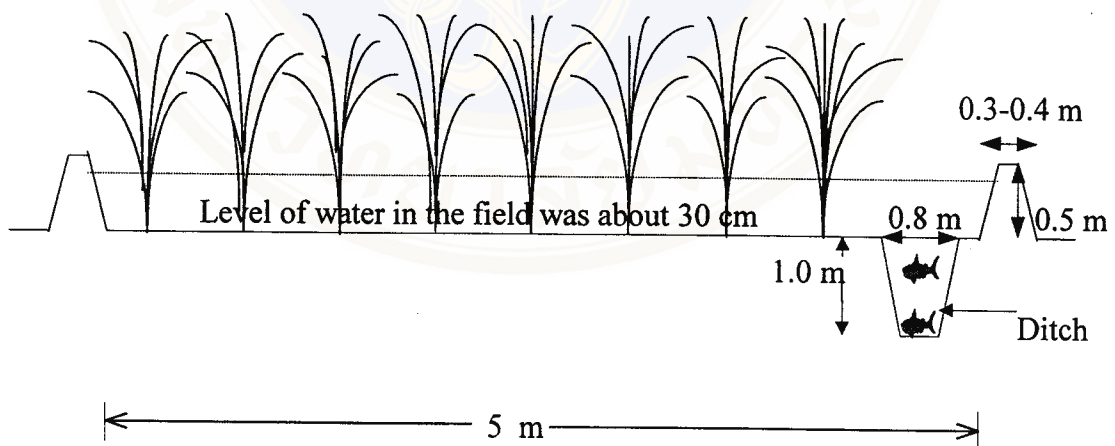


Fig. 3-1 : Experimental layout of rice field



**Fig. 3-2 : Cross section of paddy field**



**Fig. 3-3 : Cross section of rice-fish field**

## 3.2 Field preparation

### 3.2.1 Land

The experiment was conducted in Bangplama district, Suphanburi province on Ayuthaya soil series which was plain area. The soil was 10-30 cm deep, pH 3.7-5.0, poorly drained, slow runoff and permeability and moderate to rather low fertility (18&75).

### 3.2.2 Rice variety

KLG 83055-1-1-1-2-1-4 rice variety was grown in the experiment. This rice variety was recommended for the central plain area by both the Department of Agriculture and Rice Research Institute (76). The average age of rice is 118 to 125 days. The height is 110 cm and grains are brown 10.6 mm long, 2.7 mm wide and 2.0 mm thick. This rice variety is of good quality grade and high yielding, 591 to 650 kg/rai (in sowing cultivation) (77). This rice variety does not depend on light. It can be grown in both wet and dry seasons. In addition, it resists to bacterial blight diseases and white-backed planthopper . At present, the demand for fragrant rice variety is high and this rice variety is widely grown in the central plain. For this experiment, rice seed was derived from Suphanburi Rice Experiment Station and was grown at the rate of 6 kg/rai in transplanting cultivation (78).

### 3.2.3 Fish

Sex-reversed *Oreochromis niloticus* was stocked in the experiment because of its fast growth, efficient use of natural feeds, tolerance to various conditions and easy rearing. It is now an economic fish popularly consumed because of its good taste (79). The age of rice is approximately 120 days, so stocking fish introduced into the rice field should have rapid growth. In this study, fish species was procured from the Genetics Fisheries Division, Klong 5 Pathumthani, the Department of Fisheries. Age

of fingerlings was about 2 months with 11 cm in length and 25-30 g in weight. It has high survival rate at this size and is able to escape from its predators (12). Stocking density of 4 fish/m<sup>2</sup> of sex-reversed *Oreochromis niloticus* was chosen for the experiment because the previous rice-fish culture experiments reported that this rate gave high yield (38&80). The stocking rate was 100 fish/plot (6,400 fish/rai).

#### 3.2.4 Chemical fertilizer

Chemical fertilizer was applied as recommended by the Department of Agriculture for the central region. There were two types of chemical fertilizer (22): mixed fertilizer N-P<sub>2</sub>-O<sub>5</sub> : 16-20-0 at the rate of 30 kg/rai and urea fertilizer 46-0-0 at the rate of 15 kg/rai.

#### 3.2.5 Chemical pesticides

Instead of using chemical pesticides, neem extract was sprayed. Azadirachtin extract of neem seeds is able to control or drive pest, stop eating habit, and has no poison to rice, fish aquatic organisms, farmers and the environment (28). The rate of application was 100cc/ 40 litres of water /rai (81).

#### 3.2.6 Fish feeding

Although there is natural food in ricefield, it is not enough for fish feed. Supplement food such as rice bran, about 5% of fish body weight was given to fish (82).

#### 3.2.7 Control of water level

Water derived from the irrigation system, was pumped in and out of the experiment plots followed as:

##### 3.2.7.1 Paddy seedling field

After plowing, water was pumped in and maintained at the depth of 5 cm. After twenty-five days of paddy seedling, water was pumped in till reaching the depth of 10 cm.

### 3.2.7.2 Experimental fields

After plowing, water was pumped in and maintained at the depth of 5 cm. Before rice was transplanted, water was pumped in at the depth of 10 cm. For rice-fish fields (treatment 2-5), water was pumped in at the depth of 30 cm and maintained this level until rice and fish were harvested.

## 3.3 Experimental procedure

### 3.3.1 Land preparation for paddy seedling and experimental fields.

The experimental area was ploughed in order to turn over and expose the soil. Weeds were eliminated. Water was immediately pumped in and the field was flood for about 5-10 days. The harrowing was done to help smooth the soil by farmers' conventional practice. Water level was maintained to cover the soil.

### 3.3.2 Paddy seedling

To avoid sunlight, a good sprout was sown in the field during afternoon or evening. 3-5 days after sowing, water was pumped in at appropriate level for paddy seedling. Water level was maintained between 5-10 cm until paddy seedling was 20-25 days old.

### 3.3.3 Transplanting

An appropriate transplanting space would ease fish movement, weeding, spraying of chemical fertilizer and neem extract and the paddy field would receive nutrients and light throughout. Transplanting space was 20 cm between rows and 20 cm between hills (17). A total of seedling hills in controlled rice plot was 625 and 525 hills in experimental rice-fish plot. There were 3 seedlings per hill. Transplanting depth were about 2-3 cm. After transplanting, the water level in both controlled and experimented



rice-fish fields was maintained at 10 cm. Before fish released, water in the rice-fish plots (treatment 2-5) was increased to the depth of 30 cm.

#### 3.3.4 The first chemical fertilizer application

Seven days after transplanting, chemical fertilizer N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O : 16-20-0 was applied to each treatment as mentioned in experimental design.

#### 3.3.5 Chemical pesticide application and weeding

Seven days after transplanting, neem extract was sprayed in the evening once a week within a growing period of 60 days (8 times). The weed elimination was done by hand.

3.3.6 The water level in the experimental plot was maintained at 30 cm. The water was pumped in from the irrigation canal.

#### 3.3.7 Fish stocking

Sex-reversed *Oreochromis niloticus* was released after 15-20 days of transplanting. Before fish released, fish bag was floated in the water for thirty minutes for adjusting its temperature.

#### 3.3.8 Feeding method

In the morning every day, rice bran was thrown into the ditches of rice-fish fields (treatment 2-5) at an equal rate.

#### 3.3.9 The second chemical fertilizer application

Sixty days after cultivation, urea fertilizer 46-0-0 was sprayed in the morning at the rate as mentioned in experimental design.

#### 3.3.10 Harvesting

When the age of rice was 120 days, the water was pumped out of the rice-fish fields but still retained in the ditch to preserve fish. After rice was already harvested, water in the ditch was pumped out and all fish were caught by hand-net. Fish were in the field for 90-100 days altogether.

### 3.4 Data collection

The following data were recorded since the start until finish.

#### 3.4.1 Costs

##### 3.4.1.1 Fixed costs (Baht/rai/year)

1. Land taxes<sup>1</sup>
2. Land rent<sup>2</sup>
3. Opportunity cost
4. Depreciation

##### 3.4.1.2 Variable costs (Baht/rai/year)

###### 1. Labor costs for:

- 1.1 Land preparation
- 1.2 Seedling preparation and transplanting
- 1.3 Maintenance
  - 1.3.1 Digging ditch
  - 1.3.2 Lining inlet and outlet pipes
  - 1.3.3 Chemical fertilizer application
  - 1.3.4 Neem extract spraying
  - 1.3.5 Weeding
  - 1.3.6 Fish feeding
  - 1.3.7 Water pumping in-out

###### 1.4 Harvesting<sup>3</sup>

- 1.4.1 Rice

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<sup>1</sup> Tax' referred to the government term in 1973 at rate of 5 baht/rai/year for agricultural land use in Thailand.

<sup>2</sup> Rent' referred to the government term in 1981 at rate of 10% of rice productivity. The farmer did not own the area received 90 unit of rice productivity and give 10 unit for owner of land.

<sup>3</sup> Hire of labor was at the lowest rate of 130 baht/ 8 hours for Suphanburi province.

1.4.2 Threshing

1.4.3 Fish

2. Material costs<sup>4</sup>

2.1 Tools and equipments

2.2 KLG 83055-1-1-1-2-1-4 rice variety

2.3 Sex-reversed *Oreochromis niloticus*

2.4 PVC Pipe

2.5 Chemical fertilizer

2.6 Neem extract substance

2.7 Fuel

2.8 Food

3.4.2 Returns (Baht/rai/year)<sup>5</sup>

3.4.2.1 Income from the sale of rice in 1998.

3.4.2.2 Income from the sale of fish in 1998.

**3.5 Data analysis**

In this study, the cost-benefit analysis was used in determining the farmer's profit from rice-fish field. Two cases of farmers : farmers who owned the land and farmers who rented the land, were separately analysed.

3.5.1 Cost-benefit analysis

<sup>4</sup> Material cost was determined at Bangplama market price, Suphanburi province.

<sup>5</sup> Returns of rice and fish were calculated based on the price sale at Bangplama market, Suphanburi province, 1998.

The analysis was based on one rai per year. In each treatment, the cost and return were referred to whole real and estimated price. A comparison on cost and return among treatments was as follows.

#### 3.5.1.1 Cost analysis included fixed and variable costs.

##### Fixed costs

1. For farmers who owned the land, the fixed costs included.

- Land tax
- Opportunity cost
- Depreciation

2. For farmers who rented the land, the fixed costs included.

- Land rent
- Depreciation

##### Variable costs

1. Labor costs, from land preparation until harvesting, including both hired labor and in-house labor.

2. Material costs.

#### 3.5.1.2 Return analysis included the return from rice and fish.

Production = Rice production and Fish production

Total income = Production x Sale of production

Net profit = Total income - Total cost

### 3.5.2 A comparison on economic analysis included:

#### 1. Net Present Value : NPV

$$NPV = \sum_{t=1}^N B_t / (1+i)^t - \sum_{t=1}^N C_t / (1+i)^t$$

or

$$= \sum_{t=1}^N \frac{B_t - C_t}{(1+i)^t}$$

#### 2. Benefit - Cost Ratio : B/C Ratio

$$B/C \text{ Ratio} = \frac{\sum_{i=1}^N B_i / (1+i)^i}{\sum_{i=1}^N C_i / (1+i)^i}$$

#### 3. Internal Rate of Return : IRR

$$\sum_{i=1}^N C_i / (1+i)^i = \sum_{i=1}^N B_i / (1+i)^i$$

or

$$NPV = \sum_{t=1}^N \frac{B_t - C_t}{(1+i)^t} = 0$$

Notes :  $B_t$  = Benefits of project in year t

$C_t$  = Costs of project in year t

t = Year of project

N = Age of project(10 years)

$\Sigma$  = Summation

I(IRR) = Internal rate of return

#### 4. Sensitivity analysis

In farmers' real life, they have to face with risks including the increase of the interest rate, labor and material costs, and especially the fluctuation of the sale price of rice<sup>6</sup>. Therefore, the following changes were investigated.

4.1 Changes in the discount rate to 6, 10, 15 and 20%.

4.2 Changes in the production cost, e.g. increase by 5 and 10%.

4.3 Changes in the sale price of rice to 4.0 and 8.0 baht/kg.

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<sup>6</sup> From interview with Mr. Surapol Chatuporn, the agricultural scientist at Suphanburi Rice Experiment Station, Thailand.

## CHAPTER IV

### RESULTS

#### **4.1 The returns of rice culture and rice-fish culture under different rates of chemical fertilizer application**

##### **4.1.1 The return of rice yield**

The average rice yield ranged between 502.67 to 976.00 kg/rai/crop , the average return ranged between 3,418.16 to 6,636.80 baht/rai/crop (Table 4-1). Rice-fish culture with 25% chemical fertilizer application gave the lowest rice yield and return, while rice-fish culture with 100% chemical fertilizer application gave the highest rice yield and return. Rice-fish culture with reduction of fertilizer application to 75% still gave higher rice yield and return than normal rice culture.

**Table 4-1 : The return of rice yield.**

Treatments	Rice yield(kg/rai/crop)				Return
	Rep 1.	Rep 2.	Rep 3.	Average	(Baht/rai/crop)
1. Rice culture	544.00	840.00	804.00	729.33	4,959.44
2. Rice-fish culture + 100% chemical fertilizer application	1,000.00	996.00	932.00	976.00	6,636.80
3. Rice-fish culture + 75% chemical fertilizer application	916.00	804.00	1,016.00	912.00	6,201.60
4. Rice-fish culture + 50% chemical fertilizer application	472.00	712.00	796.00	660.00	4,488.00
5. Rice-fish culture + 25% chemical fertilizer application	512.00	472.00	524.00	502.67	3,418.16

Note : Price of rice was 6.8 baht/kg at Bangplama rice market, Suphanburi province, August in 1998., Rep. = Replication

#### 4.1.2 The return of fish yield

Fish harvested from rice-fish culture were divided into 2 types according to sizes of fish. The price of fish at Bangplama market, Suphanburi province, August 1998, were as follows.

Middle size (40-100 g/fish) : 10 baht/kg

Small size (<40 g/fish) : 5 baht/kg

The total weight of fish yield ranged between 237.22 to 253.44 kg/rai/crop, the return ranged between 2,127.95 to 2,404.25 baht/rai/crop (Table 4-2). Rice-fish culture with 50% chemical fertilizer application gave the highest fish yield and return and with 100% chemical fertilizer application gave the lowest fish yield and return.

Table 4-2 : The return of fish yield.

Treatments	Fish yield(kg/rai/crop)												Return(Baht/rai/crop)		
	Rep 1.			Rep 2.			Rep 3.			Average			40-100g.	<40g.	Total
	40-100g.	<40g.	Total	40-100g.	<40g.	Total	40-100g.	<40g.	Total	40-100g.	<40g.	Total	40-100g.	<40g.	Total
1. Rice culture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Rice-fish culture + 100% chemical fertilizer application	163.20	60.80	213.12	51.20	188.80	34.56	188.37	48.85	237.22	1,883.70	244.25	2,127.95	1,883.70	244.25	2,127.95
3. Rice-fish culture + 75% chemical fertilizer application	128.00	72.32	324.48	20.48	164.48	20.48	205.65	37.76	243.41	2,056.50	188.80	2,245.30	2,056.50	188.80	2,245.30
4. Rice-fish culture + 50% chemical fertilizer application	220.80	33.92	222.08	32.00	219.52	32.00	220.80	32.64	253.44	2,208.00	163.20	2,371.20	2,208.00	163.20	2,371.20
5. Rice-fish culture + 25% chemical fertilizer application	284.80	14.08	247.04	7.04	165.76	26.24	232.53	15.79	248.32	2,325.30	78.95	2,404.25	2,325.30	78.95	2,404.25

Note : Rep = Replication

#### 4.1.3 The returns of rice and fish yield

The total returns (rice and fish yields) of rice-fish culture under different rates of chemical fertilizer application in all cases were higher than the total return of rice culture without fish (Table 4-3). Rice-fish culture with 100% chemical fertilizer application gave the highest total return, and with 75%, 50%, and 25% gave lower total return, accordingly.

**Table 4-3 : Total returns of rice culture and rice-fish culture under different rates of chemical fertilizer application (Unit : baht/rai/crop).**

Items	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
Total returns	4,959.44	8,764.75	8,446.90	6,859.20	5,822.41
Rice	4,959.44	6,636.80	6,201.60	4,488.00	3,418.16
Fish	-	2,127.95	2,245.30	2,371.20	2,404.25

#### 4.2 The costs of rice culture and rice-fish culture under different rates of chemical fertilizer application

##### 4.2.1 Fixed costs

##### 4.2.1.1 Land taxes

Farmers who owned their land had to pay the land tax at the rate of 5 baht/rai/year.

##### 4.2.1.2 Opportunity cost of land/land rent

For farmers who owned the land, they had the opportunity cost of land that was not cash cost. Farmers who rented the land, they had the rent cost of land. An

average rate of opportunity cost was 100 kg/rai/crop. The price of rice was 6.8 baht/kg, the opportunity cost of land of farmers who owned the land or the cost of land rent of farmers who rented the land was 680 baht/rai/crop.

#### 4.2.1.3 Machine and equipment depreciation

Machines and equipments included two wheel tractors, water pumps and manual sprayers having 10 years of life utility. The depreciation of machines and equipments were calculated per one rai area (see Appendix A). The total depreciation cost calculated from land preparation, water pump and neem extract spraying activities is shown in Table 4-4.

**Table 4-4 : The depreciation of machines and equipments (Unit : baht/rai/crop).**

Items	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
	Non cash	Non cash	Non cash	Non cash	Non cash
<b>Depreciation cost</b>	<b>27.11</b>	<b>32.94</b>	<b>32.94</b>	<b>32.94</b>	<b>32.94</b>
1. Two wheel tractors	26.37	32.03	32.03	32.03	32.03
2. Water pump	0.65	0.82	0.82	0.82	0.82
3. Manual sprayers	0.09	0.09	0.09	0.09	0.09

Note : Calculation see Appendix A.

The fixed costs of rice culture and rice-fish culture under different rates of chemical fertilizer application were separated into 2 cases : for farmers who owned the land and farmers who rented the land. Only 5 baht of land taxes which farmers who owned the land had to pay, was only the difference (Table 4-5).

Table 4-5 : Fixed cost of farmers who owned the land(Unit : baht/rai/crop).

Items	Rice culture			Rice-fish culture under different rates of chemical fertilizer application											
	Cash	Non cash	Total	100%			75%			50%			25%		
				Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total
Fixed costs	5.00	707.11	712.11	5.00	712.94	717.94	5.00	712.94	717.94	5.00	712.94	717.94	5.00	712.94	717.94
1. Land taxes	5.00	-	5.00	5.00	-	5.00	5.00	-	5.00	5.00	-	5.00	5.00	-	5.00
2. Opportunity cost	-	680.00	680.00	-	680.00	680.00	-	680.00	680.00	-	680.00	680.00	-	680.00	680.00
3. Depreciation cost	-	27.11	27.11	-	32.94	32.94	-	32.94	32.94	-	32.94	32.94	-	32.94	32.94

Note : Only 5 baht of land taxes was the difference which farmers who owned the land had to pay more than farmers who rented the land.

#### 4.2.2 Variable costs

Variable costs can be divided into 2 groups : labor and material costs

Labor costs were separated into in-house labor and hired labor. The hired labor in-farm at Suphanburi costed 130 baht/man/day (8 hours).

##### 4.2.2.1 Labor cost for land preparation until harvest.

###### 1. Labor cost for land preparation

The in-house labor was used for land preparation. The activities consisted of plowing, furrowing and harrowing, taking 4 and 5 hours for rice culture and rice-fish culture, respectively (see Appendix A). The labor cost for land preparation were 64.98 and 81.22 baht/rai/crop for rice culture and rice-fish culture, respectively.

###### 2. Labor cost for seedling preparation and transplanting

The in-house labor were used for seedling preparation, moving and transplanting for 24 and 22 hours for rice culture and rice-fish culture, respectively (see Appendix A). The labor cost was 390 and 357.5 baht/rai/crop for rice culture and rice-fish culture, respectively.

###### 3. Labor cost for maintenance

The maintenance activities consisted of plastic pipe installing, chemical fertilizer application, neem extract spraying, weed eliminating, fish feeding and water pumping. Each activity required different labor cost as follows:

###### 3.1 Ditching

Only in rice-fish culture, the cost of ditching occurred. The cost of ditching (0.8 m width, 1.0 m depth and 40 m length) by macro tractor at Bangplama district, Suphanburi province was 600 baht/hr. The soil from ditching was filled beside the ditch for dike preparation which was 0.5 m high to prevent seepage of water. The edge of ditch was adjusted in smooth shape. For 5 m long, the ditch was dug in 3

minutes, and for 40 m long, the ditch was dug in 24 minutes. The cash cost of ditching in rice-fish culture was 240 baht/rai/crop.

### 3.2 Labor cost for plastic pipe installing

Only one point of plastic pipe was installed in rice-fish culture. Each plot required 0.5 hour, using the in-house labor cost of 8.12 baht/rai/crop.

### 3.3 Labor cost for chemical fertilizer application

The chemical fertilizer 16-20-0 and 46-0-0 were applied in rice culture and rice-fish culture at the rate of 1 hour/rai, using the labor cost of 16.25 baht/rai/crop.

### 3.4 Labor cost for neem extract spraying

Neem extract was sprayed 8 times in every treatments, at the rate of an hour per rai for each spraying, using the total labor cost of 130 baht/rai/crop.

### 3.5 Labor cost for weeding

Weed was eliminated 3 times throughout the experiment, taking 1.5 hours/rai/crop, using the labor cost of 24.37 baht/rai/crop.

### 3.6 Labor cost for fish feeding

Rice bran was given to fish once a day, taking an estimated time of 5 minutes/rai, using the labor cost of 8.92 hours/rai/crop or 144.95 baht/rai/crop.

### 3.7 Labor cost for water pumping

The water was pumped in 8 times, taking a total of 10 hours/rai/crop for rice culture. For rice-fish culture, the water was pumped in 8 times taking 10 hours/rai/crop and pumped out 1 times for catching fish taking 2 hours/rai/crop, making a total of 12 hours/rai/crop. The labor cost for water pumping were 162.5 and 195 baht/rai/crop for rice culture and rice-fish culture, respectively.

## 4. Labor cost for harvesting

### 4.1 Rice harvesting

Rice yield was harvested by using sickle, taking a total of 26.67 hours/rai/crop for rice culture and 22.40 hours/rai/crop for rice-fish culture, using the labor cost of 432.90 and 364.00 baht/rai/crop for rice culture and rice-fish culture, respectively (see Appendix A).

#### 4.2 Threshing

Both labor and machine were used for threshing. Estimated cost was calculated based on 10 kg of rice yield (one bucket), the labor cost for threshing was 1 baht. Each treatment gave different rice yield and labor cost for threshing is shown in Table 4-6.

**Table 4-6 : Labor cost for threshing (Unit : baht/rai/crop).**

Item	Rice culture		Rice-fish culture under different rates of chemical fertilizer application							
			100%		75%		50%		25%	
	Yield (Bucket)	Threshing cost (Baht)	Yield (Bucket)	Threshing cost (Baht)	Yield (Bucket)	Threshing cost (Baht)	Yield (Bucket)	Threshing cost (Baht)	Yield (Bucket)	Threshing cost (Baht)
Threshing	72.93	72.93	97.60	97.60	91.20	91.20	66.00	66.00	50.27	50.27

#### 4.3 Fish harvesting

After rice harvesting, the water in rice-fish culture was pumped out. Fish in the ditch were harvested at an estimated time of 2 hours/rai/crop and the labor cost for fish harvesting was 16.25 baht/rai/crop.

##### 4.2.2.2 Material costs

##### 1. Rice variety

The KLG 83055-1-1-1-2-1-4 rice variety was transplanted at a rate of 6 kg/rai/crop. The rice culture used 6 kg/rai/crop while the rice-fish culture used only 5.04 kg/0.84 rai/crop. The price of rice variety was 10 baht/kg at Bangplama market,

Suphanburi province in 1998. The cost of rice variety were 60.00 and 50.40 baht/rai/crop for rice culture and rice-fish culture, respectively.

## 2. Fish fingerlings

The sex-reversed Nile tilapia (*Oreochromis niloticus*) was 3-5 cm in size. The estimated price of the C.P. Company Ltd. was 0.35 baht/fish. It was treated until 11 cm in size which was costly increase 0.01 baht/fish (see Appendix A). The price of fish was 0.36 baht/fish. The total fishes were 6,400 fish/rai/crop, the cost of fish fingerlings was 2,304 baht/rai/crop for rice-fish culture.

## 3. Plastic pipe net

Only rice-fish culture needed plastic pipe net installing to prevent the fish from escaping through irrigation and drainage holes. The price of plastic pipe net, 3.0 inch in diameter and 1 m in length, was 56 baht at Bangplama market, Suphanburi province, 1998. The cost of plastic pipe net was 56 baht/rai/crop.

## 4. Chemical fertilizer

The price of chemical fertilizer at Bangplama district Suphanburi province in 1998 were 7.6 baht/kg for fertilizer 16-20-0 and 7.4 baht/kg for fertilizer 46-0-0. Each treatment had different rate of application as well as different cost (Table 4-7).

**Table 4-7 : Cost of chemical fertilizer (Unit : baht/rai/crop).**

Items	Rice culture		Rice-fish culture under different rates of chemical fertilizer application							
			100%		75%		50%		25%	
	Quantity (kg/rai)	Price (Baht/rai)	Quantity (kg/rai)	Price (Baht/rai)	Quantity (kg/rai)	Price (Baht/rai)	Quantity (kg/rai)	Price (Baht/rai)	Quantity (kg/rai)	Price (Baht/rai)
Total costs	45	339	45	339	33.75	254.25	22.50	169.50	11.25	84.75
1. Fertilizer 16-20-0	30	228	30	228	22.5	171	15	114	7.5	57
2. Fertilizer 46-0-0	15	111	15	111	11.25	83.25	7.5	55.5	3.75	27.75

Note : Price of fertilizer 16-20-0 was 7.6 baht/kg, 1998.

Price of fertilizer 46-0-0 was 7.4 baht/kg, 1998.

### 5. Neem extract

Neem extract was procured from a commercial source, Sadaothai 111 company. The price was 300 baht/500 cc bottle at Bangplama market, Suphanburi province, 1998. Neem extract was used at the rate of 100 cc/40 litre of water/one rai rice area for one spraying and was sprayed 8 times/crop (Table 4-8).

**Table 4-8 : Cost of neem extract (Unit : baht/rai/crop).**

Item	Rice culture		Rice-fish culture under different rates of chemical fertilizer application							
			100%		75%		50%		25%	
	Quantity (cc/rai)	Price (Baht/rai)	Quantity (cc/rai)	Price (Baht/rai)	Quantity (cc/rai)	Price (Baht/rai)	Quantity (cc/rai)	Price (Baht/rai)	Quantity (cc/rai)	Price (Baht/rai)
Neem extract	800	480	672	403.2	672	403.2	672	403.2	672	403.2

Note : Price of neem extract was 300 baht/500 cc bottle, 1998.

### 6. Fish food

In rice-fish culture, rice bran was daily used for fish food at the rate of 5% of fish body weight. The rate of fish feeding changed every month. Average body weight of fish was measured every month until fish harvesting by sampling 10 fish/plot. The price of rice bran was 1 baht/kg at Bangplama market, Suphanburi province, 1998. The cost of fish feeding was calculated and presented in Table 4-9.

Table 4-9 : Cost of fish food in rice fish culture (Unit : baht/rai/crop).

Items	Rice-fish culture under different rates of chemical fertilizer application															
	100%				75%				50%				25%			
	Fish weight (g/fish)	5% rice bran weight (g/fish)	Cost (baht/fish/month)		Fish weight (g/fish)	5% rice bran weight (g/fish)	Cost (baht/fish/month)		Fish weight (g/fish)	5% rice bran weight (g/fish)	Cost (baht/fish/month)		Fish weight (g/fish)	5% rice bran weight (g/fish)	Cost (baht/fish/month)	
1. Fish releasing (30 days)	27.27	1.36	0.04	256	25.54	1.28	0.04	256	31.35	1.57	0.05	320	28.79	1.44	0.04	256
2. 30 days after Fish releasing (30 days)	41.11	2.05	0.06	384	41.13	2.06	0.06	384	41.52	2.07	0.06	384	42.03	2.10	0.06	384
3. 60 days after Fish releasing (30 days)	51.24	2.56	0.08	512	51.10	2.55	0.08	512	52.27	2.61	0.08	512	54.18	2.71	0.08	512
4. 90 days after Fish releasing until harvesting (17 days)	60.50	3.02	0.05	320	62.71	3.13	0.05	320	66.91	3.34	0.06	384	62.57	3.13	0.05	320
<b>Total cost</b>				<b>1,472</b>				<b>1,472</b>				<b>1,600</b>				<b>1,472</b>

Note: baht/fish/month = (5% rice bran weight (g/fish) \* number of day) / 100 g.

baht/fish/month/rai = baht/fish/month \* 6400 fish (1rai)

Price of rice bran 1 baht/kg, rate of releasing 6400 fish/rai,

The final sampling until harvesting used 17 days

### 7. Fuel

The fuel was used for two wheel tractors and water pumping machine. The price of fuel was 8.9 baht/litre at Bangplama market, Suphanburi province, 1998. The rice culture and rice-fish culture required different amount of fuel (see Appendix A) (Table 4-10).

**Table 4-10 : The cost of fuel (Unit : baht/rai/crop).**

Items	Rice culture		Rice-fish culture under different rates of chemical fertilizers application							
			100%		75%		50%		25%	
	Quantity (Litre/rai)	Price (Baht/rai)	Quantity (Litre/rai)	Price (Baht/rai)	Quantity (Litre/rai)	Price (Baht/rai)	Quantity (Litre/rai)	Price (Baht/rai)	Quantity (Litre/rai)	Price (Baht/rai)
Fuel cost	15.75	140.17	18.45	164.2	18.45	164.2	18.45	164.2	18.45	164.2
1. Land preparation	6.75	60.07	7.95	70.75	7.95	70.75	7.95	70.75	7.95	70.75
2. Water pump	9.00	80.10	10.50	93.45	10.50	93.45	10.50	93.45	10.50	93.45

Note : Price of fuel was 8.9 baht/litre, 1998.

Calculation see Appendix A

Both farmers who owned and who rented the land had to pay the total variable costs as presented in Table 4-11.

Table 4-11 : Total variable costs of farmers who owned the land and who rented the land (Unit : baht/rai/crop).

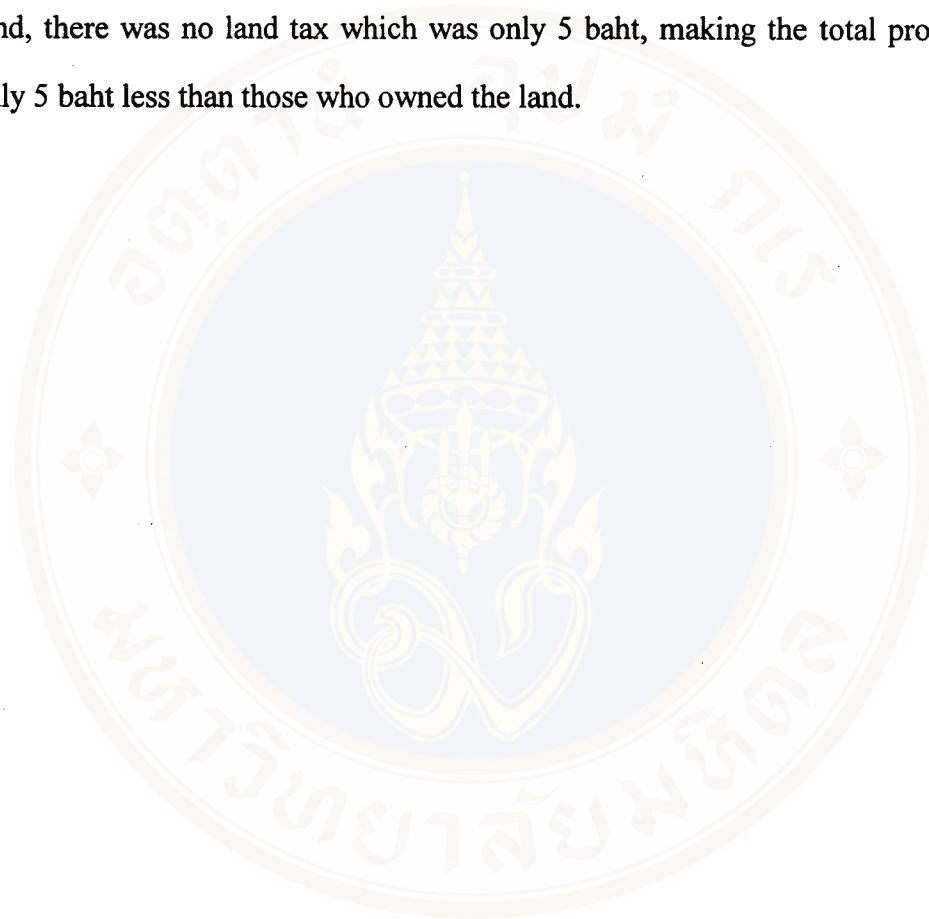
Items	Rice culture			Rice-fish culture under different rates of chemical fertilizer application											
				100%			75%			50%			25%		
	Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total
Total variable costs	1525.00	788.10	2313.10	5490.40	973.66	6464.06	5399.25	973.66	6372.91	5417.30	973.66	6390.96	5188.82	973.66	6162.48
1. Total labor costs	505.83	788.10	1293.93	701.60	973.66	1675.26	695.20	973.66	1668.86	670.00	973.66	1643.66	654.27	973.66	1627.93
1.1 Land preparation	-	64.98	64.98	-	81.22	81.22	-	81.22	81.22	-	81.22	81.22	-	81.22	81.22
1.2 Seedling preparation and transplanting	-	390	390.00	-	357.50	357.50	-	357.50	357.50	-	357.50	357.50	-	357.50	357.50
1.3 Maintenanancing	0.00	333.12	333.12	240.00	518.69	758.69	240.00	518.69	758.69	240.00	518.69	758.69	240.00	518.69	758.69
-Ditching	-	-	0.00	240.00	-	240.00	240.00	-	240.00	240.00	-	240.00	240.00	-	240.00
-Plastic pipe installing	-	-	0.00	-	8.12	8.12	-	8.12	8.12	-	8.12	8.12	-	8.12	8.12
-Chemical fertilizer application	-	16.25	16.25	-	16.25	16.25	-	16.25	16.25	-	16.25	16.25	-	16.25	16.25
-Neem extract spraying	-	130.00	130.00	-	130.00	130.00	-	130.00	130.00	-	130.00	130.00	-	130.00	130.00
-Weeding	-	24.37	24.37	-	24.37	24.37	-	24.37	24.37	-	24.37	24.37	-	24.37	24.37
- Fish feeding	-	-	0.00	-	144.95	144.95	-	144.95	144.95	-	144.95	144.95	-	144.95	144.95
-Water pumping	-	162.50	162.50	-	195.00	195.00	-	195.00	195.00	-	195.00	195.00	-	195.00	195.00
1.4 Rice harvesting and threshing	505.83	-	505.83	461.60	-	461.60	455.20	-	455.20	430.00	-	430.00	414.27	-	414.27
1.5 Fish harvesting	-	-	0.00	-	16.25	16.25	-	16.25	16.25	-	16.25	16.25	-	16.25	16.25

Table 4-11 (Cont.)

Items	Rice culture			Rice-fish culture under different rates of chemical fertilizer application											
	Cash	Non cash	Total	100%			75%			50%			25%		
				Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total	Cash	Non cash	Total
2. Total material costs	1019.17	0.00	1019.17	4788.80	0.00	4788.80	4704.05	0.00	4704.05	4747.30	0.00	4747.30	4534.55	0.00	4534.55
2.1 Rice variety	60.00	-	60.00	50.40	-	50.40	50.40	-	50.40	50.40	-	50.40	50.40	-	50.40
2.2 Fish fingerling	-	-	0.00	2304.00	-	2304.00	2304.00	-	2304.00	2304.00	-	2304.00	2304.00	-	2304.00
2.3 Plastic pipe net	-	-	0.00	56.00	-	56.00	56.00	-	56.00	56.00	-	56.00	56.00	-	56.00
2.4 Chemical fertilizer	339.00	-	339.00	339.00	-	339.00	254.25	-	254.25	169.50	-	169.50	84.75	-	84.75
2.5 Neem extract substance	480.00	-	480.00	403.20	-	403.20	403.20	-	403.20	403.20	-	403.20	403.20	-	403.20
2.6 Fish food	-	-	0.00	1472.00	-	1472.00	1472.00	-	1472.00	1600.00	-	1600.00	1472.00	-	1472.00
2.7 Fuel	140.17	-	140.17	164.20	-	164.20	164.20	-	164.20	164.20	-	164.20	164.20	-	164.20



The total cost of production (fixed and variable costs) of rice culture and rice-fish culture under different rates of chemical fertilizer application were separated into 2 cases : farmers who owned the land and who rented the land. For those who owned the land, the total production cost was presented in Table 4-12. For those who rented the land, there was no land tax which was only 5 baht, making the total production cost only 5 baht less than those who owned the land.



**Table 4-12 : Total production cost of farmers who owned the land (Unit : baht/rai/crop).**

Items	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
<b>Total production costs</b>	<b>3025.21</b>	<b>7182.00</b>	<b>7090.85</b>	<b>7108.90</b>	<b>6880.42</b>
<b>Total fixed costs</b>	<b>712.11</b>	<b>717.94</b>	<b>717.94</b>	<b>717.94</b>	<b>717.94</b>
1. Land tax <sup>1</sup>	5.00	5.00	5.00	5.00	5.00
2. Opportunity cost of land	680.00	680.00	680.00	680.00	680.00
3. Depreciation	27.11	32.94	32.94	32.94	32.94
<b>Total variable costs</b>	<b>2313.10</b>	<b>6464.06</b>	<b>6372.91</b>	<b>6390.96</b>	<b>6162.48</b>
<b>1. Labor costs</b>	<b>1293.93</b>	<b>1675.26</b>	<b>1668.86</b>	<b>1643.66</b>	<b>1627.93</b>
1.1 Land preparation	64.98	81.22	81.22	81.22	81.22
1.2 Seedling preparation and transplanting	390.00	357.50	357.50	357.50	357.50
1.3 Maintanancing	333.12	758.69	758.69	758.69	758.69
-Ditching	0.00	240.00	240.00	240.00	240.00
-Plastic pipe installing	0.00	8.12	8.12	8.12	8.12
-Chemical fertilizer application	16.25	16.25	16.25	16.25	16.25
-Neem extract spraying	130.00	130.00	130.00	130.00	130.00
-Weeding	24.37	24.37	24.37	24.37	24.37
- Fish feeding	0.00	144.95	144.95	144.95	144.95
-Water pumping	162.50	195.00	195.00	195.00	195.00
1.4 Rice harvest and threshing	505.83	461.60	455.20	430.00	414.27
1.5 Fish harvesting	0.00	16.25	16.25	16.25	16.25
<b>2. Material costs</b>	<b>1019.17</b>	<b>4788.80</b>	<b>4704.05</b>	<b>4747.30</b>	<b>4534.55</b>
2.1 Rice variety	60.00	50.40	50.40	50.40	50.40
2.2 Fish fingerling	0.00	2304.00	2304.00	2304.00	2304.00
2.3 Plastic pipe net	0.00	56.00	56.00	56.00	56.00
2.4 Chemical fertilizer	339.00	339.00	254.25	169.50	84.75
2.5 Neem extract substance	480.00	403.20	403.20	403.20	403.20
2.6 Fish food	0.00	1472.00	1472.00	1600.00	1472.00
2.7 Fuel	140.17	164.20	164.20	164.20	164.20

<sup>1</sup> Farmers who rented the land did not pay land tax (5 baht/rai/crop) that was the only difference.

First crop, the cost-benefit of rice culture and rice-fish culture under different rates of chemical fertilizer application was shown in Table 4-13.

**Table 4-13 : Cost-benefit of farmers who owned the land (Unit : baht/rai/crop).**

Items	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
<b>Net profit</b>	<b>1,934.23</b>	<b>1,582.75</b>	<b>1,356.05</b>	<b>-249.70</b>	<b>-1,058.01</b>
<b>Total returns</b>	<b>4,959.44</b>	<b>8,764.75</b>	<b>8,446.90</b>	<b>6,859.20</b>	<b>5,822.41</b>
Rice	4,959.44	6,636.80	6,201.60	4,488.00	3,418.16
Fish	0.00	2,127.95	2,245.30	2,371.20	2,404.25
<b>Total costs</b>	<b>3,025.21</b>	<b>7,182.00</b>	<b>7,090.85</b>	<b>7,108.90</b>	<b>6,880.42</b>
Fixed cost	712.11	717.94	717.94	717.94	717.94
Variable costs	2,313.10	6,464.06	6,372.91	6,390.96	6,162.48

Note : Those who rented the land, would have 5 baht/rai/crop less for fixed cost item.

First crop, the net profit of rice culture was the highest (1,934.23 baht/rai/crop), higher than of rice-fish culture in all cases. The net profit from rice-fish culture tended to decrease when the chemical fertilizer application in rice-fish culture decreased. In Suphanburi province, most farmers owned the land.<sup>1</sup> Therefore, the comparison on economic cost-benefit analysis was based on cases of farmers who owned the land.

<sup>1</sup> Agricultural Statistics of Thailand crop year 1995/96 , Office of Agricultural Economics.

### **4.3 Comparison on economic cost-benefit analysis of rice culture and rice-fish culture under different rates of chemical fertilizer application.**

Economic cost-benefit analysis was done in 10 years (age of machine), using 12% discount rate. Because farmer can grow 2 rice crops (wet and dry seasons) per year, thus cost-benefit analysis per year was calculated from two-folds of cost-benefit that gained in the first crop. Torres et al. (72) reported that there was no significant difference between rice yield in wet and dry seasons. Total fish weight under wet and dry seasons was relatively similar since the same of fish stocking density was the same at 4 fish/m<sup>2</sup> and sex-reversed *Oreochromis niloticus* was not breeding. Both crops (wet and dry season) of rice culture had no difference in the production cost (20). For rice-fish culture, material and labor costs could be saved because fish helped eradicate pests and weeds in the field (12). Natural food was generally available in the field such as termites, weeds, algae and bean (12, 37 & 39). From crop 2<sup>nd</sup> until crop 20<sup>th</sup>, there was no labor cost for plastic pipe installing, weeding, fish feeding, plastic pipe net and fish food cost. In-house labor could maintain the ditch in crop 2<sup>nd</sup> to crop 20<sup>th</sup>. Land taxes costed 5 baht for one year (see Appendix B).

The results of economic cost-benefit analysis (NPV, B/C Ratio and IRR values) of rice culture and rice-fish culture under different rates of chemical fertilizer application are shown in Table 4-14.

**Table 4-14 : Economic cost-benefit analysis of rice culture and rice-fish culture under different rates of chemical fertilizer application during a period of 10 years at discount rate of 12%.**

Criteria of decision investment	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
NPV (Baht/rai)	21,885.82	38,161.13	34,457.57	18,785.87	8,488.60
B/C Ratio	1.64	1.63	1.56	1.32	1.15
IRR (%)	37.29	36.43	36.46	35.51	33.83

Note : Calculation see Appendix B.

Table 4-14 showed that the NPV of rice-fish culture under 100% chemical fertilizer application (38,161.13 baht/rai) was the highest. The NPV tended to be lowered when the rate of chemical fertilizer application decreased. The lowest NPV was derived in the rice-fish culture under 25% chemical fertilizer application (8,488.60 baht/rai). The NPV of rice-fish culture under 75 and 50% chemical fertilizer application were higher than the NPV of rice culture without fish.

For the B/C Ratio, rice culture without fish had the highest value at 1.64, very close to 1.63 of rice-fish culture under the same 100% of fertilizer application. The B/C Ratio tended to be lowered when the rate of chemical fertilizer application decreased.

The trend of IRR was similar to the B/C Ratio. In all cases, IRR was higher than the discount rate used in this study (12%). The highest IRR was 37.29% in the rice culture without fish. The IRR from rice culture with 100% fertilizer and rice-fish culture with 100% and 75% fertilizer were not much different.

#### 4.4 Sensitivity analysis

Changes of production factors of rice culture leading to the risk for farmers are such as higher interest rate, higher production cost and fluctuation of rice price. For example, in crop year 1994/95 to 1996/97 the average price of rice was 4,000 baht/ton (4.0 baht/kg) while it was 7,660 baht/ton (7.66 baht/kg) in crop year 1997/98 (15). The rice variety used in this study, Kao Hom Klong Luang 1, tended to have higher price<sup>1</sup>.

In this study, changes in the discount rate (to 6, 10, 15 and 20%), the production cost (increased by 5 and 10%), and the price of rice (to 4.0 and 8.0 baht/kg) were analysed and presented in Table 4-15 to 4-17.

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<sup>1</sup> Information from Mr. Surapol Chatuporn, Agricultural Scientist of Suphanburi Rice Experiment Station.

**Table 4-15 : Sensitivity analysis when the discount rate changed to 6, 10, 15 and 20%.**

Criteria of decision investment	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
<b>NPV (Baht/rai)</b>					
at DR 6%	28,509.44	50,137.84	45,260.69	24,926.90	11,488.67
at DR 10%	23,800.47	41,620.05	37,577.64	20,557.70	9,352.67
at DR 12%	<b>21,885.82</b>	<b>38,161.13</b>	<b>34,457.57</b>	<b>18,785.87</b>	<b>8,488.60</b>
at DR 15%	19,440.12	33,747.90	30,476.57	16,528.00	7,389.99
at DR 20%	16,239.48	27,983.70	25,276.61	13,585.22	5,963.64
<b>B/C Ratio</b>					
at DR 6%	1.64	1.64	1.57	1.33	1.15
at DR 10%	1.64	1.63	1.53	1.32	1.15
at DR 12%	<b>1.64</b>	<b>1.63</b>	<b>1.56</b>	<b>1.32</b>	<b>1.15</b>
at DR 15%	1.64	1.62	1.56	1.32	1.14
at DR 20%	1.64	1.61	1.46	1.31	1.14

Note : Calculation see Appendix B.

Table 4-15 indicated when the discount rate decreased, the NPV in all cases would provide higher profit than the discount rate used in this study (12%). The NPV tended to decrease when the discount rate increased. The highest profit of NPV was still from rice-fish culture under 100% chemical fertilizer application while the lowest profit was from rice-fish culture under 25% chemical fertilizer application. There was no difference in B/C Ratio when the discount rate changed. The B/C Ratio tended to be lowered when the rate of chemical fertilizer application decreased in rice-fish culture. There was no difference between B/C Ratio of rice-fish culture under 100 and 75% chemical fertilizer application and of rice culture without fish.

**Table 4-16 : Sensitivity analysis when the production cost increased by 5 and 10%.**

Criteria of decision investment	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
<b>NPV (Baht/rai)</b>					
Cost of this study	21,885.82	38,161.13	34,457.57	18,785.87	8,488.60
Increased cost 5%	20,177.93	35,116.92	31,407.78	15,849.58	5,623.25
Increased cost 10%	18,470.04	32,072.72	28,358.00	12,913.28	2,757.91
<b>B/C Ratio</b>					
Cost of this study	1.64	1.63	1.56	1.32	1.15
Increased cost 5%	1.56	1.55	1.49	1.26	1.09
Increased cost 10%	1.49	1.48	1.42	1.20	1.04

Note : Calculation see Appendix B.

Table 4-16 showed that the NPV and B/C Ratio tended to decrease when the production cost increased. The maximum profit of NPV was in rice-fish culture under 100% chemical fertilizer application while the minimum profit was in rice-fish culture under 25% chemical fertilizer application. There was no difference between B/C Ratio of rice-fish culture under 100 and 75% chemical fertilizer application and rice culture without fish. However, all cases would provide lower profit than the production cost of this study when the production cost increased by 5 and 10%.

**Table 4-17 : Sensitivity analysis when the price of rice was 4.0 and 8.0 baht/kg.**

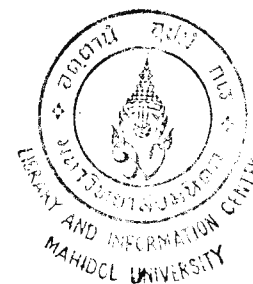
Criteria of decision investment	Rice culture	Rice-fish culture under different rates of chemical fertilizer application			
		100%	75%	50%	25%
<b>NPV (Baht/rai)</b>					
Price of rice 6.80 baht/kg.	21,885.82	38,161.13	34,457.57	18,785.87	8,488.60
Price of rice 4.00 baht/kg.	-1,190.95	7,279.39	5,600.87	-2,097.27	-7,416.48
Price of rice 8.00 baht/kg.	31,775.93	51,396.15	46,824.73	27,735.78	15,305.00
<b>B/C Ratio</b>					
Price of rice 6.80 baht/kg.	1.64	1.63	1.56	1.32	1.15
Price of rice 4.00 baht/kg.	0.97	1.12	1.09	0.96	0.87
Price of rice 8.00 baht/kg.	1.93	1.84	1.77	1.47	1.27

Note : Calculation see Appendix B.

Table 4-17 showed that NPV and B/C Ratio tended to decrease when the price of rice decreased (4.0 baht/kg). All cases would provide lower profit than the price of rice of this study (6.8 baht/kg). The maximum profit of NPV was in rice-fish culture under 100% chemical fertilizer application. When the price of rice was at 4.0 baht/kg, farmers would gain profit from rice-fish culture with 100% and 75% fertilizer application.

When the price of rice increased (8.0 baht/kg), the NPV and B/C Ratio tended to increase. The maximum profit of NPV was in rice-fish culture under 100% chemical fertilizer application while the minimum profit was in rice-fish culture under 25% chemical fertilizer application. All cases would provide higher profit than the price of rice in this study (6.8 baht/kg).

## CHAPTER V DISCUSSION



### 5.1 The returns of rice culture and rice-fish culture under different rates of chemical fertilizer application

#### 5.1.1 The return of rice yield

The highest return of rice yield was obtained from rice-fish culture under 100% chemical fertilizer application (6,636.80 baht/rai/crop). Compared to 4959.44 baht/rai/crop from rice culture without fish under the same fertilizer rate.

This indicated that rice fish culture could increase the return of rice field. Moreover, it was possible to reduce the chemical fertilizer application by 25% (or to use at 75% of the normal rate) without effect on rice yield. The return of rice year from rice fish culture under 75% fertilizer application was still higher (6,201.60 baht/rai/crop).

#### 5.1.2 The return of fish yield

Rice fish culture could give additional return of fish yield at 2,127.95-2,404.25 baht/rai/crop. The more the chemical fertilizer application rate decreased, the more the return of fish yield increased. Unfortunately, the trend of return of fish yield was opposite to the trend of return of rice yield in 5.1.1..

#### 5.1.3 The returns of rice and fish yield

Rice-fish culture in all cases gave higher total returns from of rice and fish than rice culture without fish.

## **5.2 The production cost of rice culture and rice-fish culture under different rates of chemical fertilizer application**

### **5.2.1 Fixed costs**

There was no difference in fixed cost of each treatment of rice-fish culture. Rice-fish culture, however, had higher fixed costs than rice culture without fish. The higher costs included the costs of depreciation of machines and water pumps. Fixed costs of rice-fish culture in this study was relatively high, compared with of other research in the Northeastern (65). This was probably due to the different scale of experiments.

### **5.2.2 Variable cost**

#### **5.2.2.1 Labor costs**

Rice-fish culture had higher labor costs than rice culture without fish. The higher costs included those concerning fish culture, especially ditching, plastic pipe installing, However, the possibility for reduction of fertilizer application may help reduce labour costs of rice-fish culture because the labor costs tended to decrease when the rate of chemical fertilizer application in rice-fish culture decreased.

#### **5.2.2.2 Material costs**

Rice-fish culture had much higher material costs than rice culture without fish. The higher costs included fish fingerlings and fish food. Fish fingerlings were costly, 0.35 baht/fish. Farmers should find ways to stock fingerlings themselves instead of buying. However, rice-fish culture could reduce the fertilization cost because there was possibly to reduce the amount of chemical fertilizer application. Moreover, rice-fish culture could have lower material cost because natural pesticides like neem extract was used in place of expensive chemical pesticides. All in all, rice-

fish culture still had higher total variable costs, almost 3 times of rice culture without fish.

The total production costs of rice-fish culture were 2.34 times higher than of rice culture without fish. Variable costs accounted for 89.84% of total production costs in rice-fish culture.

The net profit in the short term (one crop) of rice-fish culture was rather low, even when fertilizer application was reduced. In all cases, the net profits of rice-fish culture were lower than rice culture without fish. This might not be the case in the long term. There should be further study monitoring rice yield, fish yield, and the possibility to decrease the chemical fertilizer application as well as the possibility to reduce the variable costs in rice-fish culture.

### **5.3 Comparison on economic cost-benefit analysis of rice culture and rice-fish culture under different rates of chemical fertilizer application**

Over the long run operation (10 years), at the 12% discount rate, the NPV and B/C Ratio of all cases were positive and the IRR exceeded the discount rate (12%), which indicated that the project was profitable.

The NPV was highest in rice-fish culture under 100% chemical fertilizer application. The B/C ratio of rice culture and rice-fish culture under 100% and 75% chemical fertilizer application were not much different. At 75% chemical fertilizer application, rice-fish culture was still profitable.

The IRR value of rice culture without fish was highest but was not much different from those of rice-fish culture under 100 and 75% chemical fertilizer application. This analysis confirmed that rice-fish culture with 75% fertilizer application could be one optimal choice for farmers.

These findings are in line with the Law of Diminishing Returns (51). Increasing use of chemical fertilizer in rice culture without fish may not give much higher rice yield in the long period. According to the Law of Substitution (60), the chemical fertilizer which was costly could be substituted by fish's feces which was cheaper. As a result, 75% chemical fertilizer application in rice-fish culture would provide the same level of profit as 100% chemical fertilizer application in rice culture without fish.

#### **5.4 Sensitivity analysis**

Sensitivity analysis performed the changes of the discount rate to 6, 10, 15 and 20%, the production cost to 5% and 10% increased and price of rice to 4 and 8 baht/kg. The results indicated that rice culture without fish, and rice-fish culture under 50% and 25% chemical fertilizer application were the risk investment. Alternatively, at least 75% chemical fertilizer must be applied in rice-fish culture in order to provide profit.

## CHAPTER VI

### CONCLUSION AND RECOMMENDATIONS

#### 6.1 Conclusion

1. Among all treatments, rice-fish culture under 100% chemical fertilizer application gave the highest rice yield. Both 100 and 75% chemical fertilizer application in rice-fish culture could provide higher rice yield than rice culture without fish. Both 50 and 25% chemical fertilizer application in rice-fish culture could not maintain normal rice yield. Hence, farmers could reduce the chemical fertilizer application rate by 25% (or 75% of the normal rate) combined with rice-fish culture.

2. In all cases, rice-fish culture could provide higher total return of rice and fish yields than rice culture without fish. The highest total return was gained from rice-fish culture under 100% chemical fertilizer application. The lowest total return was from rice culture without fish.

3. There was no difference in production costs of all cases of rice-fish culture. The total production cost of rice-fish culture was 2.34 times higher than the production cost of rice culture without fish.

4. There was no difference in the production cost of farmers who owned and who rented the land.

5. The net profit in the short-run (one crop) of rice culture without fish was highest. The net profit of rice-fish culture under 100% and 75% chemical fertilizer application was slightly lower but still positive. The net profit of rice-fish culture under 50 and 25% chemical fertilizer application was negative.

6. Economic cost-benefit analysis in the long-run (10 years) showed that the NPV and B/C ratio of all cases were positive and IRR value exceeded the discount rate (12%). Rice-fish culture under 100% chemical fertilizer application seemed to be the best option. The profit (NPV, B/C ratio and IRR) tended to decrease when the chemical fertilizer application rate in rice-fish culture was decreased. The profit of rice culture without fish was within the same range as 75% and 50% chemical fertilizer application rice-fish culture.

7. Sensitivity analysis showed that if the discount rate changed 6, 10, 15 and 20%, the production cost increased by 5% and 10% and the sale price of rice changed to 4.0 and 8.0 baht/kg, rice culture without fish and rice-fish culture under 50% and 25% chemical fertilizer application were the risk investment. The net profit of rice-fish culture under 100 and 75% chemical fertilizer application tended to decrease but still quite profitable.

8. Economic cost-benefit analysis indicated that at least 75% chemical fertilizer had to be applied in rice-fish culture in order to maintain net profit and avoid risk investment. Rice-fish culture with 25% reduction of chemical fertilizer application proved to be most profitable for farmers.

## 6.2 Recommendations

1. Over the long period, rice-fish culture may greatly help reduce the chemical fertilizer application without decreasing rice yield. The comparative study on cost-benefit of rice-fish culture under different rates of chemical fertilizer application should be carried out in a longer term.

2. Economic of scale was the important point to be considered in the real rice-fish field. The experiment should be further carried out in real farms and the economic analysis should be performed on the real scale basis.

3. The results of this experiment should be promoted and practiced in farmer's field. Bigger farm size may have less production cost and use less time. Rice-fish culture may help increase farmers' income as well as improve natural fertility of rice field.

4. If rice-fish culture was practiced in long term, soil fertility could be increased and natural pesticides would cause no side-effect on natural enemies of pests as well as farmer's health. All these benefits should be also calculated and shown to farmers so that rice-fish culture and the reduction of chemical fertilizer application would be adopted as an appropriate technology applicable for rice field.

## REFERENCES

1. Office of Agricultural Economics. Agriculture Statistics of Thailand Crop Year 1991/1992. Ministry of Agriculture & Co-operatives; 1992.
2. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1981. Ministry of Commerce; 1981.
3. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1983. Ministry of Commerce; 1983.
4. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1985. Ministry of Commerce; 1985.
5. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1987. Ministry of Commerce; 1987.
6. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1989. Ministry of Commerce; 1989.
7. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1992. Ministry of Commerce; 1992.
8. Department of Business Economics. Trade Statistics and Economic Indicators of Thailand 1996. Ministry of Commerce; 1996.
9. Office of Agricultural Economics. Agriculture Statistics of Thailand Crop Year 1995/96. Paper No. 28/1996: Ministry of Agriculture & Co-operatives; 1996.
10. สำนักงานเศรษฐกิจการเกษตร. ความต้องการใช้ ปุ๋ยเคมี ในการเกษตรของไทย พ.ศ. 2535-2540. เอกสารเศรษฐกิจการเกษตร เลขที่ 48: กระทรวงเกษตรและสหกรณ์; 2535.

11. กรมการค้าภายใน. เอกสารประกอบการสัมมนา"มาตรฐานข้าวไทยสู่ความเป็นหนึ่ง". โรง  
แรมทีโอแพลนดส์: พิษณุโลก; 2539.
12. กรมประมง. การเลี้ยงปลาในนาข้าว. กระทรวงเกษตรและสหกรณ์ ชุมนุมสหกรณ์การเกษตร  
แห่งประเทศไทย จำกัด; 2540.
13. กรมวิชาการเกษตร. ทางเลือกสู่เกษตรกรรมยั่งยืน. เอกสารเพื่อสนับสนุนการปรับโครงสร้าง  
และระบบการผลิตทางการเกษตร. กรุงเทพฯ: กระทรวงเกษตรและสหกรณ์; 2538.
14. กรมวิชาการเกษตร. ผลงานวิจัยและพัฒนาระบบการทำฟาร์ม ปี พ.ศ. 2529-2534. กระทรวง  
เกษตรและสหกรณ์; 2534.
15. ประจง สุกโต. การเลี้ยงปลาในนาข้าวในระบบการเกษตร. รายงานการสัมมนาระบบการทำ  
ฟาร์ม. ครั้งที่ 7. 26-29 มีนาคม 2533; โรงแรมวังใต้ สุราษฎร์ธานี; 2533.
16. ศีพร้อม ไชยวงศ์เกียรติ. ชุมทางเกษตรฉบับ ปลานิล ปลาช่อน ปลาสร้อยและปลาดุก.  
กรุงเทพมหานคร: อักษรสยามการพิมพ์; 2526.
17. นิภูล รังสีชล. วิธีการปลูกข้าว. ใน กรมวิชาการเกษตร, บรรณาธิการ. ข้าว: ความรู้คู่ชาวนา.  
เอกสารวิชาการครบรอบ 80 ปี ศูนย์วิจัยข้าวปทุมธานี: กระทรวงเกษตรและสหกรณ์;  
2539.
18. อัมมาร สยามวาลา และวิโรจน์ ณ ระนอง. ประมวลความรู้เรื่องข้าว. กรุงเทพฯ: สถาบันวิจัย  
เพื่อการพัฒนาประเทศไทย; 2536.
19. อัจฉรา จิตตลดากร สุรพล จัตุพร วิชัย หิรัญยูปกรณ์ เกียรติสุรภัย โภคสวัสดิ์ และจิระวัชร  
เข้มสวัสดิ์. หน่วยที่ 15 กรณีศึกษาการจัดการการผลิตพืชและพืชอาหารสัตว์. เอกสาร  
การสอนชุดวิชา การจัดการการผลิตพืชและพืชอาหารสัตว์ หน่วยที่ 8-15  
มหาวิทยาลัยสุโขทัยธรรมมาธิราช; น.ป.ป.
20. สำนักงานเศรษฐกิจการเกษตร. ประมาณการต้นทุนการผลิต ข้าวนาปรัง ปีเพาะปลูก  
2539/40-2541/42. กระทรวงเกษตรและสหกรณ์; 2541.

21. สุจิตรา สันธนาภรณ์. การวิเคราะห์ต้นทุนและผลตอบแทน โดยรวมต้นทุนสุขภาพจากการใช้สารป้องกันและกำจัดศัตรูพืชของการทำวนเกษตรและเกษตรกระแสหลัก : กรณีศึกษาจังหวัดฉะเชิงเทรา [วิทยานิพนธ์ปริญญาเศรษฐศาสตรมหาบัณฑิต]. กรุงเทพฯ: คณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์; 2540.
22. นิกุล รังสิขล. การใช้ปุ๋ยเคมีในข้าว. ใน กรมวิชาการเกษตร, บรรณาธิการ. ข้าว: ความรู้คู่ชาวนา. เอกสารวิชาการครบรอบ 80 ปี ศูนย์วิจัยข้าวปทุมธานี: กระทรวงเกษตรและสหกรณ์; 2539.
23. วิศิษฐ์ โชติตกุล มะลิวัลย์ กาญจนนิรัตศัย และ มนูญ ศรีเสน. เคมีและความอุดมสมบูรณ์ของดิน เล่ม 1. กรมวิชาการเกษตร; 2518.
24. ปณต วงศ์เพชรวิเชียร. การวิเคราะห์การยอมรับและผลตอบแทนจากการใช้ปุ๋ยชีวภาพในการผลิตข้าวนาปี ในอำเภอเมือง จังหวัดชัยนาท ปีการผลิต 2536/37 [วิทยานิพนธ์วิทยาศาสตรมหาบัณฑิต]. กรุงเทพฯ: คณะเศรษฐศาสตร์ มหาวิทยาลัยเกษตรศาสตร์; 2538.
25. สมศักดิ์ ทองดีแท้. โรคข้าวและการป้องกันกำจัด. ใน กรมวิชาการเกษตร, บรรณาธิการ. ข้าว: ความรู้คู่ชาวนา. เอกสารวิชาการครบรอบ 80 ปี ศูนย์วิจัยข้าวปทุมธานี: กระทรวงเกษตรและสหกรณ์; 2539.
26. ฉันทนา บรรพศิริโชติ วิฑูรย์ เลียนจำรุณ นิรมล ยวนบุญย์ และ เจริญ ชำนิ. การประชุมปฏิบัติการเรื่อง “การสรุปบทเรียนจากการปรับตัวของเกษตรกรกรมพื้นบ้านในประเทศไทย”. เชียงใหม่: สำนักงานคณะกรรมการวัฒนธรรมแห่งชาติ; 2538.
27. อารมณ แสงวนิชย์. ผลกระทบของสารเคมีต่อการเลี้ยงปลาในนาข้าว. การฝึกอบรมการเลี้ยงปลา ณ โรงแรมขอนแก่นอินทร์: กระทรวงเกษตรและสหกรณ์; 2531.
28. กรมวิชาการเกษตร. สะเดา พืชป้องกันและกำจัดแมลงจากธรรมชาติ. ครั้งที่ 4. กรกฎาคม 2538; เอกสารทางวิชาการ โครงการวิจัยเพื่อลดการใช้สารเคมีในการป้องกันกำจัดศัตรูพืช: กระทรวงเกษตรและสหกรณ์; 2538.
29. สรสิทธิ์ วัชรโรทยาน. โครงการวิจัยและแนะนำทางเทคโนโลยีของดินและปุ๋ย. เอกสารวิชาการฉบับที่ 4. คู่มือชุดตัวอย่างปุ๋ยเคมี ประกอบการศึกษาแบบที่ 1 (N-P-K), เช่นจู้ร์ วัฒนธรรมการค้าจำกัด; 2521.

30. คณะกรรมการประสานงานองค์กรพัฒนาเอกชนภาคเหนือตอนล่างและภาคกลาง และชมรมศิษย์เก่าบูรณะชนบทและเพื่อน. การผลิตข้าวต้นทุนต่ำ. เอกสารการฝึกอบรมเทคนิคการผลิตข้าวต้นทุนต่ำแก่เกษตรกรภาคเหนือตอนล่างและภาคกลาง: พิจิตร; 2535.
31. เชาวน์ เสาวลักษณ์. การป้องกันและกำจัดแมลงศัตรูพืชโดยใช้สารสกัดสมุนไพร. รายงานการสัมมนาการใช้สารสกัดจากพืชป้องกันกำจัดศัตรูทางการเกษตร: มหาวิทยาลัยเชียงใหม่; 2536.
32. วัฒนะ ลีลาภัทร. สถานการณ์การเลี้ยงปลาในนาข้าวภาคตะวันออกเฉียงเหนือ. รายงานการอบรมหลักสูตรการเลี้ยงปลาในนาข้าว: กระทรวงเกษตรและสหกรณ์; 2531.
33. พรชัย จารุรัตน์จามร. คู่มือการเพาะเลี้ยงสัตว์น้ำ เล่ม 2.เอกสารประกอบการสอนฉบับที่ 3. ภาควิชาสัตวศาสตร์ คณะเกษตรศาสตร์ มหาวิทยาลัยขอนแก่น; 2523.
34. ชนวน รัตนวราหะ และประเวศ แสงเพชร. ระบบเกษตรผสมผสาน. กรมวิชาการเกษตร กระทรวงเกษตรและสหกรณ์; 2532.
35. โครงการพัฒนาการเกษตรอาศัยน้ำฝนฯ. ประสิทธิภาพของเกษตรกร เกี่ยวกับการเลี้ยงปลาในนาข้าว (ในพื้นที่เกษตรอาศัยน้ำฝน). กรมประมง; 2528.
36. สมาคมเทคโนโลยีที่เหมาะสม. คู่มือการเลี้ยงปลาในนาข้าว. กลุ่มพืชพันธุ์: นนทบุรี; 2531.
37. พินิจ สี่พิทักษ์เกียรติ. รายการอบรมหลักสูตรการเลี้ยงปลาในนาข้าว. กรมส่งเสริมการเกษตรและสำนักงานเกษตรภาคตะวันออกเฉียงเหนือ กระทรวงเกษตรและสหกรณ์; 2531.
38. เกรียงศักดิ์ เม่งอำพัน และจงกล พรมยะ. การเลี้ยงปลานิลเพศผู้อัตราส่วนต่างๆ ในนาข้าว. ภาควิชาเทคโนโลยีการประมง. คณะผลิตกรรมการเกษตร สถาบันเทคโนโลยีการเกษตรแม่โจ้ เชียงใหม่; 2539.
39. ภาควิชา วิชาวนัตริวัฒน์. เกษตรผสมผสานและเทคนิคเกษตรเกลือ. โครงการส่งเสริมองค์การพัฒนาเอกชนไทย มูลนิธิฟรีดริช เนามัน.ครั้งที่ 1; หจก.สภายสาร; 2533.

40. Fedoruk A and Leelapatra W. Ricefield Fisheries in Thailand. In :Cruz C R, Lightfoot C, Costa-Pierce BA, Carangal VR and Bimbao M A P, editors. Rice-fish research and development in Asia. Philippines: ICLARM; 1992. p 91-104.
41. Watanabe, K. Cost-benefit analysis of the integrated farming : a case study of northeastern Thailand[M.E. Thesis in economics]. Bangkok : Faculty of Economic, Thammasat University; 1994.
42. Chu, L C. Rice-azolla-fish cropping system. In: Mackay KT, editor. Rice - Fish Culture in China. Ottawa: IDRC; 1995. p 201-8.
43. Huarong, C. Techniques for rice-catfish culture in Zero-Tillage Ricefields. In: Mackay KT, editor. Rice - Fish Culture in China. Ottawa: IDRC; 1995. p 153-161.
44. Xieping L, Huaixun W and Yongtai Z. Economic and ecological benefits of rice-fish culture. In: Mackay KT, editor. Rice - Fish Culture in China. Ottawa: IDRC; 1995. p 129-38.
45. Langhu, W. Methods of rice-fish culture and their ecological efficiency. In: Mackay KT, editor. Rice - Fish Culture in China. Ottawa: IDRC; 1995. p 91-96.
46. Zaide W, Pu W and Zengshun J. Rice-azolla-fish symbiosis. In: Mackay KT, editor. Rice - Fish Culture in China. Ottawa: IDRC; 1995. p 125-7.
47. กรมวิชาการเกษตร. การมีส่วนร่วมของชัยพร พรหมพันธุ์ ในการพัฒนาเทคนิคการใช้สารสมุนไพรสูตรสะเดาควบคุมแมลงศัตรูข้าวสู่ระบบการทำนาแบบปล่อย. การสัมมนาระบบการทำฟาร์ม. ครั้งที่ 11. 12-15 มีนาคม 2539; กระทรวงเกษตรและสหกรณ์; 2539.
48. พิมพ์พร นันทะ. เกษตรยั่งยืน. กระทรวงเกษตรและสหกรณ์; 2536.
49. Pretty, J N. Regenerating agriculture. Earthscan publications Ltd.: London; 1995.

50. Rola, A C and Pingali, P L. Pesticides, rice productivity, and farmers' health an economic assessment. International Rice Research Institute, Philippines and World Resources Institute: USA; 1993.
51. วันรักษ์ มิ่งมณีนาคิน. หลักเศรษฐศาสตร์จุลภาค. กรุงเทพฯ: ไทยวัฒนาพานิช จำกัด; 2533.
52. Sexton, R L. Microeconomics. Prentice Hall, A simon and schuster company; 1995.
53. นราทิพย์ ชูติวงศ์. ทฤษฎีเศรษฐศาสตร์จุลภาค. พิมพ์ครั้งที่ 3. คณะเศรษฐศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย; 2539.
54. Frisch, R. Theory of production. D. Reidel publishing company; 1965.
55. Doll, J P. and Orazem, F. Production economics. second edition. United states of America; 1984.
56. รัดนา สายคณิต และชลลดา จามรกุล. หลักเศรษฐศาสตร์เบื้องต้น. คณะเศรษฐศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย. กรุงเทพฯ: บริษัท เอียร์บุ๊กพับลิชเชอร์ จำกัด; 2528.
57. อ้อทิพย์ ราษฎร์นิยม. เศรษฐศาสตร์การเกษตร. คณะสังคมศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ ประสานมิตร; 2535.
58. วรณา ประยุกต์วงศ์. ปัจจัยที่มีผลต่อการคงอยู่ในระบบเกษตรกรรมทางเลือกของเกษตรกร : ศึกษาเฉพาะกรณี ในจังหวัดขอนแก่น[วิทยานิพนธ์ปริญญาเศรษฐศาสตรมหาบัณฑิต]. กรุงเทพฯ: คณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์; 2540.
59. วันรักษ์ มิ่งมณีนาคิน. หลักเศรษฐศาสตร์จุลภาค. พิมพ์ครั้งที่ 3. กรุงเทพฯ: ไทยวัฒนาพานิช จำกัด; 2535.
60. ฉัตร ชำชอง. หลักการจัดการฟาร์ม. คณะเศรษฐศาสตร์และบริหารธุรกิจ มหาวิทยาลัยเกษตรศาสตร์. พิมพ์ครั้งที่ 2. กรุงเทพฯ; 2525.
61. โชติกา จินดารัตน์. การประเมินโครงการเพิ่มผลผลิตยางในสวนยางขนาดย่อม โดยวิธีการกรีดยางหน้าสูง และใช้สารเคมีเร่งน้ำยาง[วิทยานิพนธ์ปริญญาวิทยาศาสตรมหาบัณฑิต]. กรุงเทพฯ: คณะเศรษฐศาสตร์ มหาวิทยาลัยเกษตรศาสตร์; 2531.

62. วิชัย ทศนีย์ภาพ. การประเมินผลทางเศรษฐกิจของโครงการลดการสูญเสียน้ำประปาของการประปานครหลวง[วิทยานิพนธ์ปริญญาเศรษฐศาสตรมหาบัณฑิต]. กรุงเทพฯ: คณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์; 2537.
63. นรินทร์ ทองพันธุ์ และคณะ. การเลี้ยงปลาในนาข้าวภาคตะวันออกเฉียงเหนือ.หน่วยวิจัยและพัฒนาระบบการทำฟาร์มอุบลราชธานี สถาบันวิจัยการทำฟาร์ม กรมวิชาการเกษตรกระทรวงเกษตรและสหกรณ์; 2531.
64. เฉลิม สุขพงษ์ มนต์ ถิเชวงวงศ์ ศุภชัย ตั้งชูพงศ์ นพพร คงรอด และสุนนา สุทธิชัยกุล. การทดสอบผลผลิตข้าวในแปลงเลี้ยงปลาในนาข้าว.สถาบันวิจัยการทำฟาร์ม กรมวิชาการเกษตร กระทรวงเกษตรและสหกรณ์; 2530.
65. โยธิน ถิถานนท์ และคณะ. การศึกษาภาวะทางเศรษฐกิจและสังคมของเกษตรกรที่เลี้ยงปลาในนาข้าวเขตพื้นที่พัฒนาทุ่งกุลาร้องไห้.เอกสารเผยแพร่ฉบับที่ 15. สถาบันประมงน้ำจืดแห่งชาติ บางเขน: กรุงเทพฯ; 2532.
66. ชาญชัย อ่อนสอาด พิสมัย พิชิตมาร และนรินทร์ ทองพันธุ์. การวิจัยการเลี้ยงปลาในนาข้าวในระบบการทำฟาร์มพื้นที่เกษตรกรจังหวัดนครราชสีมา. สำนักงานวิจัยเพื่อการพัฒนา ระบบการทำฟาร์มอุบลราชธานี สถาบันวิจัยการทำฟาร์ม กรมวิชาการเกษตร กระทรวงเกษตรและสหกรณ์; 2533.
67. กรมวิชาการเกษตร. ผลงานวิจัยและพัฒนาระบบการทำฟาร์ม ปี พ.ศ. 2529-2534 . สถาบันวิจัยการทำฟาร์ม กระทรวงเกษตรและสหกรณ์; 2534.
68. Begam, R A and Setboonsarng, S. Economy of rice fish culture in varying environment[M.S. Thesis in Agricultural]. Bangkok : Faculty of Graduate Studies, Asian Institute of Technology;1994.
69. Sevilleja, R C. Rice-fish farming development in the Philippines: past, present and future. In : Cruz C R, Lightfoot C, Costa-Pierce BA, Carangal VR and Bimbao M A P, editors. Rice-fish research and development in Asia. Philippines: ICLARM; 1992. p 77-89.

70. Koesoemadinata S and Costa-Pierce B A. Development of rice-fish farming in Indonesia: past, present and future. In :Cruz C R, Lightfoot C, Costa-Pierce BA, Carangal VR and Bimbao M A P, editors. Rice-fish research and development in Asia. Philippines: ICLARM; 1992. p 45-62.
71. Mang-umphan, K. Culture of Nile Tilapia in paddies using chemical and commercial organic fertilizers technical. Paper No.2/1987. Nongkhai Inland Fisheries Station, Inland Fisheries Division: Department of Fisheries; 1986.
72. Torres J N, Macabale N A and Mercado J R. On-farm rice-fish farming systems research in Guimba, Nueva Ecija, Philippines. In : Cruz C R, Lightfoot C, Costa-Pierce BA, Carangal VR and Bimbao M A P, editors. Rice-fish research and development in Asia. Philippines: ICLARM; 1992. p 295-99.
73. Partohardjono, S. Case studies for sustainable rice-fish farming systems in Indonesia. Regular Issue No.19. FAO Regional Commission on farm Management for Asia and the Far East: RAPA; 1995.
74. สุรพล อุปคิสสกุล. สถิติการวางแผนการทดลองเบื้องต้น. มหาวิทยาลัยเกษตรศาสตร์; 2521.
75. บรรจง เขื่อนมนัส เล็ก มอญเจริญ และบำรุง มาโนช. รายงานการสำรวจความเหมาะสมของดินจังหวัดปทุมธานี นนทบุรี กรุงเทพมหานคร สมุทรสาคร และสมุทรปราการ. กองสำรวจดิน กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์; 2521. ฉบับที่ 189.
76. กรมวิชาการเกษตร. พันธุ์ข้าวเจ้าหอมคลองหลวง 1. เอกสารคำแนะนำ กระทรวงเกษตรและสหกรณ์; 2540.
77. กรมวิชาการเกษตร. ข้าวเจ้าหอมคลองหลวง 1. เอกสารข้อมูลเสนอคณะกรรมการวิจัยและพัฒนา กรมวิชาการเกษตร. ชุมนุมสหกรณ์การเกษตรแห่งประเทศไทย จำกัด; 2540.
78. กรมวิชาการเกษตร. เทคโนโลยีการผลิตข้าวหอมนาปรัง. ศูนย์วิจัยข้าวปทุมธานี; 2540.
79. มานพ ตั้งตรงไพโรจน์. การพัฒนาการเพาะเลี้ยงปลาไน. เอกสารเผยแพร่ ฉบับที่ 23. สถาบันวิจัยการเพาะเลี้ยงสัตว์น้ำจืด: กรมประมง; 2536.

80. Gallo, G C. Integrated rice-fish culture[M.S. Thesis in Agricultural]. Bangkok:  
Faculty of Graduate Studies, Asian Institute of Technology; 1988.
81. บริษัทผลิตภัณฑ์สะเดาไทย จำกัด. สะเดาไทย ชีวิตปลอดสารพิษ พืชดีด้วยสะเดาไทย:  
สุพรรณบุรี; มปป.
82. กรมประมง. ปลาที่เพาะเลี้ยงง่าย. ชุมนุมสหกรณ์การเกษตรแห่งประเทศไทย จำกัด; มปป.



The background of the page features a large, faint watermark of the Mahidol University logo. The logo is circular and contains the university's name in Thai script: "มหาวิทยาลัยมหิดล" (Mahidol University) at the bottom and "จุฬาลงกรณ์มหาวิทยาลัย" (Chulalongkornrajavidyalaya University) at the top. In the center of the logo is a traditional Thai emblem, the Chakrasimha, which depicts a lion with its mouth open, holding a crown and a sword. The text "APPENDIX A" is centered over this watermark.

**APPENDIX A**

**Calculation of production cost of rice culture and rice-fish culture  
with different rates of chemical fertilizer application**

Labor, fuel and depreciation cost calculation of this study could be shown as follow.

### 1. Land preparation until transplanting

#### Rice culture treatment

Unit : /rai

Items	Activities	Labor cost (130 baht/ 8 hr.)		Fuel cost (8.9 baht/litre)		Depreciation cost			
						Two wheel tractors		Pumping water machine	
		hr.	baht	litre	baht	hr.	baht	hr.	baht
1.	Plough	0.5	8.12	0.75	6.67	0.5	0.94	-	-
2.	Furrow	1.5	24.36	3	26.7	1.5	2.82	0.5	0.03
3.	Harrow	2	32.5	3	26.7	2	3.77	1	0.06
	<b>Total</b>	4.0	73.12	6.75	60.07	4	7.53	1.5	0.09

#### Rice-fish culture with different rates of chemical fertilizer application treatment

Unit : /rai

Items	Activities	Labor cost (130 baht/ 8 hr.)		Fuel cost (8.9 baht/litre)		Depreciation cost			
						Two wheel tractors		Pumping water machine	
		hr.	baht	litre	baht	hr.	baht	hr.	baht
1.	Plough	0.5	8.12	0.75	6.67	0.5	0.94	-	-
2.	Furrow	2	32.5	3.5	31.15	2	3.77	1	0.06
3.	Harrow	2.5	40.6	3.7	32.93	2.5	4.71	1.5	0.09
	<b>Total</b>	5	81.22	7.95	70.75	5	9.42	2.5	0.15

## 2. Pumping water in-out

### Rice culture treatment

Unit : /rai

Items	Activities	Labor cost (130 baht/ 8 hr.)		Fuel cost (8.9 baht/litre)		Depreciation cost			
						Two wheel tractors		Pumping water machine	
		hr.	baht	litre	baht	hr.	baht	hr.	baht
1.	Before releasing fish, water was pumped in a level of 10 cm.	2	32.5	1.5	13.35	2	3.77	2	0.11
2.	After releasing fish, water was pumped increase a level of 30 cm.	2	32.5	1.5	13.35	2	3.77	2	0.11
3 - 8	Water was pumped maintain in a level of 30 cm until rice harvest.	6	97.5	6	53.4	6	11.3	6	0.34
<b>Total</b>		10	162.5	9	80.1	10	18.84	10	0.56

**Rice-fish culture with different rates of chemical fertilizer application treatment**

Unit : /rai

Items	Activities	Labor cost (130 baht/ 8 hr.)		Fuel cost (8.9 baht/litre)		Depreciation cost			
						Two wheel tractors		Pumping water machine	
		hr.	baht	litre	baht	hr.	baht	hr.	baht
1.	Before releasing fish, water was pumped in a level of 10 cm.	2	32.5	1.5	13.35	2	3.77	2	0.11
2.	After releasing fish, water was pumped increase a level of 30 cm.	2	32.5	1.5	13.35	2	3.77	2	0.11
3 - 8	Water was pumped maintain in a level of 30 cm until rice harvest.	6	97.5	6	53.4	6	11.3	6	0.34
9.	Water was pumped out for fish harvest	2	32.5	1.5	13.35	2	3.77	2	0.11
	<b>Total</b>	12	195	10.5	93.45	12	22.61	12	0.67

### 3. Spraying neem extract

#### Rice culture treatment

Unit : /rai

Items	Activity	Labor cost (130 baht/8 hr.)		Depreciation cost	
		hr.	baht	hr.	baht
1 - 8	Every week after transplanting until ear stage, neem extract was sprayed in the field(8 times/crop).	8	130	8	0.09

#### Rice-fish culture with different rates of chemical fertilizer application treatment

Unit : /rai

Items	Activity	Labor cost (130 baht/8 hr.)		Depreciation cost	
		hr.	baht	hr.	baht
1 - 8	Every week after transplanting until ear stage, neem extract was sprayed in the field(8 times/crop).	8	130	8	0.09

**Remark :** Depreciation( Two wheel tractors, Pumping water machine and Manual spray of chemical pesticide) could be calculated in one day as follow.

Price of Two wheel tractors was 55,000 baht/unit and utility life was 10 years;  
an average of depreciation was 5,500 baht/year.

So a one day of depreciation was 15.07 baht/day(8 hr.).

Price of Pumping water machine was 1,700 baht/unit and utility life was 10 years;

an average of depreciation was 170 baht/year.

So a one day of depreciation was 0.46 baht/day(8 hr.).

Price of Manual spray of chemical pesticide was 330 baht/unit and utility life was 10 years;

an average of depreciation was 33 baht/year.

So a one day of depreciation was 0.09 baht/day(8 hr.).

#### 4. Paddy seedling and move seedling to transplanting

Unit : /rai

Activities	Ricefield only treatment		Rice-fish culture with different rates of chemical fertilizer application treatment	
	Labor cost		Labor cost	
	hr.	baht	hr.	baht
Paddy seedling	8	130	8	130
Moving and transplanting	16	260	14	227.5
<b>Total</b>	24	390	22	357.5

### 5. Rice harvest

Unit : /rai

Activities	Ricefield only treatment		Rice-fish culture with different rates of chemical fertilizer application treatment	
	Labor cost		Labor cost	
	hr.	baht	hr.	baht
A 4 m <sup>2</sup> of field area was harvested.	4/60	1.08	4/60	1.08
It was calculated in a one rai area	26.67	432.9	22.40**	364

Remark : \* = Rice harvest area was 1,600 m<sup>2</sup>.

\*\* = Because of ditch area, rice harvest area was only 1,344 m<sup>2</sup>.

### 6. Sex-reversed of *Oreochromis niloticus*.

The sex-reversed of *Oreochromis niloticus* was purchased from CP Company Ltd. that was 3 cm in length and was 5 g in weight, price of it was 0.35 baht/fish. It was stocked until it was 11 cm in length that duration time was about 60 days. The rice bran was food in a rate of 5% of body fish weight. So food rate could be calculated as follow.

Start, sex-reversed of *Oreochromis niloticus* was 3 cm in length and weight was 5 g.

5% body fish weight was 0.25 g/fish/day.

Stocking duration time was 60 days

So total quantity of rice bran was 15 g/fish that was 0.015 kg/fish.

Price of rice bran was 1 baht/kg.

Sex-reversed of *Oreochromis niloticus* was 11 cm in length, cost of food was increased at 0.01 baht/fish.

Price of 3 cm in length of sex-reversed of *Oreochromis niloticus* was 0.35 baht/fish.

So price of 11 cm in length of sex-reversed of *Oreochromis niloticus* was 0.35 +0.01 = 0.36 baht/fish.



**APPENDIX B**

**Details of The Economic Analysis ; NPV , B/C Ratio , IRR and  
Sensitivity**

The detail of cost-benefit of rice culture and rice-fish culture under different rates of chemical fertilizer application ; during 10 years period are shown in Table B-1 to B-5.

**Table B-1 : Cost-benefit of rice culture during 10 years period (Unit : baht/rai/year)**

Items	Year1			Year2			Year3		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>
<b>Total return</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>
Rice	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88
<b>Total costs</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>
<b>Fixed costs</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	27.11	27.11	54.22	27.11	27.11	54.22	27.11	27.11	54.22
<b>Variable costs</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>
<b>1. Labor costs</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>
1.1 Land preparation	64.98	64.98	129.96	64.98	64.98	129.96	64.98	64.98	129.96
1.2 Seedling preparation and transplanting	390.00	390.00	780.00	390.00	390.00	780.00	390.00	390.00	780.00
1.3 Maintenanacing	333.12	333.12	666.24	333.12	333.12	666.24	333.12	333.12	666.24
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	24.37	48.74	24.37	24.37	48.74	24.37	24.37	48.74
-Water pumping	162.50	162.50	325.00	162.50	162.50	325.00	162.50	162.50	325.00
1.4 Rice harvest and threshing	505.83	505.83	1011.66	505.83	505.83	1011.66	505.83	505.83	1011.66
<b>2. Material costs</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>
2.1 Rice variety	60.00	60.00	120.00	60.00	60.00	120.00	60.00	60.00	120.00
2.2 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.3 Neem extract substance	480.00	480.00	960.00	480.00	480.00	960.00	480.00	480.00	960.00
2.4 Fuel	140.17	140.17	280.34	140.17	140.17	280.34	140.17	140.17	280.34

Table B-1 (Cont.)

Items	Year4			Year5			Year6		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>
<b>Total return</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>
Rice	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88
<b>Total costs</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>
<b>Fixed costs</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	27.11	27.11	54.22	27.11	27.11	54.22	27.11	27.11	54.22
<b>Variable costs</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>
<b>1. Labor costs</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>
1.1 Land preparation	64.98	64.98	129.96	64.98	64.98	129.96	64.98	64.98	129.96
1.2 Seedling preparation and transplanting	390.00	390.00	780.00	390.00	390.00	780.00	390.00	390.00	780.00
1.3 Maintanancing	333.12	333.12	666.24	333.12	333.12	666.24	333.12	333.12	666.24
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	24.37	48.74	24.37	24.37	48.74	24.37	24.37	48.74
-Water pumping	162.50	162.50	325.00	162.50	162.50	325.00	162.50	162.50	325.00
1.4 Rice harvest and threshing	505.83	505.83	1011.66	505.83	505.83	1011.66	505.83	505.83	1011.66
<b>2. Material costs</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>
2.1 Rice variety	60.00	60.00	120.00	60.00	60.00	120.00	60.00	60.00	120.00
2.2 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.3 Neem extract substance	480.00	480.00	960.00	480.00	480.00	960.00	480.00	480.00	960.00
2.4 Fuel	140.17	140.17	280.34	140.17	140.17	280.34	140.17	140.17	280.34

**Table B-1 (Cont.)**

Items	Year7			Year8			Year9		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>
<b>Total return</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>
Rice	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88	4959.44	4959.44	9918.88
<b>Total costs</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>
<b>Fixed costs</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	27.11	27.11	54.22	27.11	27.11	54.22	27.11	27.11	54.22
<b>Variable costs</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>
<b>1. Labor costs</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>
1.1 Land preparation	64.98	64.98	129.96	64.98	64.98	129.96	64.98	64.98	129.96
1.2 Seedling preparation and transplanting	390.00	390.00	780.00	390.00	390.00	780.00	390.00	390.00	780.00
1.3 Maintanancing	333.12	333.12	666.24	333.12	333.12	666.24	333.12	333.12	666.24
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	24.37	48.74	24.37	24.37	48.74	24.37	24.37	48.74
-Water pumping	162.50	162.50	325.00	162.50	162.50	325.00	162.50	162.50	325.00
1.4 Rice harvest and threshing	505.83	505.83	1011.66	505.83	505.83	1011.66	505.83	505.83	1011.66
<b>2. Material costs</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>
2.1 Rice variety	60.00	60.00	120.00	60.00	60.00	120.00	60.00	60.00	120.00
2.2 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.3 Neem extract substance	480.00	480.00	960.00	480.00	480.00	960.00	480.00	480.00	960.00
2.4 Fuel	140.17	140.17	280.34	140.17	140.17	280.34	140.17	140.17	280.34

**Table B-1 (Cont.)**

Items	Year10		
	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1934.23</b>	<b>1939.23</b>	<b>3873.46</b>
<b>Total return</b>	<b>4959.44</b>	<b>4959.44</b>	<b>9918.88</b>
Rice	4959.44	4959.44	9918.88
<b>Total costs</b>	<b>3025.21</b>	<b>3020.21</b>	<b>6045.42</b>
<b>Fixed costs</b>	<b>712.11</b>	<b>707.11</b>	<b>1419.22</b>
1. Land tax	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00
3. Depreciation	27.11	27.11	54.22
<b>Variable costs</b>	<b>2313.10</b>	<b>2313.10</b>	<b>4626.20</b>
<b>1. Labor costs</b>	<b>1293.93</b>	<b>1293.93</b>	<b>2587.86</b>
1.1 Land preparation	64.98	64.98	129.96
1.2 Seedling preparation and transplanting	390.00	390.00	780.00
1.3 Maintenanacing	333.12	333.12	666.24
-Chemical fertilizer application	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00
-Weeding	24.37	24.37	48.74
-Water pumping	162.50	162.50	325.00
1.4 Rice harvest and threshing	505.83	505.83	1011.66
<b>2. Material costs</b>	<b>1019.17</b>	<b>1019.17</b>	<b>2038.34</b>
2.1 Rice variety	60.00	60.00	120.00
2.2 Chemical fertilizer	339.00	339.00	678.00
2.3 Neem extract substance	480.00	480.00	960.00
2.4 Fuel	140.17	140.17	280.34

**Table B-2 : Cost-benefit of rice-fish culture under 100% chemical fertilizer application during 10 years period(Unit : baht/rai/year).**

Items	Year1			Year2			Year3		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1582.75</b>	<b>3533.19</b>	<b>5115.94</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>
<b>Total returns</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>
Rice	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60
Fish	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90
<b>Total costs</b>	<b>7182.00</b>	<b>5231.56</b>	<b>12413.56</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>6464.06</b>	<b>4518.62</b>	<b>10982.68</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>
<b>1. Labor costs</b>	<b>1675.26</b>	<b>1257.82</b>	<b>2933.08</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	758.69	341.25	1099.94	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	240.00	0.00	240.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	8.12	0.00	8.12	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	0.00	24.37	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	144.95	0.00	144.95	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	461.60	461.60	923.20	461.60	461.60	923.20	461.60	461.60	923.20
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>4788.80</b>	<b>3260.80</b>	<b>8049.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	56.00	0.00	56.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	1472.00	0.00	1472.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-2 (Cont.)

Items	Year4			Year5			Year6		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>
<b>Total returns</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>
Rice	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60
Fish	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90
<b>Total costs</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>
<b>1. Labor costs</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintanancing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	461.60	461.60	923.20	461.60	461.60	923.20	461.60	461.60	923.20
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

**Table B-2 (Cont.)**

Items	Year7			Year8			Year9		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>
<b>Total returns</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>
Rice	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60	6636.80	6636.80	13273.60
Fish	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90	2127.95	2127.95	4255.90
<b>Total costs</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>
<b>1. Labor costs</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	461.60	461.60	923.20	461.60	461.60	923.20	461.60	461.60	923.20
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	339.00	339.00	678.00	339.00	339.00	678.00	339.00	339.00	678.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

**Table B-2 (Cont.)**

Items	Year10		
	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3528.19</b>	<b>3533.19</b>	<b>7061.38</b>
<b>Total returns</b>	<b>8764.75</b>	<b>8764.75</b>	<b>17529.50</b>
Rice	6636.80	6636.80	13273.60
Fish	2127.95	2127.95	4255.90
<b>Total costs</b>	<b>5236.56</b>	<b>5231.56</b>	<b>10468.12</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88
<b>Variable costs</b>	<b>4518.62</b>	<b>4518.62</b>	<b>9037.24</b>
<b>1. Labor costs</b>	<b>1257.82</b>	<b>1257.82</b>	<b>2515.64</b>
1.1 Land preparation	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00
1.4 Rice harvest and threshing	461.60	461.60	923.20
1.5 Fish harvesting	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3260.80</b>	<b>3260.80</b>	<b>6521.60</b>
2.1 Lime	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00
2.5 Chemical fertilizer	339.00	339.00	678.00
2.6 Neem extract substance	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40

**Table B-3 : Cost-benefit of rice-fish culture under 75% chemical fertilizer application during 10 years period(Unit : baht/rai/year).**

Items	Year1			Year2			Year3		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1356.05</b>	<b>3306.49</b>	<b>4662.54</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>
<b>Total returns</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>
Rice	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20
Fish	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60
<b>Total costs</b>	<b>7090.85</b>	<b>5140.41</b>	<b>12231.26</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>6372.91</b>	<b>4427.47</b>	<b>10800.38</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>
<b>1. Labor costs</b>	<b>1668.86</b>	<b>1251.42</b>	<b>2920.28</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintanancing	758.69	341.25	1099.94	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	240.00	0.00	240.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	8.12	0.00	8.12	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	0.00	24.37	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	144.95	0.00	144.95	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	455.20	455.20	910.40	455.20	455.20	910.40	455.20	455.20	910.40
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>4704.05</b>	<b>3176.05</b>	<b>7880.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	56.00	0.00	56.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	254.25	254.25	508.50	254.25	254.25	508.50	254.25	254.25	508.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	1472.00	0.00	1472.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-3 (Cont.)

Items	Year4			Year5			Year6		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>
<b>Total returns</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>
Rice	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20
Fish	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60
<b>Total costs</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>
<b>1. Labor costs</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	455.20	455.20	910.40	455.20	455.20	910.40	455.20	455.20	910.40
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	254.25	254.25	508.50	254.25	254.25	508.50	254.25	254.25	508.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

**Table B-3 (Cont.)**

Items	Year7			Year8			Year9		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>
<b>Total returns</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>
Rice	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20	6201.60	6201.60	12403.20
Fish	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60	2245.30	2245.30	4490.60
<b>Total costs</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>
<b>1. Labor costs</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintencancing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	455.20	455.20	910.40	455.20	455.20	910.40	455.20	455.20	910.40
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	254.25	254.25	508.50	254.25	254.25	508.50	254.25	254.25	508.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-3 (Cont.)

Items	Year10		
	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>3301.49</b>	<b>3306.49</b>	<b>6607.98</b>
<b>Total returns</b>	<b>8446.90</b>	<b>8446.90</b>	<b>16893.80</b>
Rice	6201.60	6201.60	12403.20
Fish	2245.30	2245.30	4490.60
<b>Total costs</b>	<b>5145.41</b>	<b>5140.41</b>	<b>10285.82</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88
<b>Variable costs</b>	<b>4427.47</b>	<b>4427.47</b>	<b>8854.94</b>
<b>1. Labor costs</b>	<b>1251.42</b>	<b>1251.42</b>	<b>2502.84</b>
1.1 Land preparation	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00
1.4 Rice harvest and threshing	455.20	455.20	910.40
1.5 Fish harvesting	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3176.05</b>	<b>3176.05</b>	<b>6352.10</b>
2.1 Lime	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00
2.5 Chemical fertilizer	254.25	254.25	508.50
2.6 Neem extract substance	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40

**Table B-4 : Cost-benefit of rice-fish culture under 50% chemical fertilizer application during 10 years period(Unit : baht/rai/year).**

Items	Year1			Year2			Year3		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>-249.70</b>	<b>1828.74</b>	<b>1579.04</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>
<b>Total returns</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>
Rice	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00
Fish	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40
<b>Total costs</b>	<b>7108.90</b>	<b>5030.46</b>	<b>12139.36</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>6390.96</b>	<b>4317.52</b>	<b>10708.48</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>
<b>1. Labor costs</b>	<b>1643.66</b>	<b>1226.22</b>	<b>2869.88</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	758.69	341.25	1099.94	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	240.00	0.00	240.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	8.12	0.00	8.12	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	0.00	24.37	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	144.95	0.00	144.95	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	430.00	430.00	860.00	430.00	430.00	860.00	430.00	430.00	860.00
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>4747.30</b>	<b>3091.30</b>	<b>7838.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	56.00	0.00	56.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	169.50	169.50	339.00	169.50	169.50	339.00	169.50	169.50	339.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	1600.00	0.00	1600.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-4 (Cont.)

Items	Year4			Year5			Year6		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>
<b>Total returns</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>
Rice	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00
Fish	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40
<b>Total costs</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>
<b>1. Labor costs</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintanancing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	430.00	430.00	860.00	430.00	430.00	860.00	430.00	430.00	860.00
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	169.50	169.50	339.00	169.50	169.50	339.00	169.50	169.50	339.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

**Table B-4 (Cont.)**

Items	Year7			Year8			Year9		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>
<b>Total returns</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>
Rice	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00	4488.00	4488.00	8976.00
Fish	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40	2371.20	2371.20	4742.40
<b>Total costs</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>
<b>1. Labor costs</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	430.00	430.00	860.00	430.00	430.00	860.00	430.00	430.00	860.00
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	169.50	169.50	339.00	169.50	169.50	339.00	169.50	169.50	339.00
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-4 (Cont.)

Items	Year10		
	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>1823.74</b>	<b>1828.74</b>	<b>3652.48</b>
<b>Total returns</b>	<b>6859.20</b>	<b>6859.20</b>	<b>13718.40</b>
Rice	4488.00	4488.00	8976.00
Fish	2371.20	2371.20	4742.40
<b>Total costs</b>	<b>5035.46</b>	<b>5030.46</b>	<b>10065.92</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88
<b>Variable costs</b>	<b>4317.52</b>	<b>4317.52</b>	<b>8635.04</b>
<b>1. Labor costs</b>	<b>1226.22</b>	<b>1226.22</b>	<b>2452.44</b>
1.1 Land preparation	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00
1.4 Rice harvest and threshing	430.00	430.00	860.00
1.5 Fish harvesting	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3091.30</b>	<b>3091.30</b>	<b>6182.60</b>
2.1 Lime	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00
2.5 Chemical fertilizer	169.50	169.50	339.00
2.6 Neem extract substance	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40

**Table B-5 : Cost-benefit of rice-fish culture under 25% chemical fertilizer application during 10 years period(Unit : baht/rai/year).**

Items	Year1			Year2			Year3		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>-1058.01</b>	<b>908.68</b>	<b>-149.33</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>
<b>Total returns</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>
Rice	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32
Fish	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50
<b>Total costs</b>	<b>6880.42</b>	<b>4913.73</b>	<b>11794.15</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>6162.48</b>	<b>4200.79</b>	<b>10363.27</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>
<b>1. Labor costs</b>	<b>1627.93</b>	<b>1194.24</b>	<b>2822.17</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	758.69	341.25	1099.94	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	240.00	0.00	240.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	8.12	0.00	8.12	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	24.37	0.00	24.37	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	144.95	0.00	144.95	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	414.27	414.27	828.54	414.27	414.27	828.54	414.27	414.27	828.54
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>4534.55</b>	<b>3006.55</b>	<b>7541.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	56.00	0.00	56.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	84.75	84.75	169.50	84.75	84.75	169.50	84.75	84.75	169.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	1472.00	0.00	1472.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-5 (Cont.)

Items	Year4			Year5			Year6		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>
<b>Total returns</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>
Rice	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32
Fish	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50
<b>Total costs</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>
<b>1. Labor costs</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	414.27	414.27	828.54	414.27	414.27	828.54	414.27	414.27	828.54
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	84.75	84.75	169.50	84.75	84.75	169.50	84.75	84.75	169.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

**Table B-5 (Cont.)**

Items	Year7			Year8			Year9		
	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>
<b>Total returns</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>
Rice	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32	3418.16	3418.16	6836.32
Fish	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50	2404.25	2404.25	4808.50
<b>Total costs</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00	5.00	0.00	5.00	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00	680.00	680.00	1360.00	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88	32.94	32.94	65.88	32.94	32.94	65.88
<b>Variable costs</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>
<b>1. Labor costs</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>
1.1 Land preparation	81.22	81.22	162.44	81.22	81.22	162.44	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00	357.50	357.50	715.00	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50	341.25	341.25	682.50	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00	130.00	130.00	260.00	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00	195.00	195.00	390.00	195.00	195.00	390.00
1.4 Rice harvest and threshing	414.27	414.27	828.54	414.27	414.27	828.54	414.27	414.27	828.54
1.5 Fish harvesting	16.25	16.25	32.50	16.25	16.25	32.50	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>
2.1 Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80	50.40	50.40	100.80	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 Chemical fertilizer	84.75	84.75	169.50	84.75	84.75	169.50	84.75	84.75	169.50
2.6 Neem extract substance	403.20	403.20	806.40	403.20	403.20	806.40	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40	164.20	164.20	328.40	164.20	164.20	328.40

Table B-5 (Cont.)

Items	Year10		
	Crop 1	Crop 2	Total
<b>Net profit</b>	<b>903.68</b>	<b>908.68</b>	<b>1812.36</b>
<b>Total returns</b>	<b>5822.41</b>	<b>5822.41</b>	<b>11644.82</b>
Rice	3418.16	3418.16	6836.32
Fish	2404.25	2404.25	4808.50
<b>Total costs</b>	<b>4918.73</b>	<b>4913.73</b>	<b>9832.46</b>
<b>Fixed costs</b>	<b>717.94</b>	<b>712.94</b>	<b>1430.88</b>
1. Land tax	5.00	0.00	5.00
2. Opportunity cost of land	680.00	680.00	1360.00
3. Depreciation	32.94	32.94	65.88
<b>Variable costs</b>	<b>4200.79</b>	<b>4200.79</b>	<b>8401.58</b>
<b>1. Labor costs</b>	<b>1194.24</b>	<b>1194.24</b>	<b>2388.48</b>
1.1 Land preparation	81.22	81.22	162.44
1.2 Seedling preparation and transplanting	357.50	357.50	715.00
1.3 Maintenanacing	341.25	341.25	682.50
-Ditching	0.00	0.00	0.00
-Plastic pipe installing	0.00	0.00	0.00
-Chemical fertilizer application	16.25	16.25	32.50
-Neem extract spraying	130.00	130.00	260.00
-Weeding	0.00	0.00	0.00
- Fish feeding	0.00	0.00	0.00
-Water pumping	195.00	195.00	390.00
1.4 Rice harvest and threshing	414.27	414.27	828.54
1.5 Fish harvesting	16.25	16.25	32.50
<b>2. Material costs</b>	<b>3006.55</b>	<b>3006.55</b>	<b>6013.10</b>
2.1 Lime	0.00	0.00	0.00
2.2 Rice variety	50.40	50.40	100.80
2.3 Fish fingerling	2304.00	2304.00	4608.00
2.4 Plastic pipe net	0.00	0.00	0.00
2.5 Chemical fertilizer	84.75	84.75	169.50
2.6 Neem extract substance	403.20	403.20	806.40
2.7 Fish food	0.00	0.00	0.00
2.8 Fuel	164.20	164.20	328.40

**Table B-6 : Cost-benefit analysis of rice culture investment ,NPV&BCR**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	9918.88	6045.42	3873.46	0.8929	8856.57	5397.96	3458.61
2	9918.88	6045.42	3873.46	0.7972	7907.33	4819.41	3087.92
3	9918.88	6045.42	3873.46	0.7118	7060.26	4303.13	2757.13
4	9918.88	6045.42	3873.46	0.6355	6303.45	3841.86	2461.58
5	9918.88	6045.42	3873.46	0.5674	5627.97	3430.17	2197.80
6	9918.88	6045.42	3873.46	0.5066	5024.90	3062.61	1962.29
7	9918.88	6045.42	3873.46	0.4523	4486.31	2734.34	1751.97
8	9918.88	6045.42	3873.46	0.4039	4006.24	2441.75	1564.49
9	9918.88	6045.42	3873.46	0.3606	3576.75	2179.98	1396.77
10	9918.88	6045.42	3873.46	0.3220	3193.88	1946.63	1247.25
<b>Total</b>	<b>99188.80</b>	<b>60454.20</b>	<b>38734.60</b>		<b>56043.66</b>	<b>34157.83</b>	<b>21885.82</b>

At Discount Rate 12% NPV = 21885.82 BCR = 1.64

**Table B-7 : Cost-benefit analysis of rice culture investment ,IRR**

Years	Total benefit	Total cost	Net profit	DR 10%	NPV	DR 15%	NPV
1	9918.88	6045.42	3873.46	0.9091	3521.36	0.8696	3368.36
2	9918.88	6045.42	3873.46	0.8264	3201.03	0.7561	2928.72
3	9918.88	6045.42	3873.46	0.7513	2910.13	0.6575	2546.80
4	9918.88	6045.42	3873.46	0.6830	2645.57	0.5718	2214.84
5	9918.88	6045.42	3873.46	0.6209	2405.03	0.4972	1925.88
6	9918.88	6045.42	3873.46	0.5645	2186.57	0.4323	1674.50
7	9918.88	6045.42	3873.46	0.5132	1987.86	0.3759	1456.03
8	9918.88	6045.42	3873.46	0.4665	1806.97	0.3269	1266.23
9	9918.88	6045.42	3873.46	0.4241	1642.73	0.2843	1101.22
10	9918.88	6045.42	3873.46	0.3855	1493.22	0.2472	957.52
<b>Total</b>	<b>99188.80</b>	<b>60454.20</b>	<b>38734.60</b>		<b>23800.47</b>		<b>19440.12</b>

IRR = 37.29

**Table B-8 : Cost-benefit analysis of rice-fish culture investment under 100% chemical fertilizer application, NPV&BCR**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	17529.50	12413.56	5115.94	0.8929	15652.09	11084.07	4568.02
2	17529.50	10468.12	7061.38	0.7972	13974.52	8345.19	5629.33
3	17529.50	10468.12	7061.38	0.7118	12477.50	7451.21	5026.29
4	17529.50	10468.12	7061.38	0.6355	11140.00	6652.49	4487.51
5	17529.50	10468.12	7061.38	0.5674	9946.24	5939.61	4006.63
6	17529.50	10468.12	7061.38	0.5066	8880.44	5303.15	3577.30
7	17529.50	10468.12	7061.38	0.4523	7928.59	4734.73	3193.86
8	17529.50	10468.12	7061.38	0.4039	7080.17	4228.07	2852.09
9	17529.50	10468.12	7061.38	0.3606	6321.14	3774.80	2546.33
10	17529.5	10468.12	7061.38	0.3220	5644.50	3370.73	2273.76
<b>Total</b>	<b>175295.00</b>	<b>106626.64</b>	<b>68668.36</b>		<b>99045.18</b>	<b>60884.06</b>	<b>38161.13</b>

At Discount Rate 12% NPV = 38161.13 BCR = 1.63

**Table B-9 : Cost-benefit analysis in rice-fish culture investment under 100% chemical fertilizer application, IRR**

Years	Total benefit	Total cost	Net profit	DR 10%	NPV	DR 15%	NPV
1	17529.5	12413.56	5115.94	0.9091	4650.90	0.8696	4448.82
2	17529.5	10468.12	7061.38	0.8264	5835.52	0.7561	5339.11
3	17529.5	10468.12	7061.38	0.7513	5305.21	0.6575	4642.86
4	17529.5	10468.12	7061.38	0.6830	4822.92	0.5718	4037.70
5	17529.5	10468.12	7061.38	0.6209	4384.41	0.4972	3510.92
6	17529.5	10468.12	7061.38	0.5645	3986.15	0.4323	3052.63
7	17529.5	10468.12	7061.38	0.5132	3623.90	0.3759	2654.37
8	17529.5	10468.12	7061.38	0.4665	3294.13	0.3269	2308.37
9	17529.5	10468.12	7061.38	0.4241	2994.73	0.2843	2007.55
10	17529.5	10468.12	7061.38	0.3855	2722.16	0.2472	1745.57
<b>Total</b>	<b>175295.00</b>	<b>106626.64</b>	<b>68668.36</b>		<b>41620.05</b>		<b>33747.90</b>

IRR = 36.43

**Table B-10 : Cost-benefit analysis in rice-fish culture investment under 75% chemical fertilizer application ,NPV&BCR**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	16893.80	12231.26	4662.54	0.8929	15084.47	10921.29	4163.18
2	16893.80	10525.82	6367.98	0.7972	13467.74	8391.18	5076.55
3	16893.80	10525.82	6367.98	0.7118	12025.01	7492.28	4532.73
4	16893.80	10525.82	6367.98	0.6355	10736.01	6689.16	4046.85
5	16893.80	10525.82	6367.98	0.5674	9585.54	5972.35	3613.19
6	16893.80	10525.82	6367.98	0.5066	8558.40	5332.38	3226.02
7	16893.80	10525.82	6367.98	0.4523	7641.07	4760.83	2880.24
8	16893.80	10525.82	6367.98	0.4039	6823.41	4251.38	2572.03
9	16893.80	10525.82	6367.98	0.3606	6091.90	3795.61	2296.29
10	16893.80	10525.82	6367.98	0.3220	5439.80	3389.31	2050.49
<b>Total</b>	<b>168938.00</b>	<b>106963.64</b>	<b>61974.36</b>		<b>95453.35</b>	<b>60995.78</b>	<b>34457.57</b>

At Discount Rate 12% NPV = 34457.57 BCR = 1.56

**Table B-11 : Cost-benefit analysis in rice-fish culture investment under 75% chemical fertilizer application ,IRR**

Years	Total benefit	Total cost	Net profit	DR 10%	NPV	DR 15%	NPV
1	16893.80	12231.26	4662.54	0.9091	4238.72	0.8696	4054.54
2	16893.80	10525.82	6367.98	0.8264	5262.50	0.7561	4814.83
3	16893.80	10525.82	6367.98	0.7513	4784.26	0.6575	4186.95
4	16893.80	10525.82	6367.98	0.6830	4349.33	0.5718	3641.21
5	16893.80	10525.82	6367.98	0.6209	3953.88	0.4972	3166.16
6	16893.80	10525.82	6367.98	0.5645	3594.72	0.4323	2752.88
7	16893.80	10525.82	6367.98	0.5132	3268.05	0.3759	2393.72
8	16893.80	10525.82	6367.98	0.4665	2970.66	0.3269	2081.69
9	16893.80	10525.82	6367.98	0.4241	2700.66	0.2843	1810.42
10	16893.80	10525.82	6367.98	0.3855	2454.86	0.2472	1574.16
<b>Total</b>	<b>168938.00</b>	<b>106963.64</b>	<b>61974.36</b>		<b>37577.64</b>		<b>30476.57</b>

IRR = 36.46

**Table B-12 : Cost-benefit analysis in rice-fish culture investment under 50% chemical fertilizer application ,NPV&BCR**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	13718.40	12139.36	1579.04	0.8929	12249.16	10839.23	1409.92
2	13718.40	10065.92	3652.48	0.7972	10936.31	8024.55	2911.76
3	13718.40	10065.92	3652.48	0.7118	9764.76	7164.92	2599.84
4	13718.40	10065.92	3652.48	0.6355	8718.04	6396.89	2321.15
5	13718.40	10065.92	3652.48	0.5674	7783.82	5711.40	2072.42
6	13718.40	10065.92	3652.48	0.5066	6949.74	5099.40	1850.35
7	13718.40	10065.92	3652.48	0.4523	6204.83	4552.82	1652.02
8	13718.40	10065.92	3652.48	0.4039	5540.86	4065.63	1475.24
9	13718.40	10065.92	3652.48	0.3606	4946.86	3629.77	1317.08
10	13718.40	10065.92	3652.48	0.3220	4417.32	3241.23	1176.10
<b>Total</b>	<b>137184.00</b>	<b>102732.64</b>	<b>34451.36</b>		<b>77511.70</b>	<b>58725.84</b>	<b>18785.87</b>

At Discount Rate 12% NPV = 18785.87 BCR = 1.32

**Table B-13 : Cost-benefit analysis in rice-fish culture investment under 50% chemical fertilizer application ,IRR**

Years	Total benefit	Total cost	Net profit	DR 10%	NPV	DR 15%	NPV
1	13718.40	12139.36	1579.04	0.9091	1435.51	0.8696	1373.13
2	13718.40	10065.92	3652.48	0.8264	3018.41	0.7561	2761.64
3	13718.40	10065.92	3652.48	0.7513	2744.11	0.6575	2401.51
4	13718.40	10065.92	3652.48	0.6830	2494.64	0.5718	2088.49
5	13718.40	10065.92	3652.48	0.6209	2267.82	0.4972	1816.01
6	13718.40	10065.92	3652.48	0.5645	2061.82	0.4323	1578.97
7	13718.40	10065.92	3652.48	0.5132	1874.45	0.3759	1372.97
8	13718.40	10065.92	3652.48	0.4665	1703.88	0.3269	1194.00
9	13718.40	10065.92	3652.48	0.4241	1549.02	0.2843	1038.40
10	13718.40	10065.92	3652.48	0.3855	1408.03	0.2472	902.89
<b>Total</b>	<b>137184.00</b>	<b>102732.64</b>	<b>34451.36</b>		<b>20557.70</b>		<b>16528.00</b>

IRR = 35.51

**Table B-14 : Cost-benefit analysis in rice-fish culture investment under 25% chemical fertilizer application ,NPV&BCR**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	11644.82	11794.15	-149.33	0.8929	10397.66	10531.00	-133.34
2	11644.82	9832.46	1812.36	0.7972	9283.25	7838.44	1444.81
3	11644.82	9832.46	1812.36	0.7118	8288.78	6998.75	1290.04
4	11644.82	9832.46	1812.36	0.6355	7400.28	6248.53	1151.75
5	11644.82	9832.46	1812.36	0.5674	6607.27	5578.94	1028.33
6	11644.82	9832.46	1812.36	0.5066	5899.27	4981.12	918.14
7	11644.82	9832.46	1812.36	0.4523	5266.95	4447.22	819.73
8	11644.82	9832.46	1812.36	0.4039	4703.34	3971.33	732.01
9	11644.82	9832.46	1812.36	0.3606	4199.12	3545.59	653.54
10	11644.82	9832.46	1812.36	0.3220	3749.63	3166.05	583.58
<b>Total</b>	<b>116448.20</b>	<b>100286.29</b>	<b>16161.91</b>		<b>65795.56</b>	<b>57306.96</b>	<b>8488.60</b>

At Discount Rate 12% NPV = 8488.60 BCR = 1.15

**Table B-15 : Cost-benefit analysis in rice-fish culture investment under 25% chemical fertilizer application ,IRR**

Years	Total benefit	Total cost	Net profit	DR 10%	NPV	DR 15%	NPV
1	11644.82	11794.15	-149.33	0.9091	-135.76	0.8696	-129.86
2	11644.82	9832.46	1812.36	0.8264	1497.73	0.7561	1370.33
3	11644.82	9832.46	1812.36	0.7513	1361.63	0.6575	1191.63
4	11644.82	9832.46	1812.36	0.6830	1237.84	0.5718	1036.31
5	11644.82	9832.46	1812.36	0.6209	1125.29	0.4972	901.11
6	11644.82	9832.46	1812.36	0.5645	1023.08	0.4323	783.48
7	11644.82	9832.46	1812.36	0.5132	930.10	0.3759	681.27
8	11644.82	9832.46	1812.36	0.4665	845.47	0.3269	592.46
9	11644.82	9832.46	1812.36	0.4241	768.62	0.2843	515.25
10	11644.82	9832.46	1812.36	0.3855	698.66	0.2472	448.02
<b>Total</b>	<b>116448.20</b>	<b>100286.29</b>	<b>16161.91</b>		<b>9352.67</b>		<b>7389.99</b>

IRR = 33.83

Table B-16 : Sensitivity analysis of rice culture, discount rate 6% and 10%

Years	Total benefit	Total cost	Net profit	DR 6%	PV of benefit	PV of cost	NPV	DR 10%	PV of benefit	PV of cost	NPV
1	9918.88	6045.42	3873.46	0.9434	9357.47	5703.25	3654.22	0.9091	9017.25	5495.89	3521.36
2	9918.88	6045.42	3873.46	0.8900	8827.80	5380.42	3447.38	0.8264	8196.96	4995.94	3201.03
3	9918.88	6045.42	3873.46	0.8396	8327.89	5075.73	3252.16	0.7513	7452.05	4541.92	2910.13
4	9918.88	6045.42	3873.46	0.7921	7856.74	4788.58	3068.17	0.6830	6774.60	4129.02	2645.57
5	9918.88	6045.42	3873.46	0.7473	7412.38	4517.74	2894.64	0.6209	6158.63	3753.60	2405.03
6	9918.88	6045.42	3873.46	0.7050	6992.81	4262.02	2730.79	0.5645	5599.21	3412.64	2186.57
7	9918.88	6045.42	3873.46	0.6651	6597.05	4020.81	2576.24	0.5132	5090.37	3102.51	1987.86
8	9918.88	6045.42	3873.46	0.6274	6223.11	3792.90	2430.21	0.4665	4627.16	2820.19	1806.97
9	9918.88	6045.42	3873.46	0.5919	5870.99	3578.28	2292.70	0.4241	4206.60	2563.86	1642.73
10	9918.88	6045.42	3873.46	0.5584	5538.70	3375.76	2162.94	0.3855	3823.73	2330.51	1493.22
Total	99188.8	60454.2	38734.6		73004.94	44495.50	28509.44		60946.56	37146.08	23800.47

At Discount Rate 6% NPV = 28509.44 BCR = 1.64

At Discount Rate 10% NPV = 23800.47 BCR = 1.64

**Table B-17 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,discount rate 6% and 10%**

Years	Total benefit	Total cost	Net profit	DR 6%	PV of benefit	PV of cost	NPV	DR 10%	PV of benefit	PV of cost	NPV
1	17529.50	12413.56	5115.94	0.9434	16537.33	11710.95	4826.38	0.9091	15936.07	11285.17	4650.90
2	17529.50	10468.12	7061.38	0.8900	15601.26	9316.63	6284.63	0.8264	14486.38	8650.85	5835.52
3	17529.50	10468.12	7061.38	0.8396	14717.77	8789.03	5928.73	0.7513	13169.91	7864.70	5305.21
4	17529.50	10468.12	7061.38	0.7921	13885.12	8291.80	5593.32	0.6830	11972.65	7149.73	4822.92
5	17529.50	10468.12	7061.38	0.7473	13099.80	7822.83	5276.97	0.6209	10884.07	6499.66	4384.41
6	17529.50	10468.12	7061.38	0.7050	12358.30	7380.02	4978.27	0.5645	9895.40	5909.25	3986.15
7	17529.50	10468.12	7061.38	0.6651	11658.87	6962.35	4696.52	0.5132	8996.14	5372.24	3623.90
8	17529.50	10468.12	7061.38	0.6274	10998.01	6567.70	4430.31	0.4665	8177.51	4883.38	3294.13
9	17529.50	10468.12	7061.38	0.5919	10375.71	6196.08	4179.63	0.4241	7434.26	4439.53	2994.73
10	17529.50	10468.12	7061.38	0.5584	9788.47	5845.40	3943.07	0.3855	6757.62	4035.46	2722.16
<b>Total</b>	<b>175295.00</b>	<b>106626.64</b>	<b>68668.36</b>		<b>129020.63</b>	<b>78882.78</b>	<b>50137.84</b>		<b>107710.01</b>	<b>66089.96</b>	<b>41620.05</b>

**At Discount Rate 6% NPV = 50137.84 BCR = 1.64**

**At Discount Rate 10% NPV = 41620.05 BCR = 1.63**

Table B-18 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,discount rate 6% and 10%

Years	Total benefit	Total cost	Net profit	DR 6%	PV of benefit	PV of cost	NPV	DR 10%	PV of benefit	PV of cost	NPV
1	16893.80	12231.26	4662.54	0.9434	15937.61	11538.97	4398.64	0.9091	12691.98	11119.44	4238.72
2	16893.80	10525.82	6367.98	0.8900	15035.48	9367.98	5667.50	0.8264	13961.04	8698.54	5262.50
3	16893.80	10525.82	6367.98	0.8396	14184.03	8837.48	5346.56	0.7513	12692.31	7908.05	4784.26
4	16893.80	10525.82	6367.98	0.7921	13381.58	8337.50	5044.08	0.6830	11538.47	7189.14	4349.33
5	16893.80	10525.82	6367.98	0.7473	12624.74	7865.95	4758.79	0.6209	10489.36	6535.48	3953.88
6	16893.80	10525.82	6367.98	0.7050	11910.13	7420.70	4489.43	0.5645	9536.55	5941.83	3594.72
7	16893.80	10525.82	6367.98	0.6651	11236.07	7000.72	4235.34	0.5132	8669.90	5401.85	3268.05
8	16893.80	10525.82	6367.98	0.6274	10599.17	6603.90	3995.27	0.4665	7880.96	4910.30	2970.66
9	16893.80	10525.82	6367.98	0.5919	9999.44	6230.23	3769.21	0.4241	7164.66	4464.00	2700.66
10	16893.80	10525.82	6367.98	0.5584	9433.50	5877.62	3555.88	0.3855	6512.56	4057.70	2454.86
Total	168938.00	106963.64	61974.36		124341.75	79081.05	45260.69		101137.78	66226.32	37577.64

At Discount Rate 6% NPV = 45260.69 BCR = 1.57

At Discount Rate 10% NPV = 37577.64 BCR = 1.53

**Table B-19 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,discount rate 6% and 10%**

Years	Total benefit	Total cost	Net profit	DR 6%	PV of benefit	PV of cost	NPV	DR 10%	PV of benefit	PV of cost	NPV
1	13718.40	12139.36	1579.04	0.9434	12941.94	11452.27	1489.67	0.9091	12471.40	11035.89	1435.51
2	13718.40	10065.92	3652.48	0.8900	12209.38	8958.67	3250.71	0.8264	11336.89	8318.48	3018.41
3	13718.40	10065.92	3652.48	0.8396	11517.97	8451.35	3066.62	0.7513	10306.63	7562.53	2744.11
4	13718.40	10065.92	3652.48	0.7921	10866.34	7973.22	2893.13	0.6830	9369.67	6875.02	2494.64
5	13718.40	10065.92	3652.48	0.7473	10251.76	7522.26	2729.50	0.6209	8517.75	6249.93	2267.82
6	13718.40	10065.92	3652.48	0.7050	9671.47	7096.47	2575.00	0.5645	7744.04	5682.21	2061.82
7	13718.40	10065.92	3652.48	0.6651	9124.11	6694.84	2429.26	0.5132	7040.28	5165.83	1874.45
8	13718.40	10065.92	3652.48	0.6274	8606.92	6315.36	2291.57	0.4665	6399.63	4695.75	1703.88
9	13718.40	10065.92	3652.48	0.5919	8119.92	5958.02	2161.90	0.4241	5817.97	4268.96	1549.02
10	13718.40	10065.92	3652.48	0.5584	7660.35	5620.81	2039.54	0.3855	5288.44	3880.41	1408.03
<b>Total</b>	<b>137184.00</b>	<b>102732.64</b>	<b>34451.36</b>		<b>100970.17</b>	<b>76043.27</b>	<b>24926.90</b>		<b>84292.71</b>	<b>63735.01</b>	<b>20557.70</b>

**At Discount Rate 6% NPV = 24926.90 BCR = 1.33**

**At Discount Rate 10% NPV = 20557.70 BCR = 1.32**

Table B-20 : Sensitivity analysis of rice-fish culture investment under 25% chemical fertilizer application ,discount rate 6% and 10%

Years	Total benefit	Total cost	Net profit	DR 6%	PV of benefit	PV of cost	NPV	DR 10%	PV of benefit	PV of cost	NPV
1	11644.82	11794.15	-149.33	0.9434	10985.72	11126.60	-140.88	0.9091	10586.31	10722.06	-135.76
2	11644.82	9832.46	1812.36	0.8900	10363.89	8750.89	1613.00	0.8264	9623.28	8125.54	1497.73
3	11644.82	9832.46	1812.36	0.8396	9776.99	8255.33	1521.66	0.7513	8748.75	7387.13	1361.63
4	11644.82	9832.46	1812.36	0.7921	9223.86	7788.29	1435.57	0.6830	7953.41	6715.57	1237.84
5	11644.82	9832.46	1812.36	0.7473	8702.17	7347.80	1354.38	0.6209	7230.27	6104.97	1125.29
6	11644.82	9832.46	1812.36	0.7050	8209.60	6931.88	1277.71	0.5645	6573.50	5550.42	1023.08
7	11644.82	9832.46	1812.36	0.6651	7744.97	6539.57	1205.40	0.5132	5976.12	5046.02	930.10
8	11644.82	9832.46	1812.36	0.6274	7305.96	6168.89	1137.07	0.4665	5432.31	4586.84	845.47
9	11644.82	9832.46	1812.36	0.5919	6892.57	5819.83	1072.74	0.4241	4938.57	4169.95	768.62
10	11644.82	9832.46	1812.36	0.5584	6502.47	5490.45	1012.02	0.3855	4489.08	3790.41	698.66
Total	116448.20	100286.29	16161.91		85708.20	74219.53	11488.67		71551.60	62198.92	9352.67

At Discount Rate 6% NPV = 11488.67 BCR = 1.15

At Discount Rate 10% NPV = 9352.67 BCR = 1.15

**Table B-21 : Sensitivity analysis of rice culture, discount rate 15% and 20%**

Years	Total benefit	Total cost	Net profit	DR 15%	PV of benefit	PV of cost	NPV	DR 20%	PV of benefit	PV of cost	NPV
1	9918.88	6045.42	3873.46	0.8696	8625.46	5257.10	3368.36	0.8333	8265.40	5037.65	3227.75
2	9918.88	6045.42	3873.46	0.7561	7499.67	4570.94	2928.72	0.6944	6887.67	4197.94	2689.73
3	9918.88	6045.42	3873.46	0.6575	6521.66	3974.86	2546.80	0.5787	5740.06	3498.48	2241.57
4	9918.88	6045.42	3873.46	0.5718	5671.62	3456.77	2214.84	0.4823	4783.88	2915.71	1868.17
5	9918.88	6045.42	3873.46	0.4972	4931.67	3005.78	1925.88	0.4019	3986.40	2429.65	1556.74
6	9918.88	6045.42	3873.46	0.4323	4287.93	2613.44	1674.50	0.3349	3321.83	2024.61	1297.22
7	9918.88	6045.42	3873.46	0.3759	3728.51	2272.47	1456.03	0.2791	2768.36	1687.28	1081.08
8	9918.88	6045.42	3873.46	0.3269	3242.48	1976.25	1266.23	0.2326	2307.13	1406.16	900.97
9	9918.88	6045.42	3873.46	0.2843	2819.94	1718.71	1101.22	0.1938	1922.28	1171.60	750.68
10	9918.88	6045.42	3873.46	0.2472	2451.95	1494.43	957.52	0.1615	1601.90	976.34	625.56
<b>Total</b>	<b>99188.8</b>	<b>60454.2</b>	<b>38734.6</b>		<b>49780.87</b>	<b>30340.75</b>	<b>19440.12</b>		<b>41584.90</b>	<b>25345.42</b>	<b>16239.48</b>

**At Discount Rate 15% NPV = 19440.12 BCR = 1.64**

**At Discount Rate 20% NPV = 16239.48 BCR = 1.64**

Table B-22 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,discount rate 15% and 20%

Years	Total benefit	Total cost	Net profit	DR 15%	PV of benefit	PV of cost	NPV	DR 20%	PV of benefit	PV of cost	NPV
1	17529.50	12413.56	5115.94	0.8696	15243.65	10794.83	4448.82	0.8333	14607.33	10344.22	4263.11
2	17529.50	10468.12	7061.38	0.7561	13254.05	7914.95	5339.11	0.6944	12172.48	7269.06	4903.42
3	17529.50	10468.12	7061.38	0.6575	11525.65	6882.79	4642.86	0.5787	10144.32	6057.90	4086.42
4	17529.50	10468.12	7061.38	0.5718	10023.37	5985.67	4037.70	0.4823	8454.48	5048.77	3405.70
5	17529.50	10468.12	7061.38	0.4972	8715.67	5204.75	3510.92	0.4019	7045.11	4207.14	2837.97
6	17529.50	10468.12	7061.38	0.4323	7578.00	4525.37	3052.63	0.3349	5870.63	3505.77	2364.86
7	17529.50	10468.12	7061.38	0.3759	6589.34	3934.97	2654.37	0.2791	4892.48	2921.65	1970.83
8	17529.50	10468.12	7061.38	0.3269	5730.39	3422.03	2308.37	0.2326	4077.36	2434.88	1642.48
9	17529.50	10468.12	7061.38	0.2843	4983.64	2976.09	2007.55	0.1938	3397.22	2028.72	1368.50
10	17529.5	10468.12	7061.38	0.2472	4333.29	2587.72	1745.57	0.1615	2831.01	1690.60	1140.41
Total	175295.00	106626.64	68668.36		87977.05	54229.16	33747.90		73492.43	45508.73	27983.70

At Discount Rate 15% NPV = 33747.90 BCR = 1.62

At Discount Rate 20% NPV = 27983.70 BCR = 1.61

**Table B-23 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,discount rate 15% and 20%**

Years	Total benefit	Total cost	Net profit	DR 15%	PV of benefit	PV of cost	NPV	DR 20%	PV of benefit	PV of cost	NPV
1	16893.80	12231.26	4662.54	0.8696	14690.85	10636.30	4054.54	0.8333	9775.49	10192.31	3885.29
2	16893.80	10525.82	6367.98	0.7561	12773.40	7958.57	4814.83	0.6944	11731.05	7309.13	4421.93
3	16893.80	10525.82	6367.98	0.6575	11107.67	6920.73	4186.95	0.5787	9776.44	6091.29	3685.15
4	16893.80	10525.82	6367.98	0.5718	9659.87	6018.66	3641.21	0.4823	8147.88	5076.60	3071.28
5	16893.80	10525.82	6367.98	0.4972	8399.60	5233.44	3166.16	0.4019	6789.62	4230.33	2559.29
6	16893.80	10525.82	6367.98	0.4323	7303.19	4550.31	2752.88	0.3349	5657.73	3525.10	2132.64
7	16893.80	10525.82	6367.98	0.3759	6350.38	3956.66	2393.72	0.2791	4715.06	2937.76	1777.30
8	16893.80	10525.82	6367.98	0.3269	5522.58	3440.89	2081.69	0.2326	3929.50	2448.31	1481.19
9	16893.80	10525.82	6367.98	0.2843	4802.91	2992.49	1810.42	0.1938	3274.02	2039.90	1234.11
10	16893.80	10525.82	6367.98	0.2472	4176.15	2601.98	1574.16	0.1615	2728.35	1699.92	1028.43
<b>Total</b>	<b>168938.00</b>	<b>106963.64</b>	<b>61974.36</b>		<b>84786.60</b>	<b>54310.04</b>	<b>30476.57</b>		<b>66525.14</b>	<b>45550.64</b>	<b>25276.61</b>

**At Discount Rate 15% NPV = 30476.57 BCR = 1.56**

**At Discount Rate 20% NPV = 25276.61 BCR = 1.46**

Table B-24 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,discount rate 15% and 20%

Years	Total benefit	Total cost	Net profit	DR 15%	PV of benefit	PV of cost	NPV	DR 20%	PV of benefit	PV of cost	NPV
1	13718.40	12139.36	1579.04	0.8696	11929.52	10556.39	1373.13	0.8333	11431.54	10115.73	1315.81
2	13718.40	10065.92	3652.48	0.7561	10372.48	7610.84	2761.64	0.6944	9526.06	6989.77	2536.28
3	13718.40	10065.92	3652.48	0.6575	9019.85	6618.34	2401.51	0.5787	7938.84	5825.15	2113.69
4	13718.40	10065.92	3652.48	0.5718	7844.18	5755.69	2088.49	0.4823	6616.38	4854.79	1761.59
5	13718.40	10065.92	3652.48	0.4972	6820.79	5004.78	1816.01	0.4019	5513.42	4045.49	1467.93
6	13718.40	10065.92	3652.48	0.4323	5930.46	4351.50	1578.97	0.3349	4594.29	3371.08	1223.22
7	13718.40	10065.92	3652.48	0.3759	5156.75	3783.78	1372.97	0.2791	3828.81	2809.40	1019.41
8	13718.40	10065.92	3652.48	0.3269	4484.54	3290.55	1194.00	0.2326	3190.90	2341.33	849.57
9	13718.40	10065.92	3652.48	0.2843	3900.14	2861.74	1038.40	0.1938	2658.63	1950.78	707.85
10	13718.40	10065.92	3652.48	0.2472	3391.19	2488.30	902.89	0.1615	2215.52	1625.65	589.88
Total	137184.00	102732.64	34451.36		68849.91	52321.90	16528.00		57514.39	43929.17	13585.22

At Discount Rate 15% NPV = 16528.00 BCR = 1.32

At Discount Rate 20% NPV = 13585.22 BCR = 1.31

**Table B-25 : Sensitivity analysis of rice-fish culture investment under 25% chemical fertilizer application ,discount rate 15% and 20%**

Years	Total benefit	Total cost	Net profit	DR 15%	PV of benefit	PV of cost	NPV	DR 20%	PV of benefit	PV of cost	NPV
1	11644.82	11794.15	-149.33	0.8696	10126.34	10256.19	-129.86	0.8333	9703.63	9828.07	-124.44
2	11644.82	9832.46	1812.36	0.7561	8804.65	7434.32	1370.33	0.6944	8086.16	6827.66	1258.50
3	11644.82	9832.46	1812.36	0.6575	7656.47	6464.84	1191.63	0.5787	6738.86	5690.04	1048.81
4	11644.82	9832.46	1812.36	0.5718	6658.51	5622.20	1036.31	0.4823	5616.30	4742.20	874.10
5	11644.82	9832.46	1812.36	0.4972	5789.80	4888.70	901.11	0.4019	4680.05	3951.67	728.39
6	11644.82	9832.46	1812.36	0.4323	5034.06	4250.57	783.48	0.3349	3899.85	3292.89	606.96
7	11644.82	9832.46	1812.36	0.3759	4377.29	3696.02	681.27	0.2791	3250.07	2744.24	505.83
8	11644.82	9832.46	1812.36	0.3269	3806.69	3214.23	592.46	0.2326	2708.59	2287.03	421.55
9	11644.82	9832.46	1812.36	0.2843	3310.62	2795.37	515.25	0.1938	2256.77	1905.53	351.24
10	11644.82	9832.46	1812.36	0.2472	2878.60	2430.58	448.02	0.1615	1880.64	1587.94	292.70
<b>Total</b>	<b>116448.20</b>	<b>100286.29</b>	<b>16161.91</b>		<b>58443.02</b>	<b>51053.04</b>	<b>7389.99</b>		<b>48820.91</b>	<b>42857.26</b>	<b>5963.64</b>

**At Discount Rate 15% NPV = 7389.99 BCR = 1.14**

**At Discount Rate 20% NPV = 5963.64 BCR = 1.14**

**Table B-26 : Sensitivity analysis of rice culture ,increasing cost 5%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	9918.88	6045.42	6347.69	3571.19	0.8929	8856.57	5667.85	3188.71
2	9918.88	6045.42	6347.69	3571.19	0.7972	7907.33	5060.38	2846.95
3	9918.88	6045.42	6347.69	3571.19	0.7118	7060.26	4518.29	2541.97
4	9918.88	6045.42	6347.69	3571.19	0.6355	6303.45	4033.96	2269.49
5	9918.88	6045.42	6347.69	3571.19	0.5674	5627.97	3601.68	2026.29
6	9918.88	6045.42	6347.69	3571.19	0.5066	5024.90	3215.74	1809.16
7	9918.88	6045.42	6347.69	3571.19	0.4523	4486.31	2871.06	1615.25
8	9918.88	6045.42	6347.69	3571.19	0.4039	4006.24	2563.83	1442.40
9	9918.88	6045.42	6347.69	3571.19	0.3606	3576.75	2288.98	1287.77
10	9918.88	6045.42	6347.69	3571.19	0.3220	3193.88	2043.96	1149.92
<b>Total</b>	<b>99188.8</b>	<b>60454.2</b>	<b>63476.91</b>	<b>35711.89</b>		<b>56043.66</b>	<b>35865.72</b>	<b>20177.93</b>

At Discount Rate 12%

NPV = 20177.93

BCR = 1.56

**Table B-27 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,increasing cost 5%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	17529.50	12413.56	13034.24	4495.26	0.8929	15652.09	11638.27	4013.82
2	17529.50	10468.12	10991.53	6537.97	0.7972	13974.52	8762.44	5212.07
3	17529.50	10468.12	10991.53	6537.97	0.7118	12477.50	7823.77	4653.73
4	17529.50	10468.12	10991.53	6537.97	0.6355	11140.00	6985.11	4154.88
5	17529.50	10468.12	10991.53	6537.97	0.5674	9946.24	6236.59	3709.65
6	17529.50	10468.12	10991.53	6537.97	0.5066	8880.44	5568.31	3312.14
7	17529.50	10468.12	10991.53	6537.97	0.4523	7928.59	4971.47	2957.13
8	17529.50	10468.12	10991.53	6537.97	0.4039	7080.17	4439.48	2640.69
9	17529.50	10468.12	10991.53	6537.97	0.3606	6321.14	3963.54	2357.59
10	17529.5	10468.12	10991.53	6537.97	0.3220	5644.50	3539.27	2105.23
<b>Total</b>	<b>175295</b>	<b>106626.64</b>	<b>111957.97</b>	<b>63337.028</b>		<b>99045.18</b>	<b>63928.26</b>	<b>35116.92</b>

At Discount Rate 12%

NPV = 35116.92

BCR = 1.55

**Table B-28 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,increasing cost 5%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	16893.80	12231.26	12842.82	4050.98	0.8929	15084.47	11467.36	3617.12
2	16893.80	10525.82	11052.11	5841.69	0.7972	13467.74	8810.74	4656.99
3	16893.80	10525.82	11052.11	5841.69	0.7118	12025.01	7866.89	4158.11
4	16893.80	10525.82	11052.11	5841.69	0.6355	10736.01	7023.62	3712.39
5	16893.80	10525.82	11052.11	5841.69	0.5674	9585.54	6270.97	3314.57
6	16893.80	10525.82	11052.11	5841.69	0.5066	8558.40	5599.00	2959.40
7	16893.80	10525.82	11052.11	5841.69	0.4523	7641.07	4998.87	2642.20
8	16893.80	10525.82	11052.11	5841.69	0.4039	6823.41	4463.95	2359.46
9	16893.80	10525.82	11052.11	5841.69	0.3606	6091.90	3985.39	2106.51
10	16893.80	10525.82	11052.11	5841.69	0.3220	5439.80	3558.78	1881.02
<b>Total</b>	<b>168938.00</b>	<b>106963.64</b>	<b>112311.82</b>	<b>56626.178</b>		<b>95453.35</b>	<b>64045.56</b>	<b>31407.78</b>

At Discount Rate 12% NPV = 31407.78 BCR = 1.49

**Table B-29 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,increasing cost 5%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	13718.40	12139.36	12746.33	972.07	0.8929	12249.16	11381.20	867.96
2	13718.40	10065.92	10569.22	3149.18	0.7972	10936.31	8425.78	2510.53
3	13718.40	10065.92	10569.22	3149.18	0.7118	9764.76	7523.17	2241.59
4	13718.40	10065.92	10569.22	3149.18	0.6355	8718.04	6716.74	2001.31
5	13718.40	10065.92	10569.22	3149.18	0.5674	7783.82	5996.97	1786.85
6	13718.40	10065.92	10569.22	3149.18	0.5066	6949.74	5354.36	1595.38
7	13718.40	10065.92	10569.22	3149.18	0.4523	6204.83	4780.46	1424.38
8	13718.40	10065.92	10569.22	3149.18	0.4039	5540.86	4268.91	1271.96
9	13718.40	10065.92	10569.22	3149.18	0.3606	4946.86	3811.26	1135.60
10	13718.40	10065.92	10569.22	3149.18	0.3220	4417.32	3403.29	1014.04
<b>Total</b>	<b>137184.00</b>	<b>102732.64</b>	<b>107869.27</b>	<b>29314.728</b>		<b>77511.70</b>	<b>61662.13</b>	<b>15849.58</b>

At Discount Rate 12% NPV = 15849.58 BCR = 1.26

**Table B-30 : Sensitivity analysis of rice-fish culture investment under 25% chemical fertilizer application ,increasing cost 5%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	11644.82	11794.15	12383.86	-739.04	0.8929	10397.66	11057.55	-659.89
2	11644.82	9832.46	10324.08	1320.74	0.7972	9283.25	8230.36	1052.89
3	11644.82	9832.46	10324.08	1320.74	0.7118	8288.78	7348.68	940.10
4	11644.82	9832.46	10324.08	1320.74	0.6355	7400.28	6560.95	839.33
5	11644.82	9832.46	10324.08	1320.74	0.5674	6607.27	5857.88	749.39
6	11644.82	9832.46	10324.08	1320.74	0.5066	5899.27	5230.18	669.09
7	11644.82	9832.46	10324.08	1320.74	0.4523	5266.95	4669.58	597.37
8	11644.82	9832.46	10324.08	1320.74	0.4039	4703.34	4169.90	533.45
9	11644.82	9832.46	10324.08	1320.74	0.3606	4199.12	3722.86	476.26
10	11644.82	9832.46	10324.08	1320.74	0.3220	3749.63	3324.35	425.28
<b>Total</b>	<b>116448.20</b>	<b>100286.29</b>	<b>105300.60</b>	<b>11147.5955</b>		<b>65795.56</b>	<b>60172.31</b>	<b>5623.26</b>

At Discount Rate 12%

NPV = 5623.256

BCR = 1.09

**Table B-31 : Sensitivity analysis of rice culture ,increasing cost 10%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	9918.88	6045.42	6649.96	3268.92	0.8929	8856.57	5937.75	2918.82
2	9918.88	6045.42	6649.96	3268.92	0.7972	7907.33	5301.35	2605.98
3	9918.88	6045.42	6649.96	3268.92	0.7118	7060.26	4733.44	2326.82
4	9918.88	6045.42	6649.96	3268.92	0.6355	6303.45	4226.05	2077.40
5	9918.88	6045.42	6649.96	3268.92	0.5674	5627.97	3773.19	1854.78
6	9918.88	6045.42	6649.96	3268.92	0.5066	5024.90	3368.87	1656.03
7	9918.88	6045.42	6649.96	3268.92	0.4523	4486.31	3007.78	1478.53
8	9918.88	6045.42	6649.96	3268.92	0.4039	4006.24	2685.92	1320.32
9	9918.88	6045.42	6649.96	3268.92	0.3606	3576.75	2397.98	1178.77
10	9918.88	6045.42	6649.96	3268.92	0.3220	3193.88	2141.29	1052.59
<b>Total</b>	<b>99188.80</b>	<b>60454.20</b>	<b>63476.91</b>	<b>32689.18</b>		<b>56043.66</b>	<b>37573.62</b>	<b>18470.04</b>

At Discount Rate 12%

NPV = 18470.04

BCR = 1.49

**Table B-32 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,increasing cost 10%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	17529.50	12413.56	13654.92	3874.58	0.8929	15652.09	12192.47	3459.62
2	17529.50	10468.12	11514.93	6014.57	0.7972	13974.52	9179.70	4794.81
3	17529.50	10468.12	11514.93	6014.57	0.7118	12477.50	8196.33	4281.17
4	17529.50	10468.12	11514.93	6014.57	0.6355	11140.00	7317.74	3822.26
5	17529.50	10468.12	11514.93	6014.57	0.5674	9946.24	6533.57	3412.67
6	17529.50	10468.12	11514.93	6014.57	0.5066	8880.44	5833.46	3046.98
7	17529.50	10468.12	11514.93	6014.57	0.4523	7928.59	5208.20	2720.39
8	17529.50	10468.12	11514.93	6014.57	0.4039	7080.17	4650.88	2429.28
9	17529.50	10468.12	11514.93	6014.57	0.3606	6321.14	4152.28	2168.85
10	17529.5	10468.12	11514.93	6014.57	0.3220	5644.50	3707.81	1936.69
<b>Total</b>	<b>175295.00</b>	<b>106626.64</b>	<b>111957.97</b>	<b>58005.70</b>		<b>99045.18</b>	<b>66972.46</b>	<b>32072.72</b>

At Discount Rate 12% NPV = 32072.72 BCR = 1.48

**Table B-33 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,increasing cost 10%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	16893.80	12231.26	13454.39	3439.41	0.8929	15084.47	12013.42	3071.05
2	16893.80	10525.82	11578.40	5315.40	0.7972	13467.74	9230.30	4237.44
3	16893.80	10525.82	11578.40	5315.40	0.7118	12025.01	8241.51	3783.50
4	16893.80	10525.82	11578.40	5315.40	0.6355	10736.01	7358.07	3377.94
5	16893.80	10525.82	11578.40	5315.40	0.5674	9585.54	6569.59	3015.96
6	16893.80	10525.82	11578.40	5315.40	0.5066	8558.40	5865.62	2692.78
7	16893.80	10525.82	11578.40	5315.40	0.4523	7641.07	5236.91	2404.15
8	16893.80	10525.82	11578.40	5315.40	0.4039	6823.41	4676.52	2146.89
9	16893.80	10525.82	11578.40	5315.40	0.3606	6091.90	4175.17	1916.73
10	16893.80	10525.82	11578.40	5315.40	0.3220	5439.80	3728.25	1711.56
<b>Total</b>	<b>168938.00</b>	<b>106963.64</b>	<b>112311.82</b>	<b>51278.00</b>		<b>95453.35</b>	<b>67095.35</b>	<b>28358.00</b>

At Discount Rate 12% NPV = 28358 BCR = 1.42

**Table B-34 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,increasing cost 10%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	13718.40	12139.36	13353.30	365.10	0.8929	12249.16	11923.16	326.00
2	13718.40	10065.92	11072.51	2645.89	0.7972	10936.31	8827.01	2109.30
3	13718.40	10065.92	11072.51	2645.89	0.7118	9764.76	7881.41	1883.34
4	13718.40	10065.92	11072.51	2645.89	0.6355	8718.04	7036.58	1681.46
5	13718.40	10065.92	11072.51	2645.89	0.5674	7783.82	6282.54	1501.28
6	13718.40	10065.92	11072.51	2645.89	0.5066	6949.74	5609.33	1340.41
7	13718.40	10065.92	11072.51	2645.89	0.4523	6204.83	5008.10	1196.74
8	13718.40	10065.92	11072.51	2645.89	0.4039	5540.86	4472.19	1068.67
9	13718.40	10065.92	11072.51	2645.89	0.3606	4946.86	3992.75	954.11
10	13718.40	10065.92	11072.51	2645.89	0.3220	4417.32	3565.35	851.98
<b>Total</b>	<b>137184.00</b>	<b>102732.64</b>	<b>107869.27</b>	<b>24178.10</b>		<b>77511.70</b>	<b>64598.42</b>	<b>12913.28</b>

At Discount Rate 12% NPV = 12913.28 BCR = 1.20

**Table B-35 : Sensitivity analysis of rice-fish culture investment under 25% chemical fertilizer application ,increasing cost 10%**

Years	Total benefit	Total cost	Increasing total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	11644.82	11794.15	12973.57	-1328.75	0.8929	10397.66	11584.10	-1186.44
2	11644.82	9832.46	10815.71	829.11	0.7972	9283.25	8622.28	660.97
3	11644.82	9832.46	10815.71	829.11	0.7118	8288.78	7698.62	590.16
4	11644.82	9832.46	10815.71	829.11	0.6355	7400.28	6873.38	526.90
5	11644.82	9832.46	10815.71	829.11	0.5674	6607.27	6136.83	470.44
6	11644.82	9832.46	10815.71	829.11	0.5066	5899.27	5479.24	420.03
7	11644.82	9832.46	10815.71	829.11	0.4523	5266.95	4891.94	375.01
8	11644.82	9832.46	10815.71	829.11	0.4039	4703.34	4368.46	334.88
9	11644.82	9832.46	10815.71	829.11	0.3606	4199.12	3900.14	298.98
10	11644.82	9832.46	10815.71	829.11	0.3220	3749.63	3482.66	266.97
<b>Total</b>	<b>116448.20</b>	<b>100286.29</b>	<b>105300.60</b>	<b>6133.28</b>		<b>65795.56</b>	<b>63037.65</b>	<b>2757.91</b>

At Discount Rate 12% NPV = 2757.908 BCR = 1.04

**Table B-36 : Sensitivity analysis of rice culture ,price of rice baht 4.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	5834.64	6045.42	-210.78	0.8929	5209.75	5397.96	-188.21
2	5834.64	6045.42	-210.78	0.7972	4651.38	4819.41	-168.03
3	5834.64	6045.42	-210.78	0.7118	4153.10	4303.13	-150.03
4	5834.64	6045.42	-210.78	0.6355	3707.91	3841.86	-133.95
5	5834.64	6045.42	-210.78	0.5674	3310.57	3430.17	-119.60
6	5834.64	6045.42	-210.78	0.5066	2955.83	3062.61	-106.78
7	5834.64	6045.42	-210.78	0.4523	2639.01	2734.34	-95.34
8	5834.64	6045.42	-210.78	0.4039	2356.61	2441.75	-85.13
9	5834.64	6045.42	-210.78	0.3606	2103.97	2179.98	-76.01
10	5834.64	6045.42	-210.78	0.3220	1878.75	1946.63	-67.87
<b>Total</b>	<b>58346.40</b>	<b>60454.20</b>	<b>-2107.80</b>		<b>32966.88</b>	<b>34157.83</b>	<b>-1190.95</b>

**At Discount Rate 12% NPV = -1190.95 BCR = 0.97**

**Table B-37 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,price of rice baht 4.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	12063.90	12413.56	-349.66	0.8929	10771.86	11084.07	-312.21
2	12063.90	10468.12	1595.78	0.7972	9617.34	8345.19	1272.16
3	12063.90	10468.12	1595.78	0.7118	8587.08	7451.21	1135.88
4	12063.90	10468.12	1595.78	0.6355	7666.61	6652.49	1014.12
5	12063.90	10468.12	1595.78	0.5674	6845.06	5939.61	905.45
6	12063.90	10468.12	1595.78	0.5066	6111.57	5303.15	808.42
7	12063.90	10468.12	1595.78	0.4523	5456.50	4734.73	721.77
8	12063.90	10468.12	1595.78	0.4039	4872.61	4228.07	644.54
9	12063.90	10468.12	1595.78	0.3606	4350.24	3774.80	575.44
10	12063.90	10468.12	1595.78	0.3220	3884.58	3370.73	513.84
<b>Total</b>	<b>120639.00</b>	<b>106626.64</b>	<b>14012.36</b>		<b>68163.45</b>	<b>60884.06</b>	<b>7279.39</b>

**At Discount Rate 12% NPV = 7279.3928 BCR = 1.12**

**Table B-38 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,price of rice baht 4.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	11786.60	12231.26	-444.66	0.8929	10524.26	10921.29	-397.04
2	11786.60	10525.82	1260.78	0.7972	9396.28	8391.18	1005.09
3	11786.60	10525.82	1260.78	0.7118	8389.70	7492.28	897.42
4	11786.60	10525.82	1260.78	0.6355	7490.38	6689.16	801.23
5	11786.60	10525.82	1260.78	0.5674	6687.72	5972.35	715.37
6	11786.60	10525.82	1260.78	0.5066	5971.09	5332.38	638.71
7	11786.60	10525.82	1260.78	0.4523	5331.08	4760.83	570.25
8	11786.60	10525.82	1260.78	0.4039	4760.61	4251.38	509.23
9	11786.60	10525.82	1260.78	0.3606	4250.25	3795.61	454.64
10	11786.60	10525.82	1260.78	0.3220	3795.29	3389.31	405.97
<b>Total</b>	<b>117866.00</b>	<b>106963.64</b>	<b>10902.36</b>		<b>66596.65</b>	<b>60995.78</b>	<b>5600.87</b>

At Discount Rate 12% NPV = 5600.8718 BCR = 1.09

**Table B-39 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,price of rice baht 4.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	10022.40	12139.36	-2116.96	0.8929	8949.00	10839.23	-1890.23
2	10022.40	10065.92	-43.52	0.7972	7989.86	8024.55	-34.69
3	10022.40	10065.92	-43.52	0.7118	7133.94	7164.92	-30.98
4	10022.40	10065.92	-43.52	0.6355	6369.24	6396.89	-27.66
5	10022.40	10065.92	-43.52	0.5674	5686.71	5711.40	-24.69
6	10022.40	10065.92	-43.52	0.5066	5077.35	5099.40	-22.05
7	10022.40	10065.92	-43.52	0.4523	4533.13	4552.82	-19.68
8	10022.40	10065.92	-43.52	0.4039	4048.05	4065.63	-17.58
9	10022.40	10065.92	-43.52	0.3606	3614.08	3629.77	-15.69
10	10022.40	10065.92	-43.52	0.3220	3227.21	3241.23	-14.01
<b>Total</b>	<b>100224.00</b>	<b>102732.64</b>	<b>-2508.64</b>		<b>56628.56</b>	<b>58725.84</b>	<b>-2097.27</b>

At Discount Rate 12% NPV = -2097.27 BCR = 0.96



**Table B-42 : Sensitivity analysis of rice-fish culture investment under 100% chemical fertilizer application ,price of rice baht 8.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	19871.90	12413.56	7458.34	0.8929	17743.62	11084.07	6659.55
2	19871.90	10468.12	9403.78	0.7972	15841.88	8345.19	7496.69
3	19871.90	10468.12	9403.78	0.7118	14144.82	7451.21	6693.61
4	19871.90	10468.12	9403.78	0.6355	12628.59	6652.49	5976.10
5	19871.90	10468.12	9403.78	0.5674	11275.32	5939.61	5335.70
6	19871.90	10468.12	9403.78	0.5066	10067.10	5303.15	4763.95
7	19871.90	10468.12	9403.78	0.4523	8988.06	4734.73	4253.33
8	19871.90	10468.12	9403.78	0.4039	8026.26	4228.07	3798.19
9	19871.90	10468.12	9403.78	0.3606	7165.81	3774.80	3391.00
10	19871.90	10468.12	9403.78	0.3220	6398.75	3370.73	3028.02
<b>Total</b>	<b>198719.00</b>	<b>106626.64</b>	<b>92092.36</b>		<b>112280.21</b>	<b>60884.06</b>	<b>51396.15</b>

At Discount Rate 12% NPV = 51396.154

BCR = 1.84

**Table B-43 : Sensitivity analysis of rice-fish culture investment under 75% chemical fertilizer application ,price of rice baht 8.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	19082.60	12231.26	6851.34	0.8929	17038.85	10921.29	6117.56
2	19082.60	10525.82	8556.78	0.7972	15212.65	8391.18	6821.47
3	19082.60	10525.82	8556.78	0.7118	13582.99	7492.28	6090.72
4	19082.60	10525.82	8556.78	0.6355	12126.99	6689.16	5437.83
5	19082.60	10525.82	8556.78	0.5674	10827.47	5972.35	4855.12
6	19082.60	10525.82	8556.78	0.5066	9667.25	5332.38	4334.86
7	19082.60	10525.82	8556.78	0.4523	8631.06	4760.83	3870.23
8	19082.60	10525.82	8556.78	0.4039	7707.46	4251.38	3456.08
9	19082.60	10525.82	8556.78	0.3606	6881.19	3795.61	3085.57
10	19082.60	10525.82	8556.78	0.3220	6144.60	3389.31	2755.28
<b>Total</b>	<b>190826.00</b>	<b>106963.64</b>	<b>83862.36</b>		<b>107820.51</b>	<b>60995.78</b>	<b>46824.73</b>

At Discount Rate 12% NPV = 46824.731

BCR = 1.77

**Table B-44 : Sensitivity analysis of rice-fish culture investment under 50% chemical fertilizer application ,price of rice baht 8.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	15302.40	12139.36	3163.04	0.8929	13663.51	10839.23	2824.28
2	15302.40	10065.92	5236.48	0.7972	12199.07	8024.55	4174.52
3	15302.40	10065.92	5236.48	0.7118	10892.25	7164.92	3727.33
4	15302.40	10065.92	5236.48	0.6355	9724.68	6396.89	3327.78
5	15302.40	10065.92	5236.48	0.5674	8682.58	5711.40	2971.18
6	15302.40	10065.92	5236.48	0.5066	7752.20	5099.40	2652.80
7	15302.40	10065.92	5236.48	0.4523	6921.28	4552.82	2368.46
8	15302.40	10065.92	5236.48	0.4039	6180.64	4065.63	2115.01
9	15302.40	10065.92	5236.48	0.3606	5518.05	3629.77	1888.27
10	15302.40	10065.92	5236.48	0.3220	4927.37	3241.23	1686.15
<b>Total</b>	<b>153024.00</b>	<b>102732.64</b>	<b>50291.36</b>		<b>86461.62</b>	<b>58725.84</b>	<b>27735.78</b>

**At Discount Rate 12% NPV = 27735.785 BCR = 1.47**

**Table B-45 : Sensitivity analysis of rice-fish culture investment under 25% chemical fertilizer application ,price of rice baht 8.0 per kg.**

Years	Total benefit	Total cost	Net profit	DR 12%	PV of benefit	PV of cost	NPV
1	12851.22	11794.15	1057.07	0.8929	11474.85	10531.00	943.86
2	12851.22	9832.46	3018.76	0.7972	10244.99	7838.44	2406.56
3	12851.22	9832.46	3018.76	0.7118	9147.50	6998.75	2148.75
4	12851.22	9832.46	3018.76	0.6355	8166.95	6248.53	1918.42
5	12851.22	9832.46	3018.76	0.5674	7291.78	5578.94	1712.84
6	12851.22	9832.46	3018.76	0.5066	6510.43	4981.12	1529.30
7	12851.22	9832.46	3018.76	0.4523	5812.61	4447.22	1365.39
8	12851.22	9832.46	3018.76	0.4039	5190.61	3971.33	1219.28
9	12851.22	9832.46	3018.76	0.3606	4634.15	3545.59	1088.56
10	12851.22	9832.46	3018.76	0.3220	4138.09	3166.05	972.04
<b>Total</b>	<b>128512.20</b>	<b>100286.29</b>	<b>28225.91</b>		<b>72611.96</b>	<b>57306.96</b>	<b>15305.00</b>

**At Discount Rate 12% NPV = 15305.005 BCR = 1.27**

**Note :**

Net profit = Total benefit - Total cost , DR = Discount Rate =  $1/(1+i)^n$

PV of benefit = Present value of benefit =  $B_t/(1+i)^t$  , PV of cost =

Present value of cost =  $C_t/(1+i)^t$

NPV = SUM(PV of benefit - PV of cost)

BCR = SUM(PV of benefit) /SUM( PV of cost)

IRR =  $DR(L)+(DR(U)-DR(L))(NPV(L)/(NPV(L)-NPV(U))$

DR(L) = Discount Rate (Lower) = 10%

DR(U) = Discount Rate (Upper) = 15%

NPV(L) = Net Present Value (Lower)

NPV(U) = Net Present Value (Upper)

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