Rice-based Livestock Systems in Northeast Thailand - Strategies for the Integration of Fish Culture

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Abstract

An analysis of production and distribution of rice products within a village, Ban Thap Hai, in Udorn Thani, Northeast Thailand suggests that current patterns of utilisation constrains use in integrated fish culture. Most rice bran (80%) is used by the rice miller to feed pigs. The remaining 'grower's share' is split between use as a supplementary feed for scavenging poultry and for fish. The extent of, and constraints to, integration between livestock and fish in the current situation are discussed. Potential fish production through direct use of ricebran and from livestock wastes is modelled based on data from on-station and on-farm research. The impact of changing distribution and use of surplus rice paddy and rice bran in the village on livestock and fish production is then considered. Feeding management for scavenging poultry has an important effect on productivity of both poultry and, subsequently, the amount of wastes available for fish culture. Inorganic fertilisation increases fish yields from feeding limited amounts of rice bran directly to fish or via poultry by over 100%. Retention of rice byproducts by the growers could have a major impact on total poultry and fish production in the village, potentially doubling the amount of fish that can be produced. The importance of off-farm factors in constraining smallholders' use of rice byproducts for livestock and fish will continue to increase.

KEY WORDS: Rice bran, fish, feed, integration, livestock, waste, recycling, manure, pig, poultry

Introduction

Monogastric livestock are a traditional component of farming systems in Indochina. Their future role on smallholder farms, however, is threatened by the forces of modernisation affecting even the poorer, rural areas of the region. The importance of pigs and poultry in the household economy, as a bank and source of readily available 'feast food' has been recognised. Resource-poor farmers may attach greater value to these attributes than productivity *per se*. Typically raised in small numbers, pigs and poultry were traditionally allowed to scavenge for a significant part of their diet, thus obviating the need for nutritionally complete diets. In Northeast Thailand rice paddy and it's byproducts are the major feeds used; nowadays pigs are typically penned and fed concentrate in addition to ricebran and broken rice but poultry may only be fed a little paddy grain to supplement scavenging. Poultry are normally managed as mixed flocks of native chickens and muscovy ducks, raised mainly for meat, together with egg-laying strains of domestic duck. Modernisation has led to increased availability of both 'improved' breeds and feeds. Intensification of livestock production has resulted, although typical rice growing households do not appear to have benefited. Indeed these changes may have stimulated a dichotomy of production (Little, 1995), in which smallholders in Northeast Thailand are increasingly excluded from livestock production. Part of this appears linked to macroeconomic changes in which the balance of rural livelihoods shifts towards urbanisation and specialisation. Thailand's steady economic development may have prevented the reversals of this process that have been observed in other parts of the World where external inputs have become limiting (e.g. Rodrigues, this conference, Ibrahim and Abdu, 1996).

A significant step in the effects of modernisation on rural livestock production in Northeast Thailand has been the change from manual to machine milling of rice. The convention has developed that the rice byproducts are ceded to the miller in lieu of a cash milling fee, a practice that inevitably results in the concentration of rice bran and broken rice in the hands of the rice miller, and poorer availability to the farmers who grew the rice. This is in contrast to some parts of Indo-China where rice growers pay a milling fee and keep their rice bran for their own livestock. Access to rice bran is particularly important if other feeds have not been traditionally fed to livestock, such as in Northeast Thailand. This contrasts with areas with more diversified cropping systems, such as the Red River Delta of North Vietnam, where a variety of feeds are purposefully cultivated for pigs.

Increasing the productivity of livestock systems could be a major strategy for increasing outputs of cultured fish. Ponds in Northeast Thailand, which are often stocked with young fish, typically lack nutrients and produce low fish yields (Edwards *et al.*, 1991). Although the use of livestock wastes for fish culture is traditional in other parts of Asia, such practices are relatively new to this, the poorest part of Thailand. Until recently wild fish had provided for peoples' needs but now, fish pond construction and the production of fish is being actively promoted and adopted by rice growing farmers. More fish culture could affect the village rice bran economy. Rice bran is currently the most common supplement fed directly to fish in farmers' ponds and rice fields (Edwards *et al.*, 1991). Most of this rice bran is obtained from mills within the village, perhaps resulting in competition with livestock for this limiting resource.

Several factors could increase the rice growers' livestock numbers and productivity, both to improve returns and to enhance the quantity and quality of waste available for fish culture. More on-farm feeds could be used to 'spare' the limited amounts of rice products available to rice growers. Alternatively feeds or additives could be purchased from off-farm sources. The introduction of improved strains or breeds of livestock into rural areas might utilise better diets more efficiently but be unsustainable unless overall management is changed to suit their requirements. Integration of livestock and fish may have an important role under conditions of nutrient scarcity, such as most rural areas of Northeast Thailand. Where nutrients are limiting, re-use in fish culture could improve overall efficiency and support a more diversified food production system. In contrast, when nutrients are locally super-abundant, such as around livestock feedlots, fish ponds can 'treat' the waste and reduce their impact on the local environment.

Objectives

This study attempts to investigate the effects of availability and use of rice bran from village rice mills and surplus rice paddy on livestock and fish production using a dynamic model. Using data derived from experimentation and observation of farmers' systems we will attempt to improve our understanding of livestock production systems in relation to these feed resources. The effect of different livestock feeding strategies on fish yields will be compared. It is hoped that the impacts of rice milling practices on livestock and fish culture can be illustrated and used in comparisons with other systems in Indochina.

Materials and Methods

The main sources of data for this model are from an analysis of paddy rice production and utilisation in two villages of Udorn Thani, Thailand (Thomas, 1989). Additional data for the current utilisation of rice byproducts for pig production was obtained recently in the same area (AIT Aquaculture Outreach, data). Household paddy utilisation in Northeast Thai villages was taken from Chayaputhi and Kongkajandr (1977) as cited by KKU-FORD (1982).

Input/output data for poultry-fish systems was obtained from research on and off AIT campus (AFE, 1992 and AASP, 1996-IDRC). Data concerning smallholder and commercial-scale pig-fish production systems are from Long (1995) and Poudyal (1990) respectively. The model was developed using STELLA (Systems Thinking, Experiential Learning Laboratory with Animation) II version 3.0 on the Macintosh computer.

Scenarios have been based on a wide variety of livestock and fish production systems (Table 2). The poultry used for on station trials were mainly Muscovy ducks (*Cairina moschata*) and domestic egg-laying ducks. Input/output data was obtained from controlled experimentation in earthen ponds and extrapolated from concrete tanks, for 180 day periods. This duration mirrors water availability in seasonal ponds in Northeast Thailand. The model assumes that poultry and pig wastes are used as far as is practical, i.e. pigs are penned and all the wastes (including urine) may be channelled and used for fish production. The wastes from poultry scavenging throughout the farm and its margins are assumed to be collected from night-time confinement and used the following day for fish production. The fish species cultured is the Nile tilapia (*Oreochromis niloticus*, stocked at densities of 2-4 fish/m^2).

Description of the Systems

The two villages studied, an irrigated lowland village, Ban Kan, and a rainfed upland, Ban Thap Hai, are representative of the range of rice growing conditions in the region. A single rice crop is grown in both villages; the greater planted area and higher rice yields in the irrigated area (2.6 MT/ha cf 2.25) increase the amount of paddy and, subsequently rice bran in the village. Rice millers retain most of the rice bran in both villages (80%). The greater quantities of rice bran from rice grown and milled in the village, together with additional amounts purchased by both millers and growers increase the total available in the irrigated area village. Thus, whilst in rainfed Ban Thap Hai only rice millers raise pigs, in irrigated Ban Kan pigs are also raised to some extent by rice growers. Typically pigs are fed rations in which purchased concentrate and broken rice is mixed with the rice bran.

In rainfed Ban Thap Hai, the remaining rice bran is purchased back by rice growers and used as supplementary feed for scavenging poultry (>80%) or fish (<20%). The size of poultry flocks appears to be most limited by the availability and price of this feed (Little *et al.*, 1992).

Farmers also use part of their unmilled rice paddy crop for feeding poultry, particularly chickens and egg-laying ducks. They may also improve the quality of the supplementary feed using purchased concentrates but this practice is most common for chicks and laying ducks and rare for growing/fattening birds.

Table 1 Comparison of two villages in Udornthani, Northeast Thailand in terms of rice production and byproduct distribution.

Village Type of land	Ban Kan Irrigated low land	Thap Hai Rainfed upland
Number of village household	250	162
Rice production (kg/rai/yr)	416	360
Land per household (rai)	13	13
Distribution of rice bran		
rice miller (%)	78.8	78.6
rice grower (%)	20.5	21.4
outside village (%)	0.6	0
Purchased rice bran by rice miller (kg/yr)	8,100	0
Purchased rice bran by rice grower (kg/yr)	1,670	0
Rice bran recovery (1) (%)	12.6	11.3
Result from model (180 days)		
Available rice bran for rice miller (kg/day)	332.8	155.3
Available rice bran for rice grower (kg/day)	85.4	42.3
Total rice bran in village (kg)	70,960	35,574
Available rice bran for rice miller (kg)	55,973	27,961
Poultry activity (kg)	1,078	56
Fish activity (kg)	419	419
Pig activity (kg)	58,470 (outside 3,994.5)	27,486
Available rice bran for rice grower (kg)	14,561	7,613
Poultry activity (kg)	6,993	6,188
Fish activity (kg)	2,336	1,425
Pig activity (kg)	6,056 (outside 430.9)	0

(1): % of paddy grain as rice bran

Almost all pigs are sold for slaughter outside of the village whereas most poultry products are consumed in the village and, very often, in the household. Fish is both consumed by the household and sold locally.

Options for Change

The range of scenarios modelled is given in Table 2 is based on Ban Thap Hai, the rainfed village more typical of the region. The table reflects the possible strategies to use the currently available rice bran in which rice growers retain only 20% of the total produced.

The scenarios relate to various feeding strategies to increase livestock numbers, rather than productivity per se, in order to increase livestock waste for fish culture. In particular, the effect of restricted feeding (case 1-3) and substitution of village rice bran by a mixture of sun-dried cassava root, leaf meal and ground rice husk were tested (case 4-8).

Also considered is the use of rice bran directly as a supplementary fish feed, with or without inorganic fertilisation of the fish pond (case 10-12). The use of rice bran or surplus paddy rice is also considered for egg-laying ducks. The use of rice bran for pig fattening is considered in cases 13-14.

The area of fish pond in which a given level of nutrients is added also affects the amount of fish that can be produced; more fish will be produced in a larger pond receiving the same amount of wastes than a smaller pond (Tables 3 and 4).

Table 2. Case Description.

Case	Description
1	Scavenging Muscovy ducks confined and fed village rice bran ad libitum at night; wastes collected and used to raise fish over a range of loadings (Ratio of duck: water from 1,500-2,500 ducks/ha); fish stocked at 2/m^2 in 5 m^2 concrete tanks.
2	Scavenging Muscovy ducks confined and fed a restricted ration (75 % of voluntary intake) of village rice bran at night; wastes collected and used to raise fish over a range of loadings (Ratio of duck:water from 1,500-2,500 ducks/ha; fish stocked at 2/m^2 in 5 m^2 concrete tanks)
3	Scavenging Muscovy ducks confined and fed a restricted ration (50% of voluntary intake) of village rice bran at night; wastes collected and used to raise fish over a range of loadings. (Ratio of duck:water from 1,500-2,500 ducks/ha; fish stocked at 2/m^2 in 5 m^2 concrete tanks)
4	Scavenging Muscovy ducks confined and fed a supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran] ad libitum at night; wastes collected and used to raise fish at a high rate (62.5 Kg DM/ha/day); fish stocked at 2 fish/m^2 in 5 m^2 concrete tanks
5	Scaveging Muscovy ducks fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed ad libitum and wastes collected during overnight confinement of Muscovy ducks loaded at a low rate (32.7 Kg DM/ha/day) with urea (0.5 KgN/ha/day) and TSP (0.32 KgP/ha/day) ; Monoculture Tilapia (2 fish/m^2 in 5 m^2 concrete tanks)
6	Scavenging Muscovy duck fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed restricted (levels of 50 % the voluntary intake rate) and wastes collected during overnight confinement of Muscovy ducks loaded at a high rate (62.5 Kg DM/ha/day); Monoculture Tilapia (2 fish/m^2 in 5 m^2 concrete tanks)

Table 2. (Continued).

7	Scavenging Muscovy duck fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed restricted levels of 50 % the voluntary intake rate) and wastes collected during overnight confinement of Muscovy ducks loaded at a low rate (32.7 Kg DM/ha/day) with urea (0.42 KgN/ha/day) and TSP (0.31 KgP/ha/day); Monoculture Tilapia (2 fish/m^2 in 5 m^2 concrete tanks)
8	Scavenging Khaki campell (laying duck) fed with supplementary feed (village rice bran) ad libitum; stocking density 500 ducks/ha (water area); Monoculture of Nile tilapia at a stocking density of 2 fish/m^2 in 200m^2 earthen pond, also loaded with urea (1.7 KgN/ha/day)
9	Scavenging Khaki campell (laying duck) fed with supplementary feed (paddy rice) ad libitum; stocking density 500 ducks/ha (water area); Monoculture Tilapia with 2 fish/m^2, pond add urea to get Nitrogen loading at 1.7 KgN/ha/day
10	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1fish/m^2)
11	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1 fish/m^2); add urea 1.5 KgN/ha/day and TSP 0.75 KgP/ha/day)
12	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1fish/m^2); add urea 3.0 KgN/ha/day and TSP 1.50 KgP/ha/day)
13	Hybrid pigs fed a mixture of cooked village rice bran and water hyacinth (*Eichhornia crassipes*) at rates of 4% and 5% Body wt/pig/ day respectively on a fresh weight basis. All wastes loaded daily into earthen ponds (200m^2) at a ratio of 50 pigs/ha. Mixed sex Nile tilapia and hybrid clarias catfish stocked at rates of 2 and 0.25 fish/m^2; 3 month culture period.
14	Hybrid pigs fed a mixture of rice bran (14%), dried cassava chips (35%),maize (20%), concentrate (31%) by a commercial farm. Pigs raised at a ratio of 123 pigs/ha fishpond. Fish yields of 20 Kgs/ha/d from a tilapia/carp polyculture in 0.3 ha earthen ponds managed by 3 month partial harvest .

Table 3 Potential poultry and fish production of rice growers using different rice-based feeding strategies based on current availability of paddy and rice bran to rice growers in Bang Thap Hai, Udornthani (180 day production).

Case	Management	Type	Fish inputs	No. ducks
1	*ad libitum*	rice bran	-	300
2	75 % *ad libitum*	rice bran	-	482
3	50 % *ad libitum*	rice bran	-	675
4	*ad libitum*	50 % rice bran + 50 % cassava	-	433
5	*ad libitum*	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	433
6	50 % *ad libitum*	50 % rice bran + 50 % cassava	-	903
7	50 % *ad libitum*	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	903
8	*ad libitum*	rice bran	add inorganic fertilizer (2)	220
9	*ad libitum*	paddy rice	add inorganic fertilizer(2)	1,182
10	-	-	only rice bran	-
11	-	-	rice bran + low inorganic rate (3)	-
12	-	-	rice bran + high inorganic rate (4)	-

(1) Urea 0.108 g/m2/day and TSP 0.160 g/m2/day;
(2) 1.7 KgN-ha/day ;
(3) 1.5 Kg N and 0.75 Kg P/ha/day;
(4) 3.0 Kg N and 1.5 Kg P/ha/day

Table 3 Potential poultry and fish production of ricegrowers using different rice-based feeding strategies based on current availability of paddy and rice bran to rice growers in Bang Thap Hai, Udornthani (180 day production). (continued)

Case	Kg of flock or No. of eggs	Net fish yield (kg)	Pond area (m^2)
1	865	310.7-428.5	1,501-2,001
2	1,067	458-636	1,927-3,214
3	1,264	574-672	2,701-4,497
4	731	244	1,673
5	731	522	2,789
6	988	449	3,615
7	988	921	6,023
8	6,448 eggs	1,225	4,396
9	63,402 eggs	3,311	23,639.9
10	-	732	2,878.9
11	-	1,270	2,878.9
12	-	1,580	2,878.9

Table 4: Potential poultry and fish production using different rice-based feeding strategies based on retention of rice bran by rice-growers in Ban Thap Hai, Udorn Thani (180 day period).

Case	Management	Type	Fish inputs	No. ducks
1	ad libitum	rice bran	-	1,403
2	75 % ad libitum	rice bran	-	2,252
3	50 % ad libitum	rice bran	-	3,154
4	ad libitum	50 % rice bran + 50 % cassava	-	2,021
5	ad libitum	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	2,021
6	50 % ad libitum	50 % rice bran + 50 % cassava	-	4,221
7	50 % ad libitum	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	4,221
8	ad libitum	rice bran	add inorganic fertilizer (2)	1,027
9	ad libitum	paddy rice	add inorganic fertilizer(2)	1,182
10	-	-	only rice bran	-
11	-	-	rice bran + low inorganic rate (3)	-
12	-	-	rice bran + high inorganic rate (4)	-

(1) Urea 0.108 g/m2/day and TSP 0.160 g/m2/day;
(2) 1.7 KgN-ha/day ;
(3) 1.5 Kg N and 0.75 Kg P/ha/day;
(4) 3.0 Kg N and 1.5 Kg P/ha/day

Table 4: Potential poultry and fish production using different rice-based feeding strategies based on retention of rice bran by rice-growers in Ban Thap Hai, Udorn Thani (180 day period).(Continued)

Case	Kg of flock or No. of eggs	Net fish yield (kg)	Pond area (m^2)
1	4,041	1,452-2,002	7,015-9,349
2	4,985	2,139-2,974	9,002-15,021
3	5,905	2,681-3,139	12,622-21,014
4	3,416	1,140	7,820
5	3,416	2,440	13,033
6	4,619	2,098	16,892
7	4,619	4,306	28,143
8	30,132 eggs	5,725	20,540
9	63,402 eggs	3,311	23,640
10	-	3,420	13,452.6
11	-	5,935	13,452.6
12	-	7,383	13,452.6

Pigs

Most pig production is based on the feeding of a dry mash of freshly milled rice bran, broken rice and purchased concentrate. Traditionally, before concentrates from feed mills were available, rice bran was fed together with leftover human food and weeds.

If pig feed is prepared by cooking rice bran with water and vegetables, approximately 50 pigs can be supported on rice bran from a village of 162 households such as Ban Thap Hai. At a ratio of 50 pigs/ha of pond, over 1-1.2 MT of fish could be produced over a period of 180 days.

The use of concentrates and other ingredients can increase the herd size for a given amount of rice bran considerably. A reduction of rice bran to around 14% of a least cost, nutritionally balanced feed used by larger operations in the area allows a theoretical increase in standing herd size to over 400 animals and fish production to over 12 MT. This eight-fold increase in pig numbers is based on the use of rice bran together with maize and soya bean, which are imported into the village and dried cassava root chips which could be obtained within the village. Increases in waste quantity and quality are offset to some extent by higher ratios of pig:pond area.

The purchasing of concentrate to mix with broken rice and rice bran is the normal current practice for rice miller/pig raisers in the region. Based on a typical ration, a mean herd size of 59 pigs is maintained on rice bran available to rice millers in Ban Thap Hai. This suggests that rice millers feed their pigs fairly inefficiently, a practice perhaps encouraged by the availability of cheap rice byproducts.

Poultry

The efficiency of rice growers using smaller amounts of rice bran for scavenging poultry is clear. Although the amount of rice bran used for poultry is a fraction of that fed to pigs by the millers, relatively large amounts of poultry and fish can be produced despite the amounts of bran and flock size being small. The poultry scavenging for natural foods over a large part of the day also makes a proportion of wastes uncollectable. Based on the total amount of rice bran available for rice growers in Ban Thap Hai a total of around 300 muscovy ducks can be raised on rice bran alone and over 400 Kg of fish produced if the waste was used as an input to fish culture. If the amount of fish produced from feeding the small amounts of rice bran directly to fish is added, over 1 MT of fish can be produced in the village derived from the small 'grower's share' of the rice bran.

Amounts of poultry waste can be increased in several ways. In practice scavenging poultry are often fed limited rations rather than ad libitum. This allows a larger flock (>100%) to be raised from the same amount of rice bran, increasing the pressure for the birds to scavenge natural feeds. Growth of individual birds is slower (Table 3, case 1), but overall flock yield is higher. The slower individual growth may synchronise better with the main demand for fattened poultry occurring between rice harvest and Thai New Year (Little *et al.* 1992). Also, after rice harvest, a seasonal abundance of rice bran allows for fattening prior to slaughter. Moreover, the area of pond that can be fertilised and amount of fish produced also increases as individual feed levels are restricted and flock size increases. Whereas ad libitum feeding of poultry could produce an estimated 428 Kg fish, limiting feeding to 75% and 50% of these levels increases fish production to 636 Kg and 672 Kg respectively.

Flock size, and wastes available for fish production, can also be increased by 'sparing' rice bran with cassava byproducts, commonly grown on the farm. Using this measure, together with restricted feeding, flock size can be increased by a factor of 3 using the same absolute amount of rice bran (cf cases 1 and 6, Table 3). There appears to be no advantages to fish production, however. Digestibility and nutrient release studies suggest that little of the nitrogen in the cassava leaf may be available for either ducks or uptake by phytoplankton (AFE, 1992).

Use of rice bran as a direct supplementary feed, particularly in fertilised ponds, is the most efficient means to produce fish for the village. Only 5% of the rice bran produced was fed directly to fish in Ban Thap Hai but use of inorganic fertilisation to increase the levels of natural feed in the pond would improve its efficiency of use considerably. Fertilisation of ponds increased yields to 1270 Kg and 1580 Kg (@1.5KgN/ha/d and 3 KgN/ha/d respectively; N:P =2) compared to 732 Kg without fertiliser. A FCR of 1.77 of feeding rice bran directly to fish compares favourably to more than 9 if the amount of rice bran to produce fish via poultry is considered.

Supplementation with inorganic fertilisers boosts fish production from the waste of poultry fed the same amount of rice bran by over 100% (cf cases 4 and 5; 6 and 7, Table 3).

Current rice bran use could have greater impact on fish production in the village as a whole if ponds received inorganic fertilisers. In Ban Thap Hai, even with the limited availability of bran for ricegrowers to raise poultry and fish, approximately 5 MT of fish could be raised per year from this source in perennial ponds (e.g. case 7, Table 3) which is equivalent to around 30 Kg/household.

The direct use of rice paddy surplus to feed small numbers of scavenging egg-laying ducks is also common among ricegrowers; the wastes of these birds can also produce significant amounts of fish. The number of ducks raised by rural households relates to their paddy surplus compared to consumption needs, the desire for home-produced eggs and the value of paddy rice on the market. If the amount of rice paddy surplus to consumption and other requirements (seed, exchange, debt service, wages etc; KKU-Ford, 1982) is utilised as supplementary feed for scavenging egg ducks, a total flock of 1182 birds, producing more than 2 eggs/household/day, can be supported. The collectable wastes from these birds can, with minimal levels of inorganic fertilisation, produce over 100 g fish/household/day. These levels contribute substantially towards household consumption requirements (Mekong Committee,1992).

Scenarios

The following situations were simulated to estimate the effect of changes in rice bran utilisation on fish production in Ban Thap Hai. Scenarios 1 and 2 reflect the current control of rice and its byproducts in the village, but that the wastes of the livestock are utilised for fish production. Scenario 2 is based on the rice growers diverting all rice bran to fish and none for poultry.

Scenarios 3 and 4 indicate possible fish yields if rice growers retain control of all the rice bran produced in the village either using it for poultry and fish at the same ratio as currently (3) or using all of the extra rice bran for fish and maintaining poultry at current levels (4). The scenarios are characterised by the ratio of the millers share, mainly fed to pigs (M), to the amount fed by the grower to poultry (GP) to the amount fed by the grower to fish (GF).

(1) current (80:16:4)

This assumes that rice bran is used at current rates by ricemillers and growers for feeding pigs and poultry respectively and that all these wastes are used for fish culture. Additional fish is produced from direct feeding of rice bran and the range reflects the level of inorganic fertilisation. It also assumes that surplus rice paddy is used to feed egg-laying ducks, the waste of which is also used in fish culture.

(2) give up feeding rice bran to poultry and use all the rice bran that they can purchase (i.e. current growers share of all rice bran) for fish culture (80:0:20)
This option would lead to an estimated 6 fold increase in the fish produced by rice growers over levels in which all poultry wastes are used for fish culture. Mean fish production, assuming all the growers rice bran was used in this way, would vary between 52-114 Kg/household/year, depending on the level of inorganic fertilisation used in the fish ponds.

(3) purchase back all their rice bran and then use it for poultry and fish production at current ratios (0:80:20)
This would produce a similar range of fish yields as (1) and (2), but all of the fish would be produced by the ricegrowers rather than a large proportion by the miller.

(4) purchase back all their rice bran, maintain poultry at current levels and use the extra for fish production (0:20:80)
This scenario indicates the levels of fish production that might be possible if rice growers gained access to all of the rice bran produced and used most of the bran for fish culture. Assuming that they maintain poultry at current levels and integrate the wastes with fish culture, it is clear that this would support only a minor part of potential fish production. Yields approaching 40 MT/over a 6 month season are possible if most of the rice bran produced in the village is used as a supplement in fertilised fish ponds. Up to 9 hectares total of ponds would be required for such a scenario, which is nearly 30% of the planted rice area. In practice, fish production would likely be constrained at much lower levels by lack of perennial water and suitable sites. Only a fraction of this pond area (about 1 ha) was available at the time the survey was carried out. However the scenario does suggest the impact that local feed resources could have on local fish production.

Table 5 Potential range of fish production in Ban Thap Hai based on number of livestock and fish fed rice based feeds for 4 different scenarios of byproduct utilization (ratio of miller's share (M): growers & poultry (GP): growers & fish (GF))

Scenario ratio M:GP:GF	Feed	Route to	Fish production (kg/180 days) Miller	Grower	Total
1.Current 80:16:4	rice bran	livestock waste	1,686-12,228	244-1,225	
	rice bran	direct feed	215-465	732-1,580	
	paddy rice	livestock waste	-	3,311	
			1,901-12,693	4,287-6,116	6,188-18,809
2. 80:0:20	rice bran	livestock waste	1,686-12,228	-	
	rice bran	direct feed	215-465 8,440	3,910-	
	paddy rice	livestock waste	-	3,311	
			1,901-12,693	7,221-11,751	9,122-24,444
3. 0:80:20	rice bran waste	livestock	- 5,725	1,140-	
	rice bran	direct feed	-	3,420-7,383	
	paddy rice	livestock waste	-	3,311	
		-	7,871-	7,871-16,419	16,419
4. 0:20:80	rice bran waste	livestock	-	244-1,225	
	rice bran	direct feed	-	15,093-32,581	
	paddy rice	livestock waste	-	3,311	
		-	18,648-	18,648-37,117	37,117

Table 6 Area of ponds (m^2) required for fish production by rice millers and growers in Bang Thap Hai for 4 different scenarios of rice bran.

Case	Ratio	Miller	Grower	Total
1.	80:16:4	9,954-34,485	1,231-4,497	11,155-38,982
2.	80:0:20	9,954-34,485	15,380-23,640	25,334-58,125
3.	0:80:20	-	5,614-28,143	5,614-28,143
4.	0:20:80	-	1,201-59,370	1,201-59,370

Note : in 1988, Area of culture pond was 1.1 ha (11,000 m^2)

Constraints to Use of Millers' Pig and Growers' Poultry Manure for Fish Culture

Currently, the linkages between the rice millers' pigs, village poultry and fish are weak. A recent survey indicated that only 3 out of 25 mills used their pig manure to raise fish; much of the rest was utilised to some extent for rice fields, vegetables or given to neighbours. Cultural aversion to the use of livestock wastes, particularly pig manure, in fish culture exists but does not seem to be a major factor in preventing integration in most cases. Lack of labour and water for raising fish and the distance between pigs and ponds constrained integration. Twenty per cent of rice millers didn't use their manure for fish culture because they used their pond water for domestic purposes and didn't want 'dirty' water (AAOP data).

The likelihood of the rice millers' pigs becoming a significant source of nutrients for fish culture look unlikely for a variety of reasons. Currently, a good deal of potential fish production is lost through poor use of pig wastes by rice millers. The central location of rice mills in the village and the need for constant attendance probably limits the efficiency of its use by these actors. The lack of waste recycling into fish culture reflects the millers' main business foci and their higher-than-average economic status. Aquaculture has been found to be of both interest to middle-income households (AAOP data). The high proportion of millers that give waste away to their neighbours (>50%) suggests that some waste may finally be used for fish culture, although the urine, which is rich in both nitrogen and phosphorus, would be likely lost. Its use elsewhere in food production is also likely to be sub-optimal; seasonal aridity constrains the efficient use of manures in the rainfed cropping systems of the region and probably a major proportion of the nutrient value is lost.

The ponds of rice growers have also been found to be unintegrated with poultry production and various factors, particularly the distance between fish and poultry operations, are believed to be important constraints (Little, 1995). Recent on-farm trials, however, suggest that rice growers will collect the waste of their scavenging poultry from overnight pens and use it in their fishponds (AASP, 1996). In general, little sustained interest for intensification of backyard poultry was found among individual farmers who are mainly motivated to raise poultry to satisfy household needs (AASP, 1996). This may be explained partly by the marginal financial returns, risk of loss from disease and an increasing reliance on off-farm income. However, the continued interest by many households in raising a small mixed poultry flock for social and cultural reasons together with the control of most of the rice crops byproducts by rice millers probably prevents the potential rise of 'medium-scale' producers from obtaining enough rice bran. The sustainability of poultry systems in their current form looks linked to the future of village life generally. The high opportunity cost of labour has been a major factor in changing rural lifestyles; the rapid replacement of other livestock, such as water buffalos by mechanised tillers is explained partly by this factor. Raising poultry requires little labour and the typical small flock can be managed by older family members close to the home provided some rice bran can be purchased back from the mill.

The use of 'surplus' rice paddy for feeding egg-laying ducks is a common practice. The relatively small surplus does appear to restrict the practice to small flocks (<15) serving to producing eggs for household consumption; retention of larger amounts of paddy to raise ducks for selling eggs is not worthwhile. As a high proportion of duck eggs are consumed by children in school packed lunches, this may have strategic nutritional impact. Integration with fish culture could improve the overall returns of duck egg production based on rice paddy. The potential impact of using more inorganic fertilisers, with or without rice bran or rice bran-derived wastes, for fish production are great (Edwards *et al.*1991, Edwards, 1993). Farmers have accepted the supplementation of ruminant manure with small quantities of inorganic fertilisers, but current trials suggest that the higher levels used in this study are also adoptable and effective under village conditions. The use of inorganic fertilisers in the fish pond, as opposed to elsewhere on the farm, is a critical issue. Current use of inorganics on rice and other crops is low, partly because of the unpredictable response on the infertile and rainfed conditions (Ragland and Boonpuckdee, 1988).

The role of inorganic fertilisers, patterns of outmigration and habitation in the village and their impacts of mechanisation and labour utilisation all affect rice yields and the availability of byproducts. Further, fundamental changes in average land holding and strategies for maintaining output (Surinteraseree,1996) will all affect levels of rice production and maybe the marketability of poultry and fish products.

Conclusion

The control of rice byproducts after local processing has a major impact on the livestock and fish production of rice growers. The use of rice bran as a supplementary feed for scavenging poultry or part of the ration of feedlot pigs, could support significant fish production if the activities were integrated. In practice, although many factors limit livestock waste re-use for fish production under Northeast Thai village the dominance of rice bran use by rice millers is a major constraint. Lack of rice bran and its high price is a critical barrier to farmers producing more monogastric livestock, particularly poultry, and their integration with fish. The model illustrates the benefits that more control of rice bran by the rice growers could bring to their poultry and fish production. Moreover, such changes would likely improve the efficiency of nutrient use and efforts to diversify by rice growers.

Other mechanisms exist to increase synergism between activities including attention to poultry feeding strategies and the use of more non-rice ingredients. The feeding of paddy grain surplus to egg-laying ducks has potential to support household needs of eggs and contribute substantially towards fish consumption needs. More direct use of rice bran for fish culture optimises fish yields but would reduce the availability of feed for poultry production. Inorganic fertilisation improves the effectiveness of both poultry manure and rice bran as inputs to fish culture. Trends in production and consumption in the village, which are linked to macroeconomic changes, may have fundamental impacts on poultry and fish production.

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