Integrated Agriculture-Aquaculture Systems in the Mekong Delta, Vietnam: An Analysis of Recent Trends

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ABSTRACT

In order to explain the trends in the development and farm attributes of Integrated Agriculture-Aquaculture (IAA) systems in the Mekong Delta of Vietnam, a participatory community appraisal and two surveys are carried out in three districts with contrasting fish culture input systems. The first survey, undertaken in December 2002, covers 90 households; the second, held December 2004, covers 80 households. The factors driving changes in the farming systems are the introduction of modern rice varieties, the policy of economic liberalization, market demand, and natural disasters. The principal components of IAA systems in the Mekong Delta which the study examines are the land use intensity, market access, farm diversity, farm inputs, and household income. The study finds that the hard-to-change farm characteristics are the land use intensities of rice, orchard and cash crops. In contrast, the easy-to-change farm characteristics are the number of farm components, the land use intensity of fish ponds, on-farm family labor, off-farm and non-farm income, and farm inputs. The main drivers of the changes over the two years are market demand and a poultry disease outbreak (Avian Influenza). Well-off farmers with good farming practices and enough capital tend to intensify their farming practices, while the poorer farmers tend towards diversification in order to safeguard their livelihood and avoid risks.

INTRODUCTION

Interactions between crops and livestock are considered crucial to the sustainable development of agriculture in Asia (Devendra and Thomas 2002). Three development pathways for farming systems can be distinguished, namely: (i) extensification, i.e., extending the cultivated area while maintaining or reducing input levels per unit area; (ii) intensification, i.e., increasing production per unit area through more intensive production practices in land use and technology; and (iii) diversification, i.e., changing farm practices and products to align them better with social, environmental and economic contexts (Erenstein 2006; Barghouti et al. 2004). One form of diversified agriculture mainly practiced in Bangladesh, China, India, Indonesia, Malaysia, Thailand and Vietnam is the smallholder Integrated Agriculture-Aquaculture system (Edwards et al. 1988; Pullin and Shehadeh 1980; Little & Muir 1987). Prein (2002) defined this system as "concurrent or sequential linkages between two or more human activity systems, one or more of which is aquaculture, directly on-site, or indirectly through off-site needs and opportunities, or both".

In Vietnam, the Integrated Agriculture-Aquaculture (IAA) systems are widespread in the Mekong Delta (MD). In this region the IAA systems are commonly practiced in the freshwater farming systems [West-East-South (WES) Programme 1997]. The IAA farms contain one or more ponds or ditches in which to raise fish. In the MD, three main IAA production systems can be identified on the basis of the intensity of the fish culture: high-input fish culture and rice as main farm components, medium-input fish culture and rice as main farm components, and low-input fish culture and fruit trees as main farm components. The fish culture classification is based on the sources of fish feed. In the low-input fish culture, fish are fed with crop residues from the farm, farm manure, and night soil. In the medium-input fish culture, fish are fed with pig and poultry manure, night soil, crop residues, and some pelleted feed (e.g., at the fingerling stage). In the high-input fish culture, the main feeds for fish are pelleted feed, some by-products from a fish-processing factory, and manure and night soil.

In the area with high-input fish culture, the gross output of crops, livestock and aquaculture contribute 66, 15 and 18% to the total agricultural gross output of the district, respectively. In areas with medium-input fish culture these figures are 77, 19 and 4% of the total agricultural gross output of the district, respectively; and in the low-input fish culture, 78, 13 and 9%, respectively. Three districts in the MD (POND-Live 2004) are selected for this study. Employment in the agricultural sector (mainly farming) is 36, 65 and 44% of the total population in the districts with high, medium and low input fish systems, respectively (2004 O Mon Statistical Yearbook; 2004 Tam Binh Statistical Yearbook; 2003 Cai Be Statistical Yearbook).

In recent years there have been rapid socioeconomic changes in the MD, with increases in agricultural and aquaculture production (AusAID 2004). Given that multi-component IAA farming systems are easily affected by economic and environmental changes (Prein 2002), our study sets out to elucidate recent trends in IAA farming systems and to ascertain which farm attributes account for the dynamics of different IAA farming systems. It is hoped that the findings would be useful when identifying feasible innovations for the IAA farming systems in the MD. An IAA farm is here defined as the combination of the agriculture and aquaculture components and the household. An IAA farming system represents farms with a relatively similar typology.

MATERIALS AND METHODS

The MD, covering about four million hectares, extends over 13 provinces. It can be divided into seven agro-ecological zones based on rainfall, temperature, soil, topography, cropping system, and water resources (Sanh et al. 1998). The districts of O Mon, Tam Binh and Cai Be (Figure 1) in Can Tho City, Vinh Long, and Tien Giang provinces; respectively, are chosen as the survey sites because these districts (a) have distinctly different agro-ecological characteristics, and freshwater farming systems; (b) have high potential for improvement in agriculture and aquaculture; and (c) are easily accessible and not subject to severe flooding (WES Programme 1997). The three districts differ in the intensity of fish culture: low input fish (LIF) in Cai Be, medium input fish (MIF) in Tam Binh, and high input fish (HIF) in O Mon (Table 1).

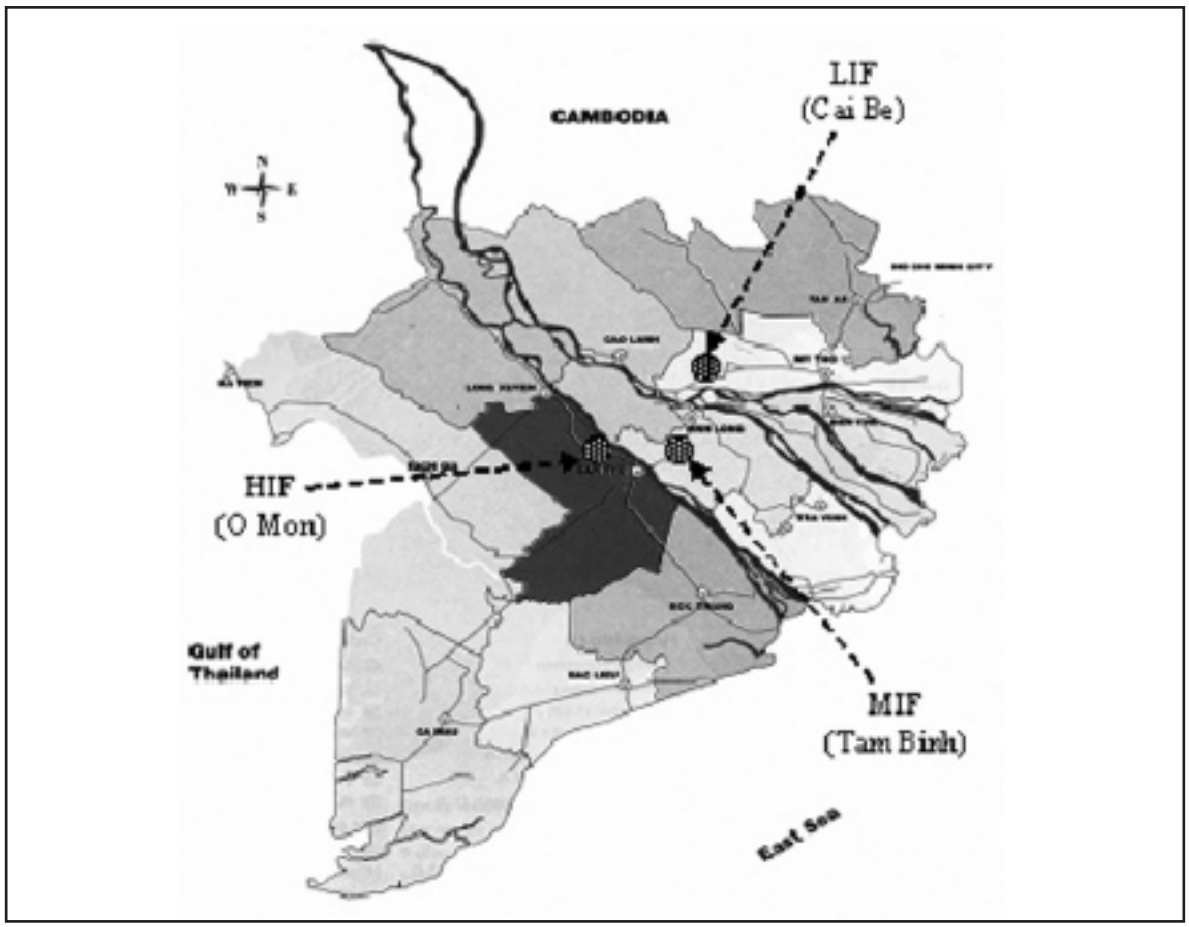

Figure 1. Study sites in the Mekong Delta: low input fish system in Cai Be, medium input fish system in Tam Binh, and high input fish system in O Mon

In each district, two hamlets were selected in 2002 and a participatory community appraisal (PCA) (Pretty and Hine 1999) was used to collect general information on the agricultural production and socioeconomic conditions of their households. In addition, in each hamlet three knowledgeable farmers ranked independently the wealth of the farm households, which numbered 743 in O Mon, 693 in Tam Binh, and 773 in Cai Be. Thirteen farmers in O Mon, 17 in Tam Binh, and 20 in Cai Be were interviewed for the detailed PCA. The PCA included timelines, transect maps, bio-resource flows and production activities. The timelines began in 1972. After the PCA, a baseline survey was done in December 2002 on randomly selected farms: 30 in O Mon, 29 in Tam Binh, and 31 in Cai Be. A structured questionnaire was used to collect information on farming patterns, land use and production characteristics. When the survey was repeated in December 2004, ten farmers had stopped farming or had moved from the village, so the households re-surveyed were 28 in O Mon, 23 in Tam Binh, and 29 in Cai Be. This time they were also asked about changes in farm activities.

Five farm components were considered: rice, orchard, cash crops, livestock, and fish pond. The farm area (in ha) included agricultural land and compound. The land use intensity (LUI) was calculated as the ratio (expressed as percentage) of the area used for each individual farm component in terms of the total agricultural area of the farm. The gross margin was calculated as the farm gross returns minus the farm variable costs (farm inputs); the net farm income was calculated as the gross margin minus the fixed farm costs. The household income was the sum of net farm income plus off-farm and non-farm income (Udo et al. 1992). Household expenditure and consumption

Table 1. Characteristics of the Low Input Fish, Medium Input Fish, and High Input Fish Systems in the Mekong Delta.

Characteristics	LIF	MIF	HIF
Soil conditions	Near rivers, high-lying land, fertile alluvial soil	Low-lying land, less fertile soil	Low-lying land, less fertile soil
Flood depth	0.3 to 0.5 m	0.5 to 1 m	0.5 to ≥ 1 m
Major source of income	Orchard	Rice	Rice, fish
Fish production	Mainly for domestic consumption, minor source of income Poly-culture*	For domestic consumption and sale, medium source of income Poly-culture*	Mainly for sale, medium to major source of income Mainly monoculture of Pangasius catfish or climbing perch
Fish yield	1 - 2 tons ha-1 yr-1	2 - 10 tons ha-1 yr-1	10 - 40 tons ha-1 yr-1
Sources of Fish feed	Small and irregular quantity of pig pen wastes, crop residues, vegetables, weeds/ grasses	Mainly pig pen wastes, poultry manure, crop residues, vegetables, weeds/ grasses, crabs, golden snail, pelleted feed	Pig pen wastes, crop residues, vegetables, weeds/grasses, crabs, golden snail, waste products from fishery processing industry, pelleted feed
Animal husbandry	Chickens, ducks for family food Pigs as security; breeding and fattening pigs mainly for sale Rarely large or small ruminants	Chickens, ducks for both food and sale Pigs as security; breeding and fattening pigs mainly for sale Rarely large or small ruminants	Chickens, ducks for both food and sale Pigs as security; breeding (major) and fattening pigs for sale Rarely large or small ruminants
Sub-components ranked in order of importance	Orchard Rice field Livestock Fish pond	Rice paddy Orchard Livestock Fish pond	Fish pond Rice field Livestock Orchard

* tilapia, kissing gourami, giant gourami, silver barb, common carp, silver carp, Pangasius catfish

were excluded from the calculations. The crop inputs were fertilizers, pesticides, seeds, and land preparation costs. The outputs were staple food crops (rice), cash crops (water melon, mushroom, pulses, maize, sesame), and fruits (mango, longan, citrus, banana, coconut). The inputs for the poultry, pigs or fish components were rice, broken rice, rice bran, vegetables, concentrates, veterinary medicines, and stock purchases. The on-farm family labor was measured in full-time equivalents. Off-farm and non-farm income was reported per household member. The annual fixed farm costs were the depreciation of equipment, land maintenance fees, and taxes. The economic data for 2002 were adjusted to take account of the average annual inflation rate of 5.1% (Viet 2004).

Statistical Analysis

One-way ANOVA (Analysis of Variation) and T-tests were applied to examine the variability and changes in farm management in the three fish input systems. Annual mean values of selected variables were linked in a factor analysis using the principal component method, to identify the relationships between the variables of interest in the three systems. Correlation coefficients of less than 0.5 were suppressed. Varimax rotation with Kaiser

Normalization was used to facilitate interpretation of the principal components (Leech et al. 2005).

RESULTS

Based on data gathered from the two surveys, this study applied the ANOVA and factor analysis on several factors relating to the farm characteristics, farm activities, and household economy. The results are presented below in terms of the main events that influenced agricultural development; the ranking of wealth among the three input systems; patterns of farm settlements, activities and bio-resource flows; the changes in the farm activities and economic characteristics of the households; and of the principal components that would explain the variance.

Timeline

Figure 2 shows an example of a timeline of around 30 years in one of the survey sites in the Mekong Delta, in which the main events are the Vietnamese revolution of 1975, the introduction of modern rice cultivars, the start of the Doi Moi economic reform policy, natural disasters, market fluctuations, and the reduction of agricultural taxes. The modern rice varieties introduced in 1972 gave farmers the opportunity to grow two or three crops per year, instead of one. The increased rice production contributed to food security in the MD and also impacted on animal production, because extra feed became available e.g., for more intensive pig production; this started around 1983.

In 1976, all provinces in southern Vietnam were urged to move gradually toward collectivization (Pingali and Xuan 1992). Land was redistributed in an attempt to implement the cooperative movement (CM), and was contracted to families or production teams to meet production targets. Under the centrally planned economic system, the emphasis was on creating large production units: cooperatives at the village, inter-village, or commune level. Farm households could use services provided by the cooperatives (Harms 1996).

The most important event in the 1980s was the Doi Moi economic reform policy. It marked the transition from a centrally planned economy to a market-oriented one.

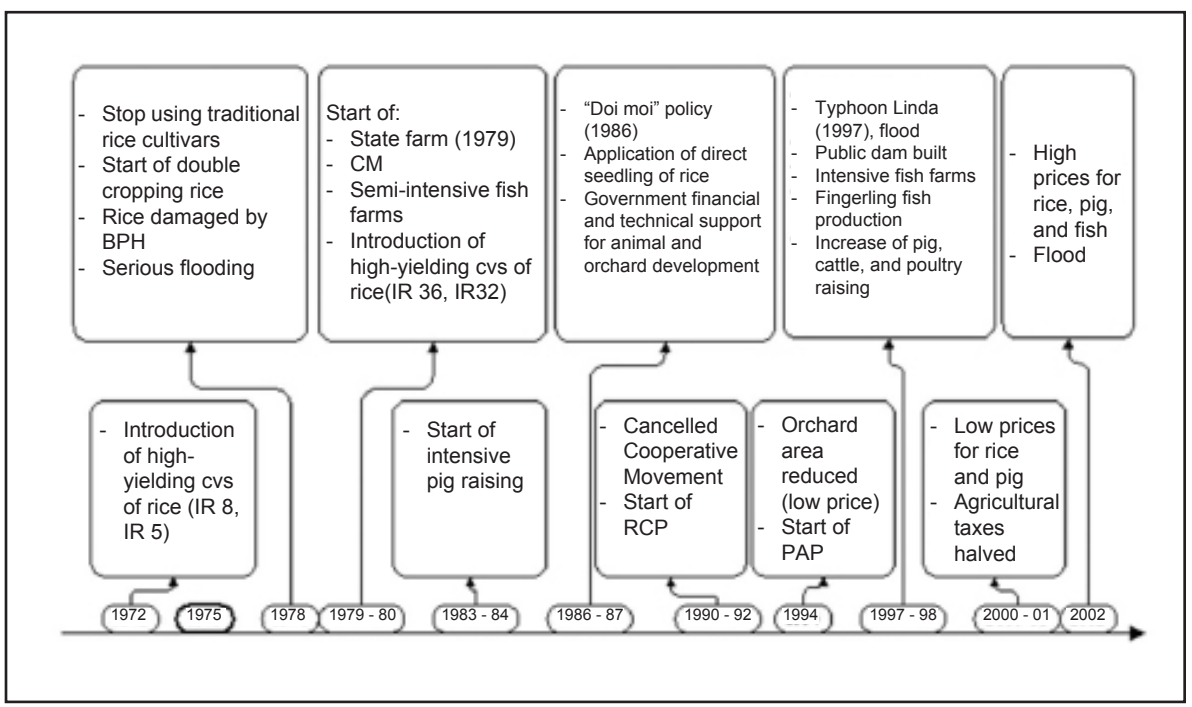

Figure 2. Timeline in O Mon

Notes: In the other two districts, the main events are similar but the chronology of technology may differ.
(The abbreviations used above and their meanings are: BPH - Brown Plant Hopper, CM - Cooperative Movement, RCP - Rural Credit Programme, and PAP - Poverty Alleviation Programme)

The cooperative movement was abandoned in 1990 as part of this policy. Farmers were supported financially via the Rural Credit Programme (RCP) and Poverty Alleviation Programme (PAP) and received technical advice from the local extension network. Encouraged by the high economic returns from fruit trees (e.g., mango, longan, and citrus) in the 1990s, the gardening development program encouraged the LIF farmers, whose lands had fertile soils, to develop orchards.

Like all other land uses, fruit orchards have been flooded annually by the Mekong River. One way to control flooding had been to build a dike around villages and orchards. This has become popular in all fruit-producing areas of the MD. Farmers have regularly been faced with market price fluctuations (e.g., low fruit prices, which resulted in less land planted to fruit trees in 1994), and the loss of produce due to insect attack, storms or floods (e.g., the Brown Plant Hopper (BPH) outbreak in 1978, typhoon Linda in 1997, or the floods of 1998 and 2002). To encourage farm activities, the government halved agricultural taxes in 2000-2001.

Wealth

The farmers' criteria for ranking wealth in the three input systems were similar. The people classified as "rich" generally had fewer than four children, all of whom went to school. They usually owned more than one hectare of land and their farming activities commonly consisted of pig husbandry, fish hatchery, or an intensive orchard.

The moderately wealthy people owned around 0.3 to 1 hectare of land. Their children all went to primary school, but rarely went on to high school. The families had a stable livelihood with no debts; they also earned their income through off-farm and non-farm activities. The poor farm households normally had more than four children, not all of whom attended school. They had little or no land to farm and lived in small palm-thatched houses.

The poorest were unskilled farmers working as hired laborers, who had debts and were classified as poor by local authorities. Ranking by wealth revealed that in the HIF system there were twice as many rich people and more poor people than in the MIF and LIF systems (Figure 3).

Farm Transect, Farm Activities and Farm Bio-resource Flows

The farm transects reflect the patterns of settlement. Commonly, farmers live near a river or canal in order to access water and transport facilities. There is usually an orchard behind the house, on raised beds of a well-drained soil. Animals are kept

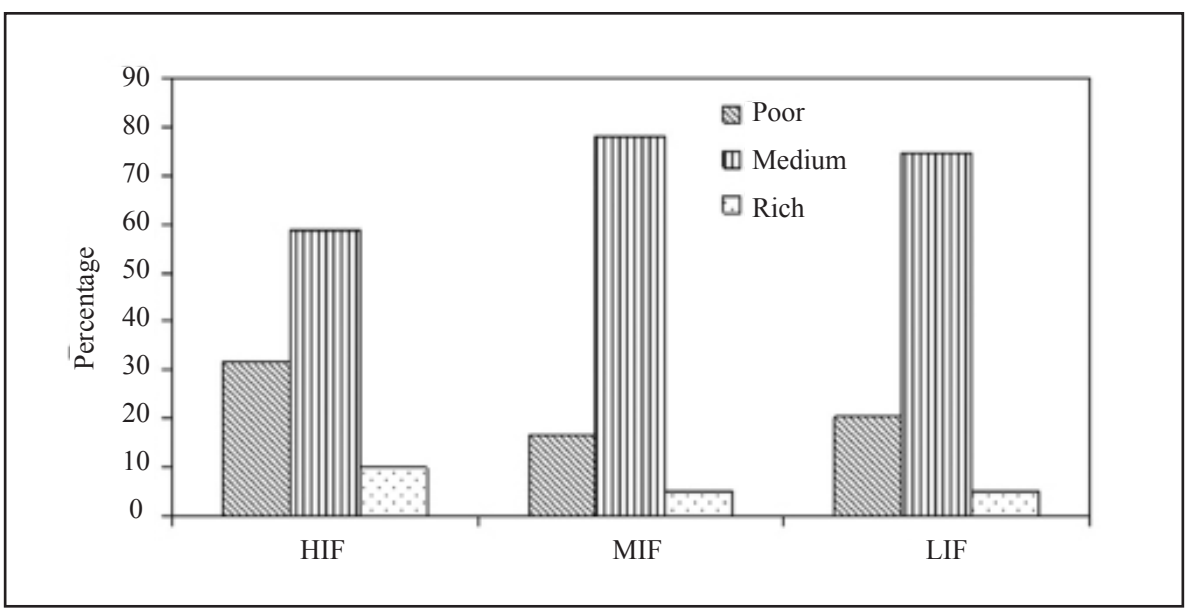

Figure 3. Ranking of wealth in the High Input Fish, Medium Input Fish, and Low Input Fish systems in the Mekong Delta

in the yard around the house or in the orchard. A pond is constructed near the house to provide water and for rearing fish. Fish are also reared in ditches between the raised beds of the orchard. Adjoining the orchard is a paddy field on land subject to annual flooding. The three fish input systems have similar soil types (young alluvial clays) but rice fields in the HIF system have problems of acid sulfate soil. The MIF system is on lower-lying land, has acid sulfate soils, and is also flooded most deeply (up to one meter in the wet season). Farms in the south of Cai Be district (LIF system) are higher-lying and their soil is fertile, recently-deposited alluvium from the Mekong River. The main water sources for the three input systems are the rivers and main canals; water flows under gravity, via inlet sluices.

Annual rice production varies from one to three cropping seasons, with yields of 4 to 6 tons per ha per crop. In places with irrigation, cash crops such as chili pepper, beans, cabbage, tomato, cucumber, and watermelon could replace rice as the dry season crop. Though fruit trees (citrus, longan, and mango) are commonly grown in the three systems, the most intensive orchards are in the LIF system: these are mono-crop orchards with high investments (e.g., high rate of fertilizer and chemical application). In the other two systems, the orchards are extensive or semi-intensive. In the HIF system, mono-fish culture (mainly catfish for export) is common, while the MIF and LIF systems have a mixture of species (e.g., common carp, silver barb, kissing gourami, tilapia, and catfish). Poultry are kept in the farmyard or orchard, mainly for family consumption. Pigs are kept in pens and sold at the market. Other animals such as rabbits are raised incidentally, depending on seasonal market demand. Large ruminants are rarely kept because of the high purchasing cost and cumbersome marketing.

The farm components in IAA farms could be linked through bio-resource flows. Traditionally, rice is the main source of food and provides cash income for the family and feed for the animals. Rice straw is used to mulch beds of vegetables and orchards, or to produce mushrooms. Weeds from the orchard and wastes from vegetables and fruits serve as other feed sources for pigs, poultry, and fish. Commonly, a catfish pond hosts a latrine supplying human excreta. Pig manure could be used to fertilize the fishpond or the orchard. The manure from chickens and ducks is a source of organic fertilizer for fruit trees when the poultry are free- range, or for fish when they are penned above the pond. The orchard trees are mulched with the enriched mud from the pond bottom and the decomposed rice straw left after mushroom cultivation. In addition, the pond is used to supply water for fruit trees and for pigs and poultry, and to produce water spinach, snails, or crabs. In this way, almost all waste and excreta are recycled on the farm.

Changes of Farming Activities and Economic Characteristics of Households

In the two survey years the farm size (5-6 persons), the farm's cultivated area (1.14 -1.23 ha in 2002 and 0.87-1.14 ha in 2004), and the LUIs of cash crops and fishpond were similar in the three systems (Table 2). The slight change in mean distance from the farm to district market in the MIF farms in 2004 was caused by the change in sample size. The maximum number of farm components was five: rice, orchard, cash crop, livestock, and fishpond. Almost all the farms had at least two components, and just under half of the farms (49% in 2002 and 44% in 2004) had four components.

In 2002, the HIF farms had a significantly lower number of farm components than the MIF and LIF farms, but by 2004 this difference had disappeared. The number of farm components had significantly decreased in 2004 compared to 2002 (Table 3). In both 2002 and 2004 the LUI of rice was significantly higher in the HIF and MIF farms than in the LIF farms, while the LUI of orchard was significantly higher in the LIF farms compared to the MIF and LIF farms. Between 2002 and 2004 the LUIs of rice, orchard, and cash crops were quite stable in the three systems (Figure 4). However, the LUI of fish ponds increased significantly from 7% to 11% ($P<0.05$). In both 2002 and 2004 the number of chickens and ducks reared in the MIF farms was significantly higher than that in the LIF and HIF farms ($P<0.05$). The numbers of pigs reared were similar between the three systems, and hardly changed between 2002 and 2004 (Figure 5).

In 2002 and 2004 no significant differences were observed between the farms in the three systems in terms of farm gross returns, variable costs, gross margins, general charges, and net farm income (Table 4).

Table 2. Farm characteristics and land use Intensity (± se = ± standard error) in the three input fish systems in 2002 and 2004.

Variables	LIF	MIF	HIF	CV[1]
2002				
Distance to district market (km)	14.0[a] ± 0.5	15.0[a] ± 1.2	7.0[b] ± 0.5	32
Farm's components (n)	4.0[a] ± 0.1	4.2[a] ± 0.1	3.4[b] ± 0.2	21
Farm size (ha)	1.24 ± 0.12	1.15 ± 0.15	1.23 ± 0.16	59
LUI[2] of rice (%)	38.0[b] ± 6.7	66.0[a] ± 4.9	69.0[a] ± 6.3	52
LUI of orchard (%)	47.0[a] ± 5.6	23.0[b] ± 4.6	23.0[b] ± 5.4	84
LUI of cash crops (%)	8.0 ± 3.6	2.0 ± 1.2	3.0 ± 1.7	268
LUI of fish pond (%)	7.0 ± 1.6	9.0 ± 1.6	5.0 ± 1.4	109
2004				
Distance to district market (km)	14.0[b] ± 0.4	17.0[a] ± 1.1	7.0[c] ± 0.5	27
Farm's components (n)	3.1 ± 0.2	3.5 ± 0.2	3.3 ± 0.2	29
Farm size (ha)	0.87 ± 0.10	1.14 ± 0.15	1.10 ± 0.14	64
LUI of rice (%)	32.0[b] ± 6.7	68.0[a] ± 5.3	74.0[a] ± 6.9	58
LUI of orchard (%)	51.0[a] ± 5.4	17.0[b] ± 3.1	16.0[b] ± 4.7	81
LUI of cash crops (%)	3.0 ± 2.5	4.0 ± 4.1	1.0 ± 0.5	545
LUI of fish pond (%)	14.0 ± 2.4	10.0 ± 1.7	9.0 ± 3.4	119

[1] Coefficient of variation in percentage
[2] Land Use Intensity. Different superscripts ([a],[b]) denote significant differences between means within rows (P<0.05).

Table 3. Changes in Household Characteristics and Household Economy (± se) Between 2002 and 2004.

Variables	Survey	Overall Mean	Change[1]	CV[2]
Farms' components (n)	2002	3.9**	± 0.1	22
	2004	3.3 ± 0.1	-15	30
LUI3 of fish pond (%)	2002	6.9 ± 0.9		110
	2004	11.3* ± 1.5	64	120
On-farm family labor (day)	2002	103.0 ± 8.0		67
	2004	202.0** ± 25.0	96	109
Variable costs (million VND)	2002	11.97 ± 1.32		95
	2004	25.12** ± 3.24	110	113
Gross returns (million VND)	2002	25.45 ± 2.34		79
	2004	43.71** ± 4.04	72	81
Off- and non-farm income (million VND)	2002	6.05 ± 1.16		166
	2004	10.05* ± 1.19	66	104
Household income (million VND)	2002	19.16 ± 2.20		99
	2004	28.26** ± 2.93	48	91

[1] Relative change in percent
[2] Coefficient of variation in percent
[3] Land Use Intensity, *P<0.05, **P<0.01

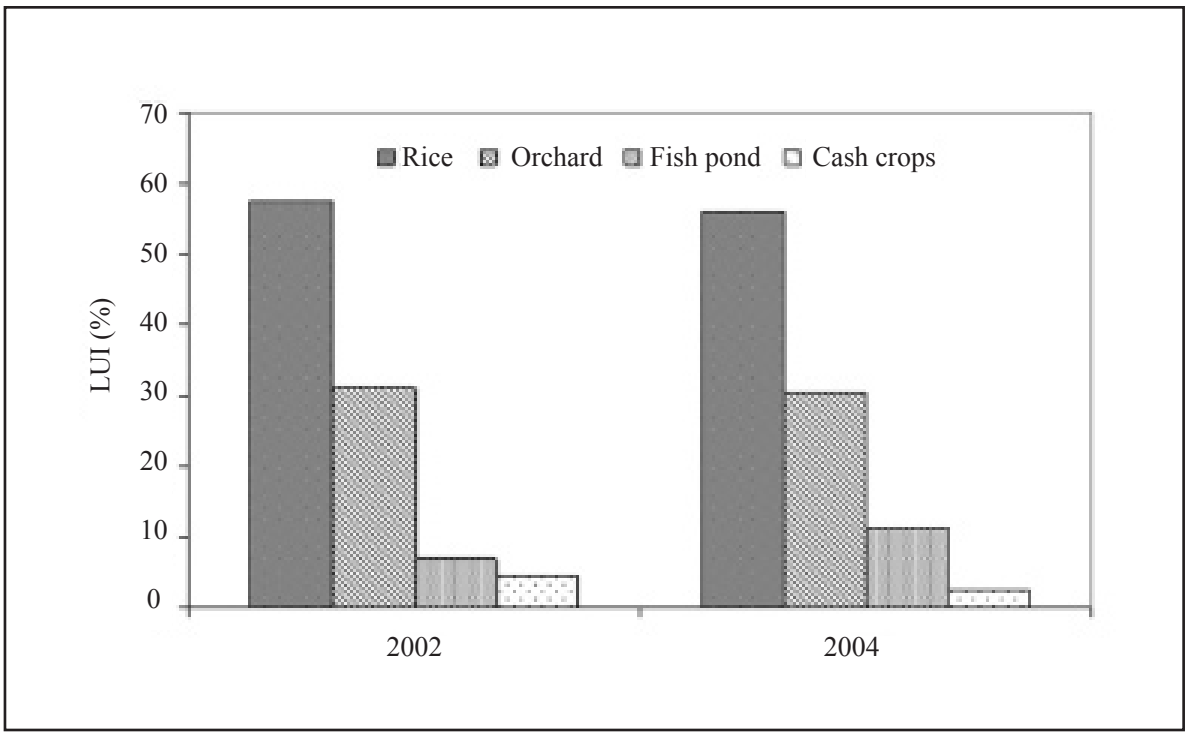

Figure 4. Changes in LUIs (land use intensity) of farm components in the three input fish systems (2002–2004).

Table 4. Household Economic Parameters1 (± se) in the Three Input Fish Systems in 2002 and 2004.

Variables	LIF	MIF	HIF	CV2
2002				
On-farm family labor (day)	110.0 ± 12.9	100.0 ± 15.2	99.0 ± 14.1	68
Variable costs	10.24 ± 2.31	12.95 ± 2.27	12.76 ± 2.31	95
Fixed costs	0.31 ± 0.05	0.38 ± 0.06	0.44 ± 0.09	90
Gross returns	23.50 ± 3.17	22.14 ± 2.66	30.58 ± 5.58	79
Gross margins	13.27 ± 2.20	9.19 ± 1.67	17.82 ± 3.65	98
Net farm income	12.96 ± 2.20	8.81 ± 1.67	17.38 ± 3.62	101
Off- and non-farm income	5.42 ± 1.78	6.04 ± 2.19	6.69 ± 2.15	168
Household income	18.38 ± 3.07	14.85 ± 2.79	24.07 ± 5.03	98
2004				
On-farm family labor (day)	211.0 ± 32.2	272 ± 72.6	134 ± 17.1	107
Variable costs	19.12 ± 3.07	33.19 ± 8.27	24.99 ± 5.52	112
Fixed costs	0.25 ± 0.05	0.43 ± 0.08	0.47 ± 0.08	96
Gross returns	40.34 ± 5.92	47.06 ± 8.86	44.64 ± 6.84	82
Gross margins	21.22 ± 3.96	13.87 ± 6.51	19.65 ± 2.83	121
Net farm income	20.97 ± 3.95	13.44 ± 6.47	19.18 ± 2.82	123
Off- and non-farm income	14.24a ± 2.51	3.77b ± 0.89	10.68a ± 1.47	96
Household income	35.21a ± 5.10	17.21b ± 6.56	29.87ab ± 2.81	88

[1] Million VND yr-1
[2] Coefficient of variation in percentage
Different superscripts (a,b) denote significant differences between means within rows (P<0.05)

However, off-farm and non-farm incomes were significantly (P<0.05) lower in the MIF farms than those in the LIF and HIF farms in 2004. Household income was significantly (P<0.05) lower in the MIF farms than that in the LIF farms in 2004. On-farm family labor was similar in all systems in 2002, but was significantly higher (P<0.05) in the MIF farms in 2004. This corresponds to an important rise in number of chickens (e.g., 6 farms had 150 to 6000 chickens per farm in 2004) in this area (see also Figure 5). The on-farm family labor and the variable costs increased significantly (P<0.05) in 2004, but despite this the farm gross returns were higher. Together with a significant increase in off-farm and non-farm income, this contributed to a significantly higher (P<0.05) household income (Table 4). The most important contributors to the gross margins were rice, orchard, and fish pond. The negative contribution of poultry was caused by the outbreaks of Avian Influenza (AI) in 2003 and 2004 (Figure 6).

Principal Components Explaining the Types of IAA systems

Nineteen average values of the main farm characteristics for 2002 and 2004 were used in the factor analysis, extracting seven principal components that explain 81% of the total variance (Table 5). All variables have high loadings (correlation coefficients greater than 0.5) indicating that a significant percentage of the variance of each variable is explained by these seven principal components. More than half of the variables carried high loadings in the first three principal components, explaining 54% of the total variance. The first principal component was strongly related to household income, the second to farm investment, the third to the LUI of the farm. The last four principal components related to household demography, farm diversity and market access.

DISCUSSION

We now proceed to ferret out the implications of the study's findings presented above. The discussion below includes how forces such as new technological developments or environmental disasters or government policies impact on the farming system. Also tackled are the motivations that propel farmers to adopting either diversification or intensification to cope with the changing farm resources and market opportunities. The key roles of on-farm strategies, relative to non-farm or off-

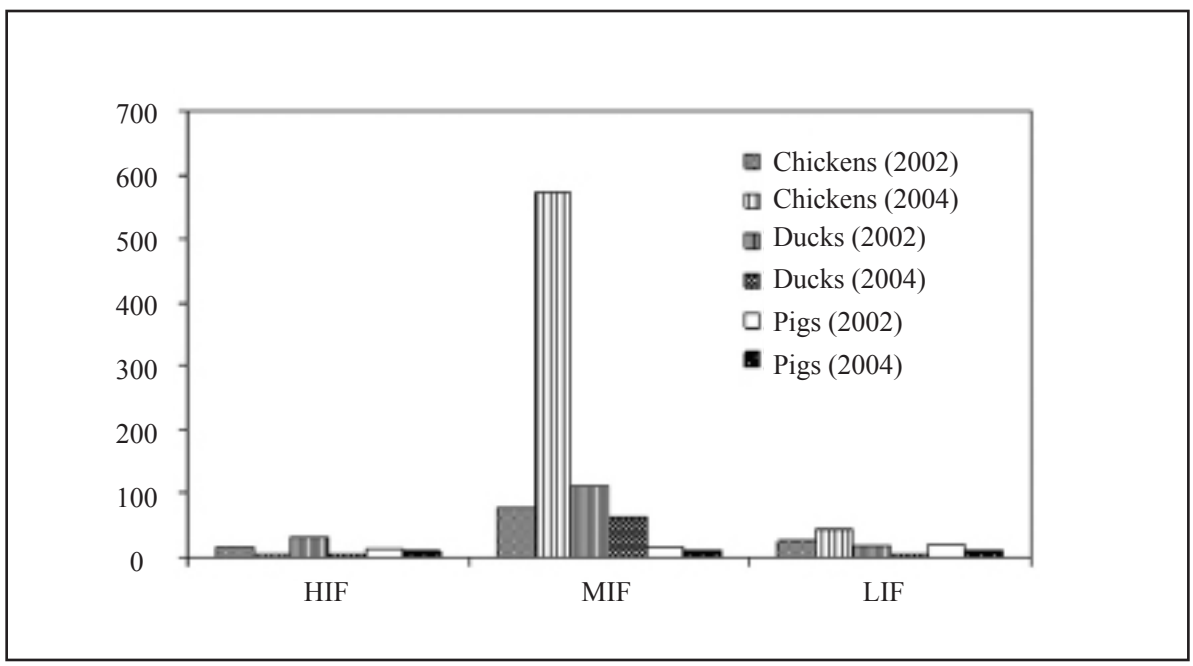

Figure 5. Number of livestock in the three input fish systems in 2002 and 2004

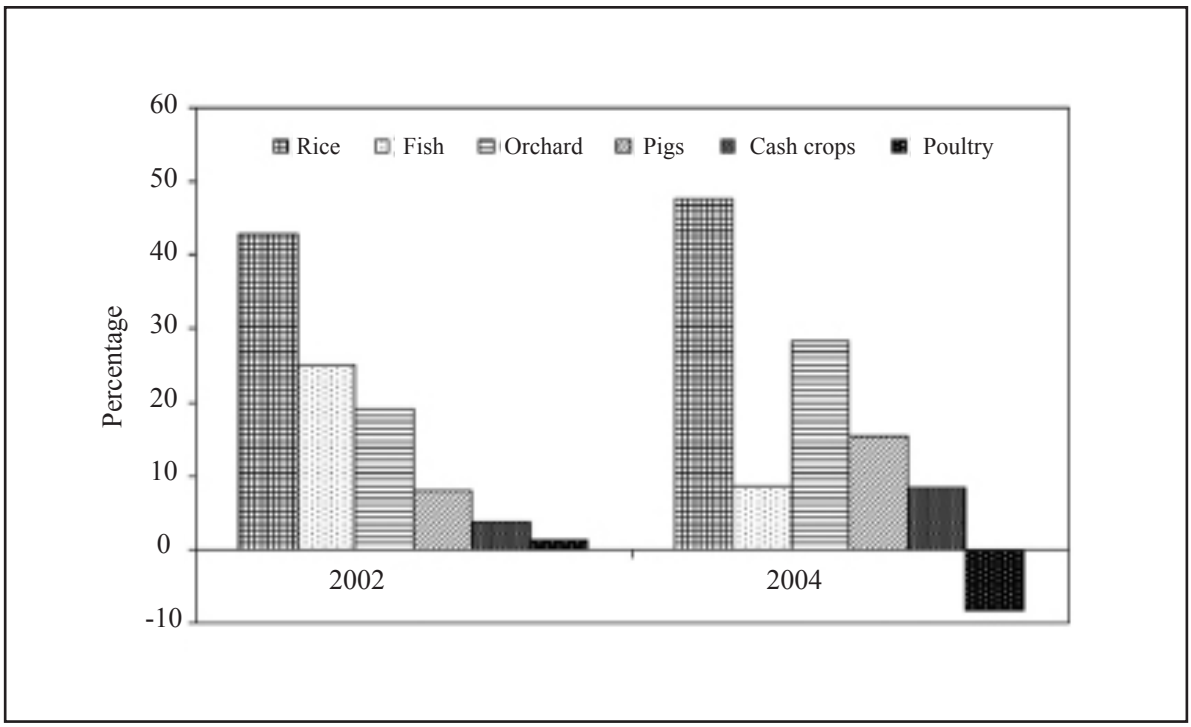

Figure 6. Average contribution of the farm components to the gross margin in 2002 and 2004

farm income, in sustaining improvements to their livelihoods are looked into, as well.

Diversification and Intensification

The farming systems in the MD are determined by agro-ecological conditions, tradition and related government policy. They are rice-based, with fruits as the secondary crop. Most farmers prioritize rice cultivation, not only for food security but also to increase income. In the past, traditional rice cultivars with a low yield and a long growth cycle were grown, but the introduction of modern high-yielding rice varieties with a short growth cycle has enhanced production. In areas with irrigation, cropping systems have switched from one cropping season of 6–8 months to two consecutive rice crops per year of four months each (Pingali and Xuan 1992). Other crops such as beans, maize or watermelon are sometimes grown as an alternative to the irrigated rice crop, to supply food or cash to the household. The rapid and widespread adoption of new rice varieties and technology (e.g., fertilizer application, insect pest control) had caused an overproduction of rice (e.g., rice export in 1990s) and a sharp decline of market prices (IFPRI 1995). This motivated farmers to develop other farm components and to use rice products to feed pigs, poultry or fish.

The Doi Moi economic reform policy has been a major force driving diversification. Government-controlled collectivized systems using production contracts have changed to systems with individual farm management, and oriented to the open market (Anh et al. 2003). Government services provided the farmers with new farm technology, and new animal breeds and cultivars. Credit and other extension activities were provided for those who engaged in fruit tree production, and no agricultural taxes were charged for the first three-year period. Since 1990 the area under fruit trees has greatly increased. After a few years, (Figure 2), a fall in the market fruit prices due to surpluses and an unstable export market slowed down farmers' investments in orchards. Farmers were also encouraged to raise hybrid pigs and to use concentrates to shorten the fattening period (e.g., 4–5 months' cycle instead of 6 or 8 months' cycle) and to produce leaner animals. The intensification of poultry started later and local breeds have remained more popular because they

Table 5. Rotated component matrix and correlation coefficients based on baseline surveys for 2002 and 2004.

No.	Variables	Components						
		1	2	3	4	5	6	7
1	Net farm income	0.972						
2	Gross margins	0.969						
3	Household income	0.924						
4	Variable costs		0.848					
5	Gross returns	0.626	0.702					
6	On-farm family labor		0.629					
7	Farm size	0.517	0.626					
8	Cultivated area	0.517	0.626					
9	Fixed costs		0.583					
10	LUI[1] of rice			-0.958				
11	LUI of orchard			0.936				
12	LUI of fish pond			0.732				
13	Off- and non-farm income				0.791			
14	Family size				0.772			
15	School years of HH[2]					0.821		
16	Years of residence of HH					-0.538		
17	Distance[3]						0.836	
18	Farm components						0.552	
19	LUI of cash crops							0.938
	Eigenvalue	5.4	2.8	2.0	1.6	1.2	1.1	1.1
	% of variance	28.5	14.8	10.7	8.7	6.6	5.9	5.6

[1] Land Use Intensity
[2] Household head
[3] from district market

are easy to sell in the local market, are resistant to common diseases, and are less demanding with regard to feed.

Between 2002 and 2004, the household characteristics and land areas in the three systems remained fairly similar (Table 3) but there were many internal changes in the systems, especially in land use and farm economy (Table 4). One change was a decrease in the number of farm components — this may have been due to fluctuations in market demand and falling farm product prices. Rice fields and orchards are likely always to be present on the farms; they represent "hard-to-change" farm components. They make major contributions to the farm income (Figure 6). Cash crops are often cultivated between rice crops in the same fields, or in a separate permanent vegetable plot. The LUI of cash crops was small and did not change in the two years, but it was different between the three input systems possibly because traditional cultural practices differ in the different agro-ecological zones: e.g., in the LIF system, watermelon is commonly grown to supply markets during the traditional Tet holiday.

Livestock and fish are easy-to-change farm components. Livestock-keeping does not require much land area, as crop wastes or grasses/weeds, used as feed, do. Animal wastes can substantially reduce farmers' input costs for fish feed or for fertilizer. In 2003 the first outbreak of AI in Vietnam occurred; it lasted till March 2004. This outbreak did not greatly affect the surveyed farms; therefore, after the first AI some farmers intensified their chicken production, hoping that they could benefit from the collapse of industrial chicken production. However, their chicken production collapsed too, as there was a second outbreak of AI at the end of 2004. The intensification of chicken production needed more on-farm family labor (Table 4). The shortage of poultry meat that followed from the AI outbreak increased the demand for pork and fish. Consequently, an increase in the LUI of fish

pond was recorded (Table 4). Pig production did not increase, due to a fall in market price, the high cost of hybrid piglets, and the continuing rise in the price of rice bran (Bosma et al. 2006).

The significant increase in off-farm and non-farm income in the LIF and HIF farms in 2004 compared to that in 2002 meant that more family members were working as hired laborers outside the farm. This reflected the increased opportunities offered by the labor market in these areas. In the MIF farms, the high on-farm family labor in 2004, mainly caused by the labor demands of increasing the poultry flock, affected the figures for labor used for off-farm and non-farm activities. The level of investments differed between the systems (Table 3). On top of the increase in costs of gasoline (21%) and fertilizer (22%) in 2003 (Incombank 2003), the variable costs increased between 2002 and 2004 by 110% (Table 4), which is evidence of farm intensification. The significant increase of household income in 2004 was the result both of an increase in the farm gross margins due to higher gross returns, and of higher off-farm and non-farm income.

Generally, it can be said that the well-off farmers with good farming skills and enough capital tend to intensify their farming systems, while the poorer farmers tend to move towards diversification, in order to safeguard their living and avoid risks. The gap between the poor and the rich in the HIF (e.g., 21%) and LIF (e.g., 15%) farms (Figure 3) indicates that the rich are successful in farming because they have sufficient financial resources to intensify their farming and to assure long-term commitment to farming. Shortage of cash means that the poor are not buffered against risk: crop failure or animal disease means they lose money and may have to stop farming and become hired laborers for rich farmers, or move to the town to work in the service sectors. The high percentage of moderately wealthy households in the MIF farms (78% of all households) indicates that more diversified farming leads to a trend towards higher incomes for these households. In addition, the job opportunities related to market access and urbanization (as in the HIF and MIF areas) can cause people to abandon agriculture: This can increase the disparity in household wealth.

Determinant Attributes of IAA systems

The principal components reflect two main attributes of the IAA farms: the diversified farm resources and household economy.

Pond aquaculture is only a minor component in the IAA systems but integrating aquaculture with fruit, rice, and livestock can help to improve the use made of local natural resources and to increase the contribution of inland aquaculture to total agricultural production. The LIF system is near the Mekong River, where the higher-lying land and fertile soil have favored the development of intensive fruit production combined with a low-input and low-output fish system (Table 1). The use of large quantities of chemicals (e.g., fertilizers, pesticides, chemical control of fruit-tree flowering) and the reduced solar radiation due to shading by fruit trees may affect the fish growth in the narrow orchard ditches (Nhan et al. 2006).

In the MIF farms, no single farm component like the fruit trees in the LIF farms or fish in the HIF area is dominant: in other words, the MIF farms show the widest variety of farm components. A government program to encourage horticulture has resulted in many orchards being established in the 1990s on land where rice had been grown. This contributed to the development of fish ponds in ditches between the raised beds for the fruit trees. However, fruit yields here are low because of the combination of the low-lying land at risk of flooding, the high groundwater, and the acidic soils.

Most fishes in the HIF area are commercially produced and of export quality. Intensive fish farming requires high capital investment, specialized labor and technical know-how. It is especially suitable for farmers with sufficient land and cash to be able to construct a large fish pond. The trading tactic of "buy first, pay later" (i.e., a farmer buys feed but only pays for it after harvesting the fish) of local feed agencies encourages farmers to engage in fish culture. For farmers who have little land or insufficient capital to rear fish for export, an alternative way of generating income is to produce fingerlings.

Changes of LUI and income diversification are common farmer responses to changing farm resource

and market opportunities (Dixon and Gulliver 2001). Off-farm and non-farm activities generate an important part of many household incomes on the farms (32 to 36%). The expected decrease in family size in the long term makes it likely that the on-farm intensification, diversification, and changes/choices of LUI will prove to be more important livelihood household strategies than off-farm and non-farm activities.

A main difference between the three research areas is market access. It affects the potential for sales of farm produce and access to external inputs, extension services, and opportunities for non-farm income. The relationship between the market access of remote farms and the farms' diversity (number of farm components) suggests that remote farms recycle their internal resources better between farm components (Bosma et al. 2006). This is illustrated by the higher number of farm components in the MIF farms (Table 2) and its higher values for ecological sustainability indicators (Phong et al. 2006).

Holling (1995) and Luu (1999) have concluded that diversification can be a key strategy to meet the increasing demand for farm products. The sustainable livelihood of IAA farmers in the MD may also depend more on farm diversification than specialization, as the diversified IAA systems can help to spread risks from market fluctuation or natural disasters. In farm diversification, individual farm components can be intensified to compensate for the income losses of other farm components. The intensification of the pig and fish components in IAA farms in the MD during the AI crisis is a good example (Phong et al. 2007). This can be considered as a "hard diversification" versus a "soft diversification" (Scottish Executive 2003) when farming practices and investments are spread over all farm components. The execution of these strategies across the IAA farms will depend on agricultural policies and extension support.

CONCLUSIONS

Over 30 years the rice-based systems in the MD have developed into integrated agriculture-aquaculture systems. The main forces driving changes in the farming systems were the introduction of modern rice varieties, economic liberalization policy, market demand, availability of production technologies, and natural disasters. These forces drove farm diversification. A "hard diversification" could help insure against risks from natural disasters. Agro-ecological conditions, level of technology support by public extension services, and access to credit accounted for the differences found among the three districts. The main attributes of the IAA farms were the diversified farm resources and household economy. Hard-to-change farm characteristics were the LUI of orchard and rice or other cash crops. Easy-to-change farm characteristics were the number of farm components, the LUI of fish pond, on-farm family labor, off-farm and non-farm income, and farm inputs. The main drivers of change over the two years have been market demand and a natural disaster (Avian Influenza). Over the 30 years, the IAA systems have proved to be dynamic, demonstrating a trend from specialization (or monoculture) with extensive farming towards diversification and intensification. Farmers have responded to threats and opportunities by increasing their inputs to improve their income. Off-farm and non-farm incomes have made an important contribution to household income; however, for farm development, ways of sustaining improvements to the household's livelihood are on-farm diversification and intensification, and changing the LUI of a particular activity. Farms in the MIF area were more diversified than the LIF and HIF farms. Overall, it can be concluded that well-off farmers with good farming skills and enough capital tended to specialize and intensify their farming practices, while the poorer farmers tended towards diversification in order to safeguard their livelihood and avoid risks.

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