Potentials for Different Models for Freshwater Aquaculture Development in the Red River Delta (Vietnam) using GIS Analysis

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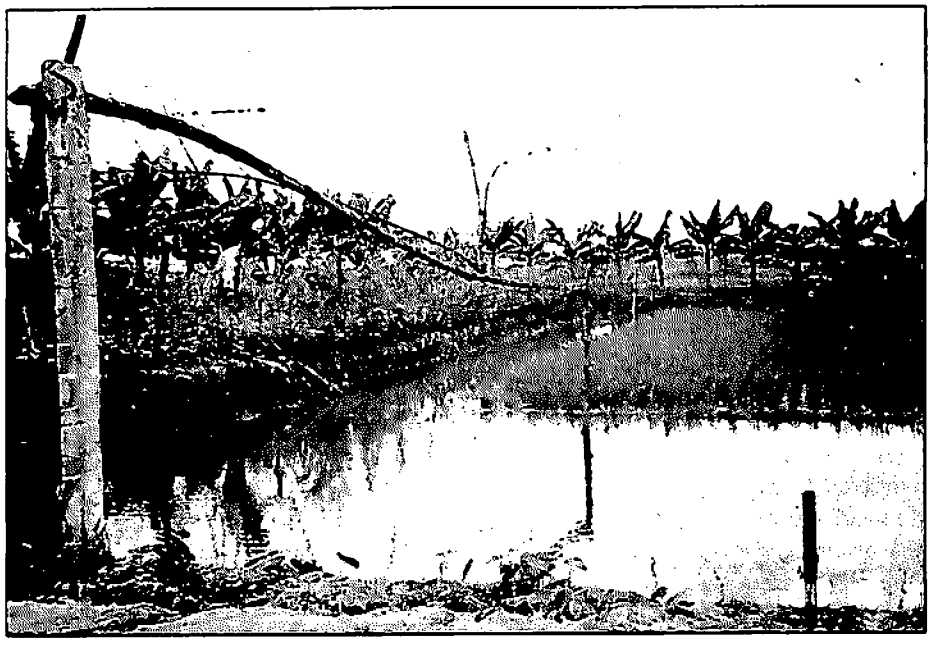
Background

Rational utilization of land, considering the relative economic efficiency of crop cultivation (especially rice as the traditional crop for many generations) and aquaculture needs special attention in the Red River Delta, Vietnam. Until the early 1980s, Vietnam was faced with problems of basic food production and everywhere the emphasis was on rice cultivation. Even after the introduction of the production-contract system, families were expected to produce their quotas and to pay land taxes in rice, so there was little scope to diversify. Changes of land use had to be approved by local authorities. Only since 1988, with the further relaxation of these regulations and the award of land use rights on 15-year leases, have individual farm families been able to think of alternative uses of their land. Rice production has increased throughout the country and, despite Vietnam's entry to the world export market, paddy prices have fallen to the relatively low level of Dong 1 000/kg ($0.09/kg) at the farm gate. This trend has also signalled the need for diversification. Aquaculture is a promising way to raise income and needs to be expanded, but this requires sound planning.



Rice-fish culture system in the lowland zone.

Application of geographical information system (GIS) techniques to assess potentials for aquaculture has been developed recently by Kapetsky et al. (1988), Meaden and Kapetsky (1991) and others. In Vietnam, the application of remote sensing and GIS techniques for planning and managing fisheries and aquaculture are still new.

This study was an attempt to apply land-based GIS analysis for freshwater aquaculture planning in the Red River Delta of Vietnam. It was based on diverse data sources in order to help decisionmakers at the site and also to contribute to the modeling of selection processes for aquaculture development planning in the region.

The Study Area and Its Aquaculture

The Red River Delta lies between latitudes 20°00'N and 21°30'N, and longitudes 105°30'E and 107°00'E and embraces seven entire provinces (Hanoi, Ha Tay, Hai Hung, Hai Phong, Nam Ha, Ninh Binh, Thai Binh) and portions of three other provinces (Ha Bac, Quang Ningh, Vinh Phu) covering a total area of 16 654 km^2 (Fig. 1). The population of the Delta was estimated at 16 788 000 in 1992, with an average annual growth rate of 2.3% and an average population density of about 1 000 persons per km^2.

The Red River Delta floodplain formed over thousands of years of sedimentation. The area has been progressively diked to protect it from flooding, resulting in a fertile alluvial plain interspersed with a network of rivers and canals. Adjacent to the sea are large areas of coastal wetlands, comprising areas of mud flats, reed beds and mangroves. About 70% of the agricultural land comprises young and alluvial soils of moderate to good fertility. About 13% of soils are saline or acid sulphate and about 10% are degraded sandy loam soils of low fertility. The remaining 7% are eroded skeletal

Integrated livestock-fish system.

soils, sand dunes, and newly deposited flats on the coast.

The inland water resources of the Delta are substantial. The Red River and its major distributaries have a total length in the Delta region of 700 km while there are several hundred km of minor tributaries and effluents. There are substantial areas of seasonal or permanent swamps, with much of the former utilized for fish production in the wet season and rice in the dry. There are numerous man-made lakes, extending to a total of 25 000 ha, some of which are stocked annually with fish.

Agriculture is the most important subsector in the Red River Delta, accounting for 73% of employment and 35.7% of GDP in 1992. Farms are small (0.2 ha to 0.4 ha) and fragmented (6 to 10 lots up to 2 km apart). From the 903 650 ha of agricultural land, almost 90% is used for annual crops, 6.6% for aquaculture and fisheries, 3.1% for perennial crops and only 0.6% for pasture. Of the 810 400 ha of annual crop land, 81% is used for paddy with average productivity of 3.36 t/ha for both the spring and monsoon crops: 605 000 ha (75%) of this rice land is double-cropped (two crops of paddy, or one crop of paddy with one, and sometimes two subsidiary crops — soybean, maize and vegetables). Several provinces (particularly Thai Binh) produce surplus food crops estimated at 415 000 tons of paddy. About 62 000 ha, mostly outside the dikes and thus prone to monsoon flooding, are used for subsidiary crops. The overall land use index (the total area planted to one or more crops divided by the total cultivated area), sometimes called the cropping intensity, is about 2.0

The Red River Delta is characterized by an abundance of water and small family-size ponds. The total area of waterbodies in the area is 145 700 ha and 20.3% of the total aquatic area is utilized for fish production. About 30-40% of farm families have small ponds around their houses, mainly to meet subsistence needs, not only from fish culture, but also from fruit and vegetable gardening and the rearing of small livestock. The so-called VAC system of integrated farming, named from the Vietnamese for garden (V-vuon), fishpond (A-ao) and animal pen (C-chuong), is intensive and fish production very often exceeds 1.5 t/ha.

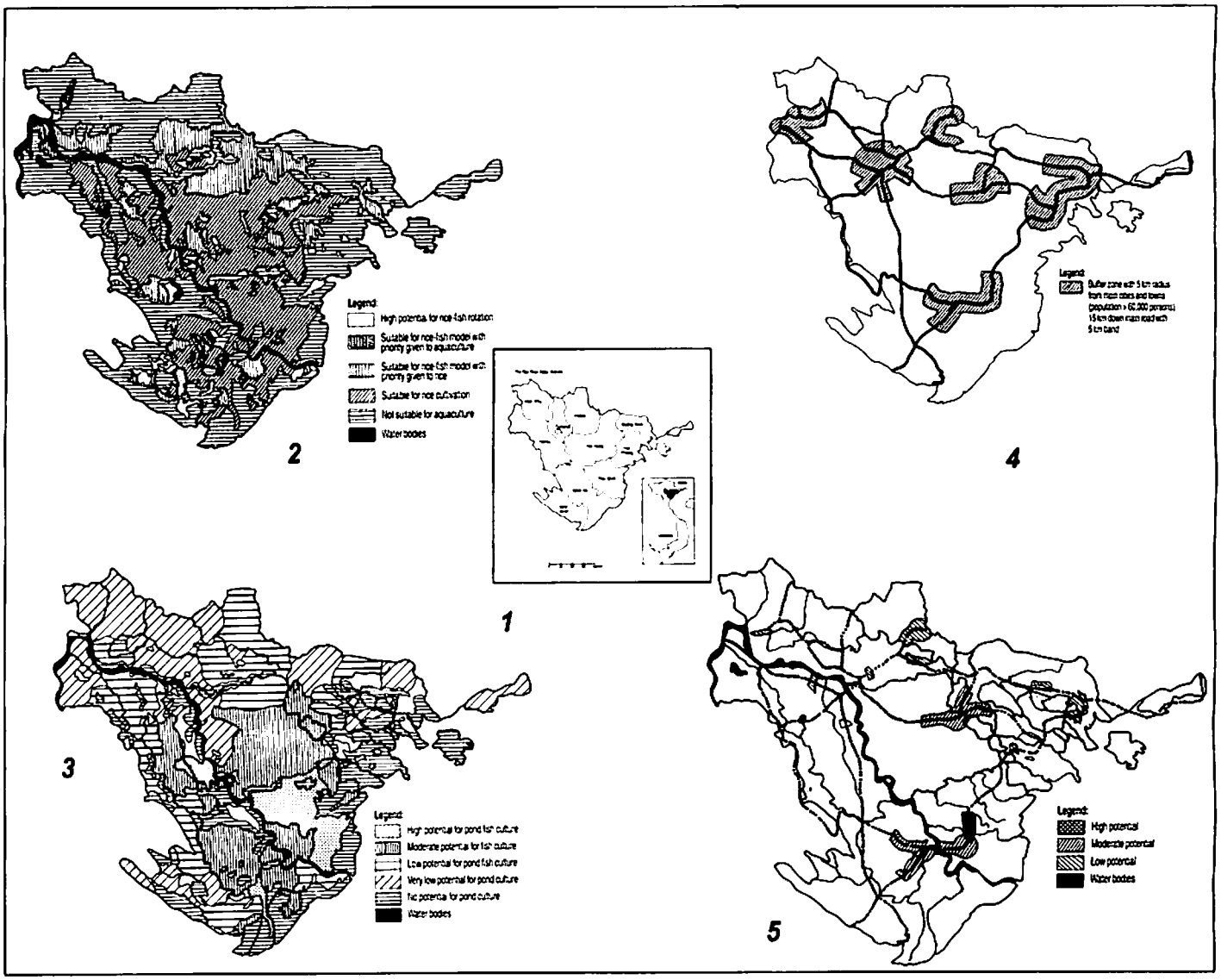
Fish cage culture has seen major growth in the Delta over the past two or three years. There are currently about 4 000 cages in the Delta provinces, compared to 500 in 1990. Monoculture of grass carp *(Ctenopharyngodon idella)* is generally practised, or polyculture of grass carp with bighead *(Aristichthys nobilis)* and Indian major carps. The fish are fed mainly on grass and crop residues. Cage culture is open to landless families, or to those whose paddy land or garden areas are too small to provide an adequate livelihood.

Methods

The Study

The study was mainly based on secondary data: false color Landsat Thematic Mapper images taken in 1992, topography, soil and water quality, landuse, seasonal flooding level, rice productivity by districts and capability of rice production supply, population and population density, city location and transportation network. The GIS software used was ARC INFO, the vector-based GIS package operated on a 486 DX PC. Maps were digitized using a digitizing table. Landsat images were used for visual interpretation to correct the boundaries of land units (areas of common characteristic) derived from other sources. Ouputs produced after analysis and processing were plotted using a color plotter. The objective was to select parameters affecting and controlling aquaculture activities in the Red River Delta.

Use of waste and manure in a VAC system.



Figs. 1-5: 1) The Red River Delta districts; 2) Areas with potential for rice-fish rotation in the Red River Delta; 3) Areas with potential for intensification of small pond culture in the Red River Delta; 4) Buffer zone of areas accessible to urban/industrial inputs; 5) Areas with potential for culture accessible to extra inputs in the Red River Delta (Tran Ngoc Thu and Demaine 1994).

Recent thinking about the development of aquaculture in the Red River Delta has focused on lands that are subject to seasonal flooding. Many of these were indeed utilized for a cropping system of spring rice and monsoon fish culture under the commune system. Most of these lands have now been converted to rice cultivation under the system whereby households have been allocated shares of all the different types of land in the commune. However, despite the overall reduction of flooding since construction of the Hoa Binh dam, these lands are still subject to local inundation and are very low yielding. Thus, it has been proposed that they should be used for seasonal aquaculture.

The first aspect of our analysis is based on the assumption that areas of low-yielding paddy (>3 t/ha/crop) with deep seasonal floods (usually >1 m) have high potential for freshwater aquaculture. Soil quality was also expected to have some influence, so that areas with saline intrusion and acid sulphate soils may not be so favorable for aquaculture. Areas not prone to flooding, uplands and areas with saline, acid sulphate soils were considered relatively less suitable.

Rice-fish models, with relative priorities given to aquaculture or to rice cultivation can applied to high potential areas, depending on water depth, productivity and economic efficiency. However, all this presumes the development of rather extensive forms of aquaculture, for which the control and water in the individual plots may require a good deal of investment in bunding. There may be greater potentials in the proliferation of small backyard ponds, in which fish are stocked and fed at rather greater intensities. Many farmers already have VAC systems, based upon inputs from home gardens and the wider agricultural system. Inputs from home gardens are, however, limited and studies by the Research Institute for Aquaculture No. 1, Ha Bac and the Asian Institute of Technology have begun to indicate that intensification of the system depends on the wider productivity of farms especially in terms of surplus rice, which can be fed through animals to produce manure for the pond. Therefore, potentials for development of fish culture may be linked to rice surplus over subsistence needs. The highest potentials for integrated aquaculture development are probably therefore with high per caput

annual output (>400 kg), double or single-crop rice farming systems. These areas should be outside saline and acid sulphate soil areas.

Another key assumption was that extra inputs may be obtained from *outside the farm system*, in order to intensify pond ricefield aquaculture. In particular, around cities, availability of night soil (human excreta) and brewery waste help in this regard. Thus we assumed that another higher potential for aquaculture development in areas to which such inputs can be easily transported: say buffer zones of perhaps 5 km radius around the main cities and towns with populations more than 60 000, and a stretch of 15 km from such urban centers down main roads in a band of 5 km width (2.5 km on each side of the road). Combining information on the availability of urban-derived inputs and farm-based rice surpluses was considered important in assessing.

Results

Potential for Rice-Fish Rotation

The areas having high potential for aquaculture under the rice-fish rotation model, areas of low-yield paddy land with deep seasonal flooding, are presented in Fig. 2. They comprise about 12 000 ha, mainly in Ninh Binh province, where agriculture is dominated by paddy production but yields are frequently below average for the Delta. These lands include a relatively large area of low-lying land with poor drainage and irrigation. In the rainy season, this area is deeply flooded. Conversion from rice to aquaculture seems possible.

Other areas, with similar potentials cover about 32 000 ha: mostly located in Nam Ha and Hai Hung provinces, with a few scattered location in Ha Tay, Hai Phong and Vinh Phu provinces. These are low-lying lands with moderate to deep seasonal flooding levels, but rice productivity is higher. Here, the extra benefits to be derived from aquaculture in the rainy season are lower and farmers may be discouraged if high investments are needed for land modification for aquaculture. This is particularly so in areas that have moderate water depths and high rice yields. Such lands have limited potential for conversion to the rice-fish rotation systems. For example, there are many lands like this in Ha Bac province and in a few areas in other provinces, totalling about 265 000 ha.

Potential for Intensification of Small Pond Culture

Fig. 3 depicts the results of analyses based on the assumption that potential for development of intensified fishpond culture may be linked to rice surplus over subsistence needs. The main potential for intensification of small pond culture is in Thai Binh province. This province is entirely low-lying, without hills or forests. Its paddy yields are the highest in the Delta region. However, this province has poor road links with the other Delta provinces, partly because of the large number of ferry crossings and partly because of the poor condition and low design standard of the main routes. These constraints are important considerations. There are also some areas of high potential in Ha Tay and Nam Ha provinces.

Areas with Access to Urban-derived Inputs

Fig. 4 depicts the areas of access to urban-derived inputs that surround the big cities and towns in the Delta, such as Ha Noi, Hai Phong, Hai Duong, Nam Dinh, Thai Binh, Uong Bi and Viet Tri. Fig. 5 shows the combination of such areas with high potential areas for intensification of small pond culture because of available on-farm inputs. These combinations can be regarded as having the highest overall potentials for pond aquaculture. They can be clearly concentrated.

The Future of the Red River Delta

A vast amount of land in the Delta, about 457 000 ha, is likely to remain predominantly suitable for rice cultivation, especially in Thai Binh, Hai Hung, Nam Ha and Ha Tay provinces. This area is characterized by shallow water, fertile alluvial soils and high price productivity and intensity. Rice will remain the main crop of the Red River Delta, which supplies over 20% of Vietnam's total rice production. Production in the area has increased greatly from about 2.2 million t/year in 1960 to the present level of nearly 5 million t/year, and yields in high productivity areas now reach an aggregate of 10-12 t/year for the two rice crops and total production per caput ranges from 400 to 530 kg/year in seven districts in Ha Tay and Thai Binh.

Nevertheless, the possibilities for increased production of fish are considerable. Recent studies of moves towards rice-fish culture in the Delta (Chung et al. 1995) have shown that with a relatively extensive culture with some field preparation, yields of up to 1.95 t/ha/year can be achieved. Thus, careful management, the 44 000 ha of land highly or moderately suitable for rice-fish culture could produce 86 000 t of fish annually, compared to perhaps 12 000 t at present. The same study in eight selected communes in the Delta shows that as many as 40% of farming families have backyard ponds. These average about 500 m^2 in size, although most are smaller, and average production is around 100 kg/pond (Chung et al. in prep.). This indicates that as much as 108 000 t may be currently produced; even a modest improvement in yield to the 150 kg/pond achieved by some farmers would raise this figure to 162 000 t.

References

Do Kim Chung, H. Demaine, Pham Van Trang, Nguyen Quang Dieu and Bui Thi Huong. VAC Systems - Traditional integrated agriculture-aquaculture in Vietnam: a socio-economic assessment. AIT Aquaculture Outreach Prog. Work. Pap. NV-7. Asian Institute of Technology, Bangkok. (In preparation)

Do Kim Chung, H. Demaine, Pham Van Trang, Nguyen Quang Dieu and Pham Bau. 1995. VAC integrated farming systems in the Red River Delta: an overview. AIT Aquaculture Outreach Prog. Work. Pap. NV-6 (November 1995). Asian Institute of Technology, Bangkok.

Kapetsky, J.M., J.M. Hill and L.D. Worthy. 1988. A geographical information system for catfish farming development. Aquaculture 68:311-320.

Meaden, G.M. and J.M. Kapetsky. 1991. Geographical information systems and remote sensing in inland fisheries and aquaculture. FAO Fish. Tech. Pap. No. 318.

Tran Ngoc Thu and H. Demaine. 1994. Application of geographical information system (GIS) analysis for freshwater aquaculture planning in the Red River Delta of Vietnam. AIT Aquaculture Outreach Progr. Work. Pap. No. NV-1. Asian Institute of Technology, Bangkok, Thailand.

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