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Techno policy aspects and socio-economic impacts of eco-industrial networking in the fishery sector: experiences from An Giang Province, Vietnam

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ABSTRACT

Eco-industrial networking is considered as a new approach for businesses to improve their competitiveness, economic viability and human and ecosystem health. A cyclic material flow with alternative usage of all materials in the loop is an essential feature of an eco-industrial network. While eco-industrial networking has been primarily applied on the high-tech sector, this paper attempts to apply the principles on the fishery sector of An Giang, a Vietnamese province in the Mekong River Delta. An Giang Province has its own market share in the trade of Tra and Basa fish. The industries in the value chain of Tra and Basa are in a situation that forces them to improve their competitiveness to retain the market share. It was found that forming an eco-industrial network and recruiting new businesses to utilize all materials in the process provides additional revenue apart from reducing waste disposal concerns. This paper details the current market situation, the issues faced and material flow patterns and presents a feasible eco-industrial network. The results of the study indicate that the eco-industrial network creates positive impacts in terms of increased competitiveness, improved socio-economic conditions and cleaner environment.

1. Introduction

1.1. Eco-industrial network

The earth has been facing tremendous pressure due to population explosion, rapid urbanization and ongoing industrialization. The day-to-day needs of people have been increasing at an exponential rate such that abundant resources a few years back have now become scarce. This rate of resource exploitation is unsustainable.

Consumption apart, the rate and quantity of waste generation have been alarming in most developing countries. Industrial production processes and domestic consumption patterns have changed in such a way that a considerable portion of resource is discarded without any use and called waste. Resource consumption and waste generation are found to be the two sides of the development coin.

This does not necessarily mean that development should be retarded to keep in pace with resource regeneration or waste assimilation rates. Production processes aimed at optimum raw material consumption, systems aimed at efficient sharing and utilization of resources and technologies focused at alternative use of discarded materials are imperative to reduce resource depletion and waste generation crises.

Production processes, systems and (or) technologies cannot single-handedly transform the consumption and disposal patterns. Appropriate policies are essential and have proved to be effective tools in the management of resources. A paradigm shift from command and control based environmental protection to market-based instruments has proved to be successful in many places. All or part of these market-based instruments is often integrated cross-boundary policies. Various instances of environmental protection and resource conservation through integrated policies are seen across the globe, thus demonstrating their roles. Therefore, the development of appropriate policies adequately considering development priorities and environmental pressures is of paramount importance as well.

An eco-industrial network is "a community of manufacturing and service businesses seeking enhanced environmental and

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economic performance through collaboration in managing environment and resource issues including information, energy, water, materials, infrastructure, and natural habitat" [1]. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only.

Eco-industrial networking, one of the applications of Industrial Ecology, is an emergent in the venture of improving competitiveness, economic viability, and human and ecosystem health. A successful eco-industrial network can be realized only by a shared view of development priorities and resource constraints. Essentially, an eco-industrial network aims at efficiently using resources while achieving development targets and meeting the demands of the community.

The corner stone of an eco-industrial network is the efficient and maximum use of both direct and derived resources. Recycling, reusing and finding alternate use of discarded materials are important characteristics of an eco-industrial network. Theoretically, under given conditions and circumstances an eco-industrial network is endeavored to achieve a zero waste and all-resource economy.

The quintessence of an eco-industrial network lies in developing new local and regional business relationships between the private sector, government and educational institutions. The ultimate goal of creating new relationships is to use existing energy, material, water, human and infrastructure resources to improve production efficiency, investment competitiveness, and community and ecosystem health.

1.2. Profile of An Giang Province

The Mekong, one of the longest rivers in Asia flows for a distance of about 4000 km across China, Myanmar, Laos, Thailand, Cambodia and Vietnam. Close to 60 million people, directly and indirectly, make their livelihoods in the Mekong River basin.

An Giang Province where the Mekong River enters Vietnam (Fig. 1) is a rich delta well known for its freshwater fishes. *Pangasius bocourti* and *Pangasius hypophthalamus*, popularly known as Catfish or Basa, are the most common species in the region. Both *P. bocourti* and *P. hypophthalamus* are edible varieties and are processed and exported to the European Union, the United States and Japan.

The Province is strategically located in the lower basin of the Mekong Delta where the Mekong River first enters Vietnam. The Mekong further branches into the Tien and Hau rivers forming interlacing waterways and irrigation networks favoring the fishery sector. These rivers are averagely flowing at 13,000 m^3/s having a maximum of 24,000 m^3/s during flood and a minimum of 5000 m^3/s in the summer [2]. With the advantageous rivers, agriculture and fishery developed rapidly and promoted various allied industries in the province.

In An Giang, about 13,000 family-level farmers produce more than 50% of the total fish yield of the Mekong Delta. The province has 10 major fish processing industries, promoted as joint venture businesses with the fish farmers, local administration, and trade houses as partners. The industries have a capacity to process about 65,000 tons of fish per year [3]. In line with the increasing number of fish farmers and processing industries, services such as hatchery, medicines, feed and raw materials for feed have grown in the region.

An Giang Province has been experiencing rapid economic growth in the recent decades with the development of fish processing and allied industries. The present growth rate of the fishery sector in Mekong Delta requires immediate attention in terms of pollution concerns and resource crises.

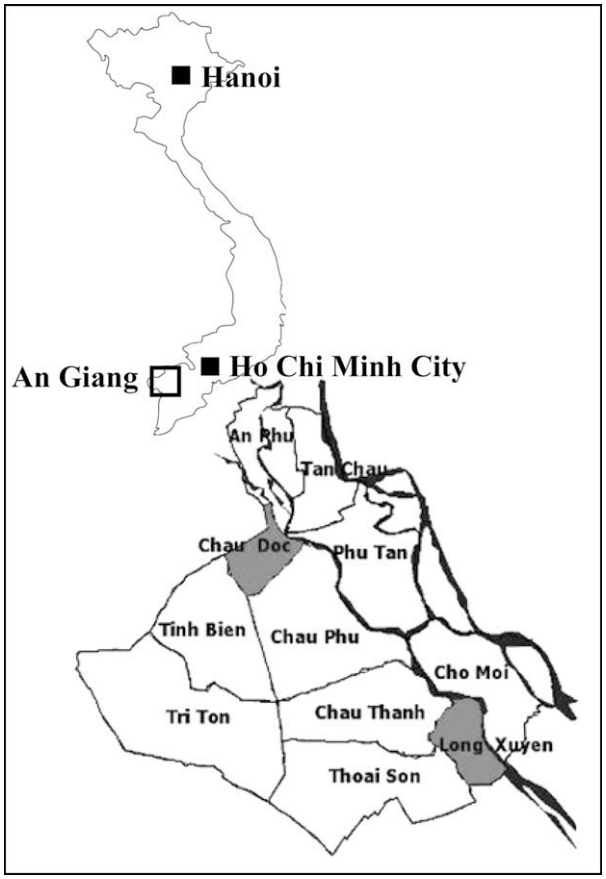


Fig. 1. Location of An Giang Province.

The fishery sector in An Giang Province has a critical supply chain closely related to the regional economy and thus has a bearing on the living conditions. While the role of the sector in uplifting the economy is encouraging, its role in environmental conservation has been generally rated as poor. The mere nature of the line of industries in the fishery value chain is the primary reason. All industries in the fishery value chain interact with water sources either directly or indirectly. For example, fish processing industries discharge effluents into water bodies without adequate treatment. Fish farms cause pollution in terms of excess and unconsumed fish feed in the water. The quality of the fish feed is another aspect, which varies from homemade to industrial, in turn varying in their ingredients and composition. The practical issues in this sector need to be visualized in multiple dimensions. Decreasing productivity due to pollution, additional expenses for waste treatment to meet regulatory standards, increasing cost of production through internalized environmental protection costs resulting in reduced competitiveness are some dimensions.

Considering the above dimensions, the fish farming and processing industries in the Mekong Delta can be no more seen in isolation. Fish farms, hatcheries, fish feed manufacturing industries and fish processing industries have to be looked up in a broader perspective. A holistic approach is essential to develop all industries in the value chain of fish processing.

This paper attempts at establishing an eco-industrial network with the fishery value chain as the central axis as a means of resolving pollution and resource concerns, and improving the competitiveness of the sector. Behind the idea of applying eco-industrial networking principles are the possible uses of different materials discarded as waste at present. In a country like Vietnam,

which is in the upward phase of development, appropriate technology is of paramount importance. Historically, Vietnam has been a country with a strong policy regime. The level of growth achieved today in Vietnam has been possible only by strong policies at the national and provincial levels. The paper places equal importance on technology and policy aspects that could drive the development of an eco-industrial network.

1.3. Fishery sector profile at An Giang Province

Freshwater fish cultivation especially, Tra fish in small pond was first introduced in Vietnam in 1940 and became popular in some province such as An Giang, Dong Than, and Can Tho. Later on, it extended to cultivation in cages and pens. After the catfish war in 1990, fish export rates increased rapidly and Tra cultivation became an important component in the economy of Vietnam. The country's fisheries sector gained prestige in the countries and territories it had trade relations. Developed countries, such as Japan and EU member countries are now its major and regular trading partners.

The Mekong River basin in Vietnam has a long tradition in the cultivation of *Pangasius* species. Tra and Basa are cultivated in large quantities for the reasons mentioned below:

- Withstand severe conditions, and survive in waters with low dissolved oxygen
- Grow faster, are omnivorous and easily adapt to changes in the feed
- Good taste and better shelf life

Owing to these reasons, Tra fish is cultivated in a larger scale compared to others. It can be observed from Fig. 2 [3] that the yield of Tra fish alone was about 55,000 tons, approximately 77% of the total cultivation in the Province.

Fig. 3 presents information on the export turnover of the An Giang Province [4]. It could be observed that over the past years, the contribution of the fishery sector to the overall exports of the Province has been increasing consistently. Interestingly, the fishery sector, in 2005 has equaled the total contribution from the other sectors such as rice, fruit and vegetable business and light industry and handicraft. Of the US$ 300 million export turnover in 2005, the fishery sector owns a massive US$ 155 million share, a little over 50% of the total.

2. Issues in the An Giang fishery sector

The An Giang fishery sector, despite various issues, has been consistently performing well in the market and has given a stiff competition to its counterparts in neighboring countries. Fish cultivation, processing and marketing in An Giang Province is

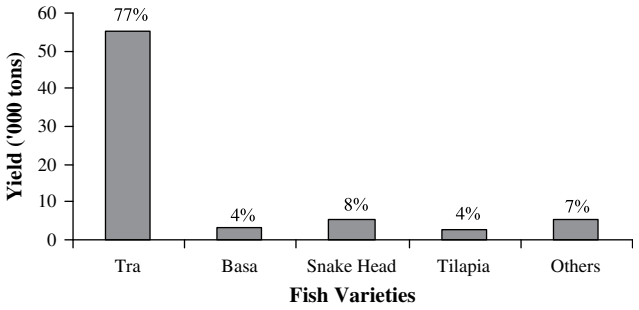


Fig. 2. Fish yield in An Giang Province.

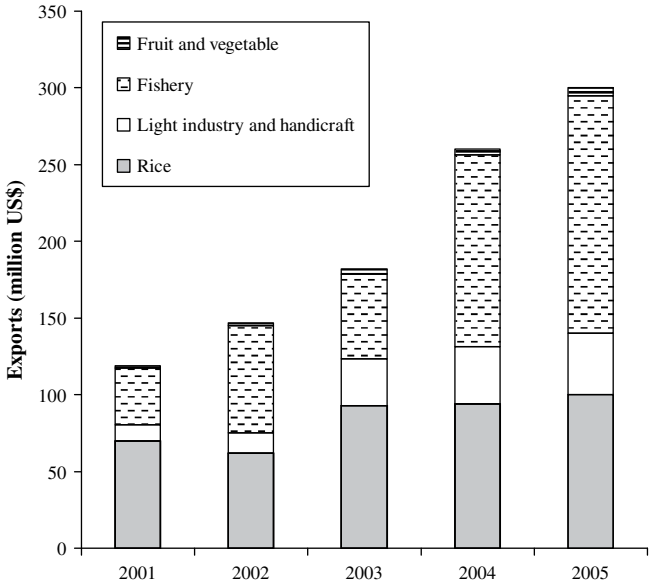


Fig. 3. Export turnover in An Giang Province.

exposed to various issues both in the upstream and downstream sides of the supply chain. The fishery sector needs to confront various issues in an environmentally and economically friendly way. The issues can be primarily classified as cultivation and processing related.

2.1. Fish cultivation related issues

Abundant water from the perennial Mekong River has helped the Province in attaining a remarkable position in the fishery sector. Well known for its fishery products, the province, in the recent years has also become rather infamous for its pollution and water resource concerns. An environmental quality assessment done by the provincial agency [2] indicated that water quality in the main branches of the Mekong River, Hau and Tien and some of the major canals, are of concern (Fig. 4). Despite prevailing Vietnamese Standards, water quality in the rivers has been poor in most of the places. Dissolved Oxygen (DO) content and Biochemical Oxygen Demand (BOD) are two important parameters for water quality. Dissolved Oxygen content is more important as far as aquatic life is concerned. Pitiably, both these key parameters do not conform to the standards. The Vietnamese Standard for Water Quality TCVN 5942:1995 requires a minimum DO content of 6 mg/L and allows a maximum BOD of 4 mg/L. However, water quality in the river has been such that both DO content and BOD has not been up to the standards even in the rainy season when maximum dilution occurs due to flooding and runoff.

This clearly indicates the level of pollution in the river. The causes for this rate of pollution are possibly many varying from unscientific practices of fish farming to lack of adequate sanitation facilities in the nearby communities. The foremost reason believed to be the major water quality deterring factor is the boom in the fishery sector resulting in huge numbers of fish farms.

A possible reason for the deteriorating water quality is the increase in the fishery cultivation areas (Fig. 5). Though the area under cultivation has been fluctuating, in general an upward trend is observed. In 2002, an extremely high area of about 10,700 ha has been utilized for fish cultivation. However, it dropped to about 8900 ha in 2003 following stringent legislations on fish farming

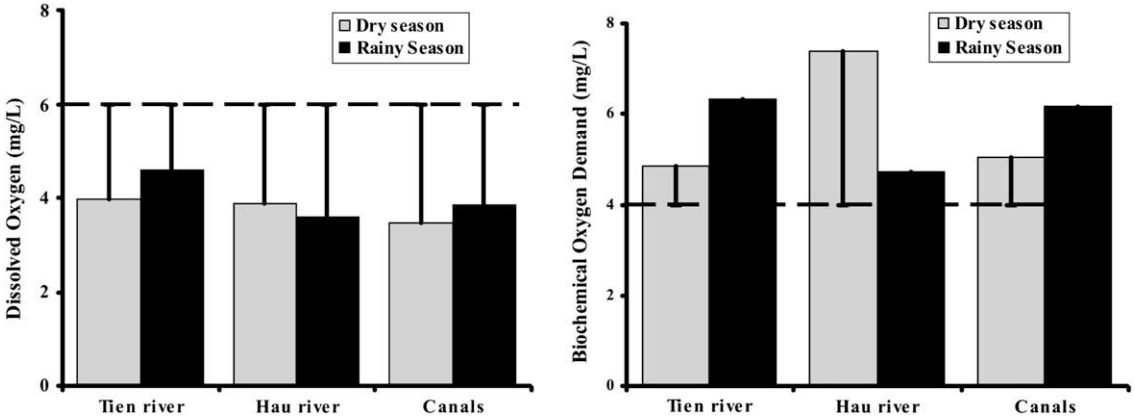


Fig. 4. Water quality in the distributaries of Mekong River.

and freshwater aquaculture. Nevertheless, the upward trend still existed and grew though not as fast as in the previous years.

Fig. 6 presents another set of interesting data that represents a valid cause for depleting water quality. Though the area under cultivation has been reduced compared to 2002, the fish yield has been following a steady growth. Intensive fish farming practices in the fish pens and cages are another important aspect. As a result of the strict rules and legislations, even though the area under cultivation was reduced, the fish density was increased to meet the demand. In simple terms, the number of fish bred in a specific area was increased. While 10 fish/m^2 is the standard, up to 30 fish/m^2 is practiced in many places. In addition, the density of fish cages itself has been increased considerably i.e., the number of fish cages in a specified area.

Apart from the above factors, other possible reasons are also believed to have contributed to the decreasing water quality. Small-scale fish farmers make use of homemade fish feed. The ingredients of these homemade fish feed are reported to contain slow degrading or non-degrading substances released in the excreta of the fish.

Fish feeding, irrespective of industrial or homemade feed is another important aspect. Though fish are fed at specified intervals of time, the quantity of feed made available is not scientifically calculated. Practically it is not possible to provide measured quantities of feed and hence farmers do it arbitrarily. Unconsumed feed remains in the water and becomes a cause of pollution.

Irrelevant to the above aspects, lack of sanitation facilities for communities living on the banks of the river also results in water pollution. Open defecation and disposal of household waste add to the pollution problems. It could be noted that most of the family-level fish farmers often live on boathouses or on the banks of the river itself.

2.2. Fish processing related issues

An Giang Province has about 10 fish processing factories in operation while four others are in the construction phase resulting in a total capacity of over 65,000 tons/year. In 2005, the demand for Tra and Basa fish from An Giang Province alone was nearly 60,000 tons.

Compared to industries in other provinces, fish processing industries in An Giang have adopted advanced technologies, equipments and processes. Most fish processing companies have obtained certifications and practice management standards such as ISO, Hazard Analysis and Critical Control Point (HACCP), HALAL, and European Food Law for fishery imports.

The province also has five dried Tra fish processing enterprises. Each company has a capacity to process about 5 tons of raw fish per month. Most process procedures such as raw material preliminary treatment, salting and sun drying are done manually. The yield mostly depends on the weather conditions, i.e., a sunny weather favors the processing conditions and improves the yield. The main

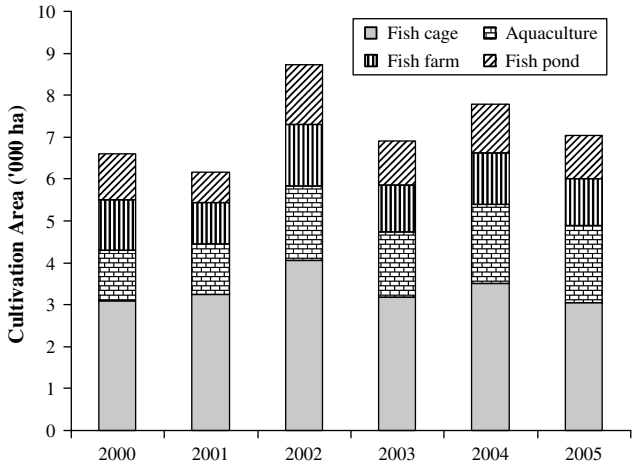


Fig. 5. Fishery cultivation area in An Giang.

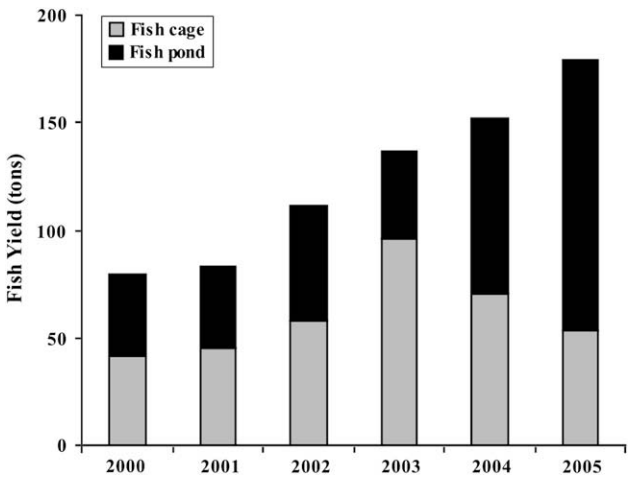


Fig. 6. Fish yield in An Giang Province.

target markets are local and regional, for example exports to Cambodia.

Several policy and legal measures such as the Fisheries Law have been steadily contributing to the performance of the sector. Bilateral trade agreements between Vietnam and other countries have favored the financial performance of these industries too. Though the financial performance of these industries has been sky rocketing, the environmental performance does not appear to be so thus posing threats to long-term sustainability.

The Vietnamese fishery sector has been consistently performing well in both international and regional markets, with ample opportunities for enhancing its competitiveness and profitability.

Presently, the fish processing industries of An Giang Province resort to end-of-pipe treatment technologies to solve wastewater disposal issues and ensure compliance with legislations. Partially, even if not fully, treated effluents are drained into the rivers and canals as a means of waste disposal. As documented and proved in many parts of the world, end-of-pipe treatment has its own costs and demerits. The An Giang fishery sector is no exception. Fish processing units spend significant portion of budgets on waste treatment and disposal costs, thus resulting in reduced profits.

3. Policy setting in the An Giang fishery sector

In Vietnam, government policies are defined in laws, decrees, ordinances, circulars and regulations, the last often at provincial level. Provinces are the lowest level at which regulations can be drafted, consistent with national legislation. Since 1996, the Government has emphasized development of the market economy under the Doi Moi (renovation) policy. In a political setup like Vietnam where the National Government holds the absolute power, policies play an important role in overall development. The administrative powers within the country are distributed. Provincial governments have powers to make decisions regarding local issues and assign development priorities based on local resources.

3.1. Action plan of the An Giang Province for fishery development until 2010

The Environmental Action plan for An Giang Province envisages the period until 2010 as an era of industrialization and modernization. Decision 02/2005/Ctr.UB in May 2005 details the following action plan for environmental protection of An Giang Province:

a. Limit the rate of pollution increase
   - 100% new manufacturers must apply cleaner production principles or install environmental standard qualified equipments and waste treatment.
   - Planning and rearrangement of the processes related to environmental protection of handicraft industries, trade villages so as to overcome the environmental pollution problems or moving to the industrial zones,
   - Control chemical safety especially toxic chemicals, minimize the production and use of toxic chemicals that cause pollution.
   - Prevent surface water pollution in Tien and Hau River, integrated irrigation system in order to make sure the water quality in the river qualify the water quality standards for Agriculture and Fishery Cultivation.

b. Improve the environment quality
   - In Long Xuyen and Chau Doc town, ensure the operation of drainage system, and central wastewater treatment system; 90% of domestic, industrial and services solid waste will be collected; invest on the complement of central solid wastes treatment system; 50% towns, domestic areas of districts have drainage system.
   - Provide all house on the river banks with sanitation facilities, especially for fishponds; and ensure 100% of fish cage houses have toilets.

3.2. Environmental policies for industries of the Province

With strong policies at the national and regional level Vietnam has been able to achieve astonishing growth rates. In the recent years, environmental protection and sustainable development have also acquired prime importance in the policies. Regulation on environmental management for the fishery sector has been formulated with adequate long-term vision. The highlights of these regulations are presented below:

Technology and planning requirements

1. Fish processing industries at the time of construction must
   a. Implement the approved plan for the construction of process space. All facilities must have the approval from Provincial Peoples Committee.
   b. Choose in advance cleaner technologies to minimize the pollution within the enterprise and its surrounding areas.
2. Environmentally polluting enterprises must upgrade the facilities and technologies and apply cleaner production options.

Wastes management

During the operating period, enterprises must satisfy the following requirements:

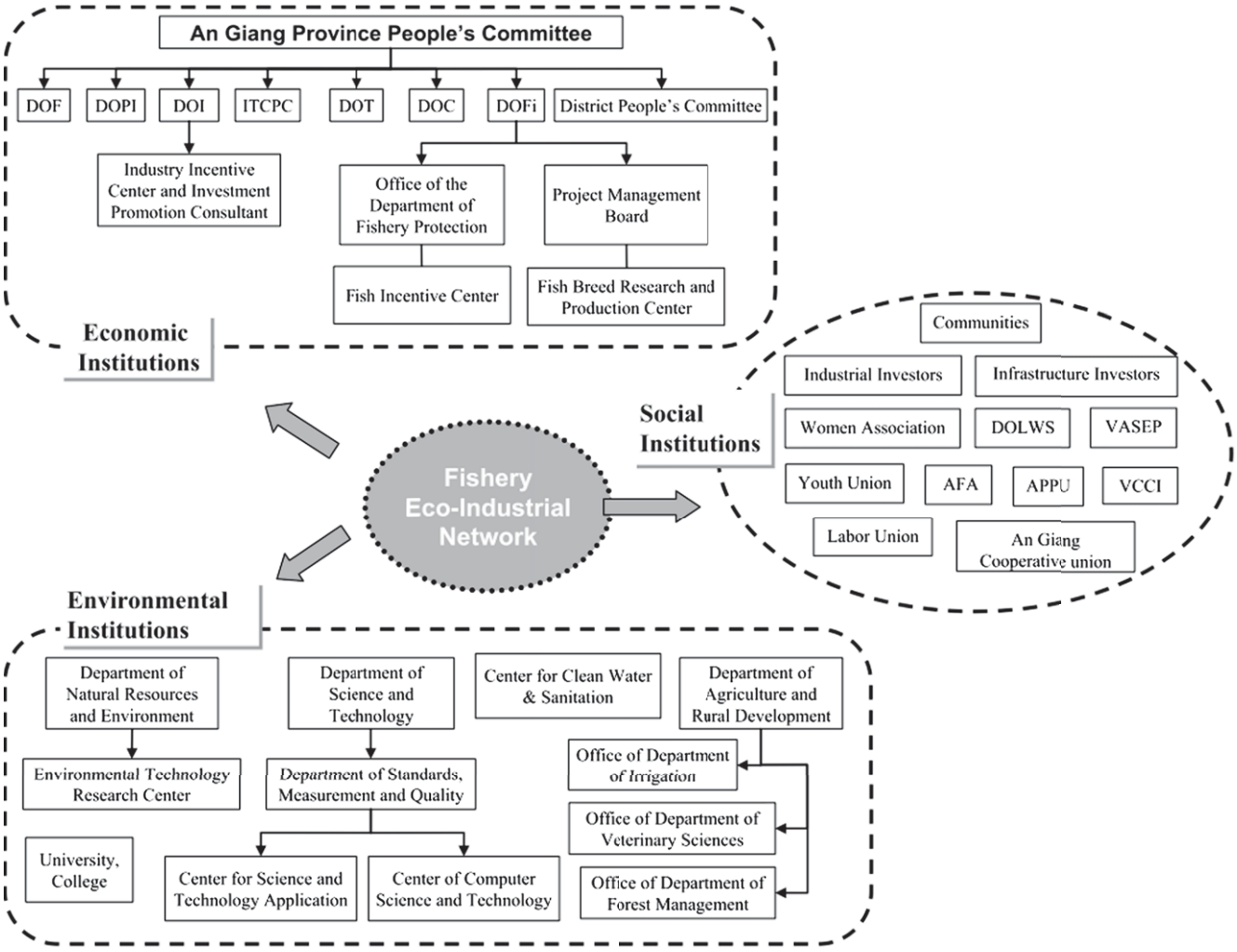
1. Collecting the waste from the production process and containing them in closed suitable device, transfer periodically to fish powder processing, and animal food process or destroying, disposing in the landfill.
2. Collecting the liquid wastes to the wastewater tank. The wastewater must be treated in the industry's wastewater treatment plant before discharge to the environment. The wastewater tank must be designed and constructed to avoid polluting the environment, groundwater, pond and water system.
3. The air emissions that cause odor and toxicity must be treated before discharge to the environment. Fish processing units that use Chloro Fluro Carbons (CFC) as the freezing agent must move to eco-friendly technologies.
4. Waste treatment technology must make sure the treated wastes qualify the Vietnamese Standard.

3.3. Fiscal support from the Government

Most of the fish farms do not pay any tax except the annual license fee and agricultural land tax, especially in the case of fishponds.

Soft Loans: Agricultural Banks lend farmers at a low interest (0.45%) and only need cage or land ownership documents as collateral security. The turnaround time and procedures to receive subsidies are observed to be farmer-friendly. However, most of the small and micro fish farmers raise the working capital from within the family or borrowings from their peers.

The An Giang Provincial Government has supported the development of the fishery industry in the province. Fig. 7 presents the various institutions governing the fishery sector both at the



CITCP: Center of Investment, Tourism and Commercial Promotion **DOLWS**: Department of Labor and Social Welfare **APPU**: AGIFISH Pure Pangasius Union
VASEP: Vietnam Association of Seafood Exporters and Processors **VCCI**: Vietnam Center of Commerce and Industry **AFA**: An Giang Fishery Association

Fig. 7. Vietnamese institution related to eco-industrial networking in the fishery sector.

national and provincial levels. Most of the raw materials come from An Giang Province, Can Tho Province and Dong Thap province.

4. Industrial networking alternatives

There are six main sectors in the proposed eco-industrial network that includes fish breeding, fish feeding, fish processing, fish/animal feed processing, animal medicine producer, fish by-product processing and waste treatment systems. Sectors interact among themselves and form a network of material exchange thus forming an eco-industrial network.

Fig. 8 shows the links and distribution of related components of the network. The baby fish from fish hatchery is transferred and fed in the fish farms. After six months, the fish is harvested and transferred to the fish processing industries where they are processed and distributed to the markets, both export and local.

The by-products from factory such as fish fat and the rejects such as skin, head and bone offer enormous potential for alternative uses. In the present situation, significant portion of these materials is either discarded as solid waste, or sold in the local market at under-price. Fish fat is often mixed with the wastewater streams, which results in higher treatment costs. As discussed in the previous sections of this paper, fish fat is a major polluter resulting in deteriorating water quality.

In order to create an eco-industrial network various new linkages, in addition to strengthening the existing ones is essential. For example, the rejects from the fish fillet processing could be used to make fish powder, a main ingredient in cattle feed.

4.1. Material flow in the network

In 2005, the quantity of baby fish and parent fish in An Giang Province produced is approximately 5 billion and 155 million, respectively, while demand for Basa and Tra fish is 167 million and for other fish (snakefish, tilapia, etc.) is 117 million. Thus, supply was well above the demand and hence the surplus was diverted to other provinces in the region. With the above quantity of parent fish, after feeding for six months, the total yield could have been

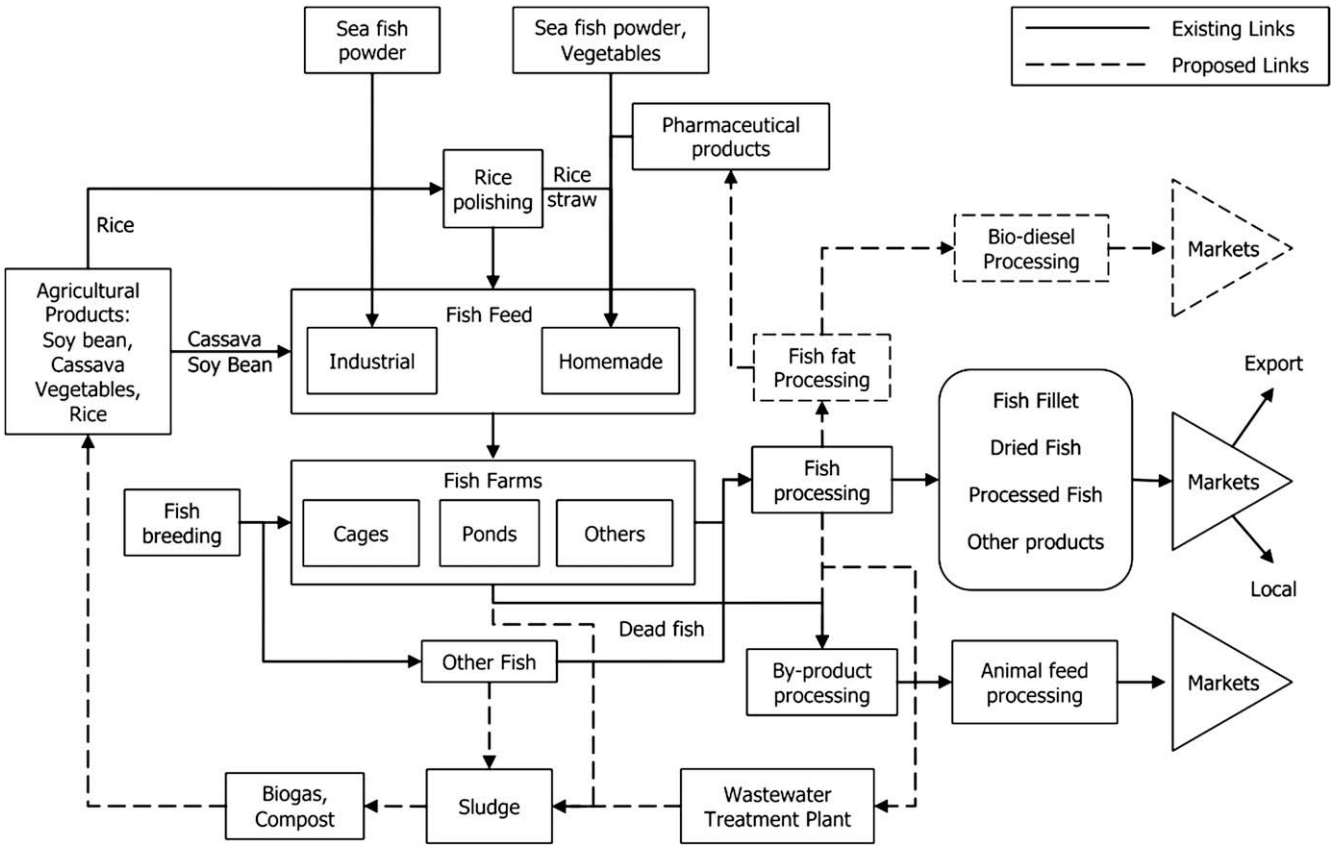


Fig. 8. Proposed fishery sector based eco-industrial network in An Giang Province.

harvested is 179,000 tons which includes 145,000 tons of Basa and Tra fish and 34,000 tons of other fish.

The 179,000 tons of processed fish could produce 60,000 tons fish fillet, 615 tons dried fish and 6000 tons of other products such as fish sauce and salted fish. In 2005, An Giang Province exported 55,000 tons of more than 60 types of products mainly processed from Tra and Basa fish. It also produced 12,000 tons of fish products for domestic consumption.

An Giang Province's strength is rice and fish. Agricultural yield (mainly rice) ranked first compared with other provinces in Mekong Delta, which contributes significantly to economic development of province as well as fishery industries. An Giang agricultural products in 2005 were 3.14 million tons rice (785,000 tons husk, 439,000 tons bran) 568,000 tons vegetable, 14,500 tons tapioca and 6700 tons soybean. Of these 2200 tons cassava, 3800 tons soybean and 1525 tons sea fish powder were used to produce 15,000 tons industrial fish feeds as pellets. About 95% of fish feed used in An Giang Province is homemade using about 199,000 tons rice bran, 67,000 tons vegetable, 23,000 tons sea fish and 4500 tons fish medicine. On the other hand, 17,000-ton rice husk was used for thermal application to prepare fish feed at the households.

In general, the provincial agricultural products were able to meet the demands for processing fish feeds. However, the province had to import sea fish powder that contains protein concentration more than those of freshwater fish.

The proposed EIN model not only includes Tra or Basa but also other kinds of fish that have lower economic value and which grow by consuming parts of dead Tra or basa fish, by-products from fish processing factories thereby reducing waste from the network and resulting in diverse fish products. In the proposed EIN model for An Giang Province, nearly 62,000 tons of by-products from fish processing industries (fish head and bones) and 17,000 tons dead fish are provided to animal feed processing factories with a capacity of 40,000 tons/year.

Tra and Basa contain high fat composition accounting for over 15%. Approximately 145,000 tons of Tra and Basa provide about 22,000 tons of fat that could be used to produce 25 m^3 biofuel. Fish fat can also be used to produce other valuable products such as medicines and high-nutrient food for children.

The 10 operating fish processing factories in An Giang Province generate about 7250 m^3 of wastewater per day and 2.62 tons of sludge. The wastewater and sludge released from fish farms were 633 million m^3 and 250 tons, respectively. Sludge generated from fish farms and wastewater treatment plants will be used for producing fertilizer while wastewater after treatment could be used for washing pig cage or irrigation. Table 1 summarizes the financial benefits from the eco-industrial network. Table 2 presents possible additional employment opportunities from the regional eco-industrial network.

An analysis of the material flow in the province shows the linkages among the various components of the fishery supply chain. Fish farms, breeding facilities, fish feed manufacturing industries, agriculture sector, and the fish processing industries, though appear to have independent business objectives still cooperate and form a closed material cycle. The efficiency of the linkages and their strengths needs to be improved yet.

4.2. Regional networking of the An Giang fishery sector

Successful eco-industrial networks, in most cases, have been achieved by the proximity of the participating industries. Physical

Table 1
Financial benefits derivable from the eco-industrial network.

By-product/waste	Quantity (tons/year)	New products	Quantity	Profit unit		Profit (billion VND/year)	
				Without Gov. subsidies	With Gov. subsidies	Without Gov. subsidies	With Gov. subsidies
Head + bone of fish	62,000	Animal feed	12,400 tons	720 VND/kg		8.93	
Fat fish	22,000	Bio-diesel	25 million liter	2000 VND/L	4000 VND/L	50	100
		Glycerin	2200 tons	10 million VND/ton		22	
Rice straw	17,000	Fuel	1.02 million liter petroleum	216,000 VND/ton	336,000 VND/ton	3.672	5.712
Pig feces (2000 heads)	2,190	Biogas	109,500 m^3 (82,125 L petroleum)	229,000 VND/ton	373,500 VND/ton	0.502	0.818
Sludge of ponds and WWTP	36,966 + 678	Compost	19,000 tons	135 VND/kg		2.565	
Total						87.669	140.025

1 USD = 16,000 VND (approx).

co-location or siting of industries within the vicinity of each other has been a key feature of the industrial networks.

An eco-industrial network is expected to support collaborative partnerships, or networks, between businesses, local governments, and the wider community resulting in more efficient and ecological resource use. Green infrastructure, Green (high performance) buildings, By-product synergy, Ecological design and Operational synergies are some of the essential services an EIN is expected to provide in the goal of increasing the environmental performance of the member industries.

Green infrastructure, green buildings and ecological design can be fully realized in the case of new eco-industrial developments. By-product and operational synergies can be experienced in any industrial network with participating businesses having a common framework of material flow and synthesis.

The An Giang fishery sector has businesses scattered over a geographically vast region. The siting of these industries is based on many factors varying from ownership of land to availability of raw materials, labor and other resources. However, the An Giang fishery sector and its allied industries have common material flows and exchanges. Such commonality allows the creation of a virtual network of material, product and by-product exchanges leading to synergies. When the synergies are realized, the eco-industrial network thus formed will rather be a regional network than one constrained by space and location.

4.3. Policy issues and environmental legislations for eco-industrial network

Regulations related to industrial environmental management in Vietnam are manifested by both focused and ad hoc legislative measures. The Law on Environmental Protection, 1993 is considered as the umbrella legislation, though various references appear in the environmental regulatory documents issued by the government and those promulgated by the Ministry of Science, Technology and Environment (MOSTE) and inter-ministries.

Table 2
Additional employment opportunities in the EIN.

Nature of employment	Average annual productivity	Working unit per labor	No. of labors
Fish feeding	1916 ha	13 persons/ha	23870
Fish processing	179,000 tons	28.125 tons/person	6365
Fish food processing	15,000 tons	120 tons/person	125
Animal food processing	2200 tons	15 tons/person	147
Bio-diesel producing	22,000 tons	270 tons/person	82
Compost production	19,000 tons	70 tons/person	272
Biogas	2000 pigs	100 pig/person	20
Total			30881

The Law on Environmental Protection (LEP) sets obligations and duties of state agencies, organizations and individuals on prevention and mitigation of pollution and environmental degradation. The Law also provides the framework for MOSTE, the Provincial and City People's Committee.

After the LEP, several environmental regulatory initiatives such as decrees and decisions were promulgated by the government to provide instructions on its implementation. Decree No. 175-CP, titled, "Guideline for Implementation of Environmental Protection Law", issued in October 1994, is considered as the first and foremost environmental regulatory document. The Decree stipulates the implementation of the LEP and assigns responsibilities at different tiers (the state management, organizations and individuals) on environmental protection, Environmental Impact Assessment, prevention of environmental deterioration and pollution and inspection of environmental protection.

The LEP and other related environmental documents were enhanced by Decree No. 261CP; and Regulations on the Punishment of Administrative Violation of Environmental Protection. This Decree indicates different types of administrative violations on environmental protection varying from illegal import/export of wastes, violations on transportation and treatment of wastewater and solid wastes, noise pollution and vibrations exceeding the permissible limits, harming the health of proximally located people and adversely affecting their life, failure in overcoming environmental incidents, etc. The degree of penalty for each case and jurisdiction for handling and procedures for implementing penalties has also been described.

In 1995, the MOSTE issued the national environmental standards (TCVN-1995) including standards on water quality and discharged industrial wastewater characteristics, ambient air quality and industrial emission, noise and vibration in public and residential areas, and soil quality.

Through various circulars and decrees released in October 1999, February 2001 and April 2001, the MOSTE encourages the implementation of waste treatment and environmental protection activities.

Environmental legislations and policy measures envisaging end-of-pipe treatment and pollution control are more prevalent. Most environmental legislations of Vietnam emphasizes on handling of generated wastes to meet the national environmental standards. The LEP stipulates organizations and or personnel to implement environmental protection measures, install waste treatment facilities in order to meet environmental standards and prevent environmental deterioration and accidents.

A decision in December 1996, "Implementation of Vietnamese Environmental Standards", forces industries and businesses to pay attention to generated wastes from their production processes.

Legislations concerning waste reuse and recycling, and cleaner production are faintly addressed. For instance, few paragraphs in

some legislative environmental documents mention shortly about the application of waste reuse and recycling or/and cleaner production. Article 11 of the LEP, for example, mentions that the state encourages and creates favorable conditions for personnel, who use and exploit environmental components properly, apply modern technologies, cleaner production, reuse wastes, save raw materials, use recycling energy, and apply biological products in scientific research, production and consumption.

Except for article 15 of the Decree No. 291CP in May, 1995 mentioning about tax benefits for cleaner production projects or those on the reuse of wastes to reduce environmental pollution, no other legislative or policy documents gives real incentives, guidelines or instruments for practical implementation for such cleaner production and waste reuse and recycling projects and measures.

More precisely, policies concerning industrial ecology and ecological modernization are rare, rather uncommon. Articles 1 and 14 of the LEP, at a broader scope, mention the requirement to ensure ecological balance during exploiting agricultural, forest, and aquaculture and carrying out environmental protection activities as well. Ideas of industrial ecology and ecological modernization have not appeared in any legislative environmental documents promulgated by Vietnamese National Assembly, Government, MOSTE or other ministries yet [5].

5. Conclusions

Vietnam is a country that faced the downside of economic development owing to policies inconsistent with priorities and needs of its citizens. After the Doi Moi in 1986, the country experienced a revolution in policies governing the production and marketing of goods, services sector and international exports and imports. Being a communist country with strong control on power, Vietnam has the potential to implement any policy aimed at the welfare of the nation, amidst strong opposition.

In the present situation, the transformation of the existing industries into an eco-industrial network involves tremendous reforms, both at the technology and policy faces. An understanding of the current policies indicates that the Government insists on environmental protection and natural resource conservation. Policies arranged by various ministries and departments emphasize this. However, a general lack of coordination among sectoral policies exists. The paradigm shift from independent industries to eco-industrial networks, in order to be effective and smooth needs appropriate integration of sectoral policies. Including environmental protection and resource conservation into developmental policies is essential for a smooth transition.

The transformation to an eco-industrial network brings in tangible and intangible benefits to both the community and the industry. The overall benefits reflect over the country's economy as well in the future.

The eco-industrial network in An Giang Province requires introduction of newer technologies, especially those affordable, cost-effective and easily replicable. Technology transfer from developed countries is likely to play an important role in this venture. For example, biofuel generation from fish fat is a novel venture and is still carried out in the pilot scale. Large-scale application of this technology, no doubt can avoid problems in wastewater treatment apart from reducing dependence on fossil fuels.

The level and scale of operations in the An Giang fishery sector are such that significant external push is required to implement newer activities. Appropriate policies providing fiscal rebates and incentives are of paramount importance in driving the transition to an eco-industrial network.

In addition to creating resource benefits and reducing pollution concerns, the startup of new businesses creates employment opportunities thus leading to improved living conditions.

References

[1] Lowe EA, Moran SR, Holmes DB. Eco-industrial parks: a guidebook for local development teams. USA: Indigo Development; 1997.
[2] DONRE. Report: environmental monitoring results in 2005. An Giang Province, Vietnam: Department of Natural Resource and Environment; 2005.
[3] DoI. Report: development status of fish processing industry in An Giang Province in 2001–2005 phase and orientation to 2006–2010 phase. An Giang, Vietnam: An Giang Province, Department of Industry; 2005.
[4] ASD. Province statistical yearbook – 2005. An Giang Province, Vietnam: An Giang Statistical Agency; 2005.
[5] Dieu TTM. Greening food processing industry in Vietnam: putting industrial ecology to work. Wageningen University, ISBN 9058088251; 2003.