ORIGINAL ARTICLE

Impacts of mangrove management systems on mangrove changes in the Northern Coast of Vietnam

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ABSTRACT   This research examined mangrove management in Hai Phong city, Vietnam. A combination of logistic regression model data and field survey data were used to investigate the driving forces of mangrove changes. The results indicate that implementation of mangrove management investigated by the authorities, community or local people has affected mangrove change. The main driving force of mangrove loss is over expansion of shrimp aquaculture. The poorer families would like to participate in mangrove conservation activities more than richer households. Mangrove rehabilitation programs have been successfully managed by community-based forest management in cooperation with local authorities in some coastal communes. Nevertheless, the failure to convert shrimp culture from mangrove forest is recognized in other communities. These communes have to replant mangrove in abandoned shrimp ponds and follow the mangrove management used in former communes.

Key words: sustainable aquaculture, driving forces, mangrove conservation, mangrove changes.

INTRODUCTION

Mangrove forests appear in the inter-tidal zones along the coast in most tropical and semi-tropical regions (Edward and Suthawan 2004). They are among the most important and productive of ecosystems and are found along in coastal zones and offshore islands. Mangroves play an important role in coastal zones and can reduce damage from the effects of Tsunami. The most obvious evidence can be found from the Indian Ocean tsunami in Dec, 2004 (Danielsen et al. 2005). Moreover, mangrove ecosystems stabilize coastlines, clean water, protect land from erosion, and in many cases promote coastal accretion, and provide a natural barrier against storms, cyclones, tidal bores and other potentially damaging natural forces. For centuries, mangroves have contributed significantly to the socio-economic lives of coastal dwellers. In addition, they are a source of timber for fire-wood and provide building materials, charcoal, tannin, food, honey, herbal medicines, and other forest products (Hong and San 1993, Tuan et al. 2002).

There are a variety of causes for mangrove deforestation and degradation in Vietnam. In the past, according to Hong and San (1993), mangrove forests were destroyed by military herbicides in the American war in Southern Vietnam (Hong and San 1993). Moreover, population growth is mainly linked to deforestation on a micro scale (Carr 2004). In Vietnam, rapid population growth especially in coastal areas has resulted in greater demand for fuel wood, charcoal and housing materials. This situation has led to over exploitation of mangrove forests. Due to population pressure in Vietnam, mangroves were converted into agricultural land-use. Without a clear understanding of the characteristics and dynamics of the changing processes of the soil, people cannot use the land gainfully for any other purpose. The land quickly degenerates and after some years is left fallow, leading farmers to clear other forest areas. Nomadic life and farming practices in coastal areas have thus become a big threat to mangrove areas (Hong 1995).

Importantly, since the early 1980s, shrimp (*Penaeus monodon*) farming for export was encouraged by the government and became a common activity (Tuan, Oanh et al. 2002). On December 21, 1994, the Prime Minister issued National Decree 773-TTg that allowed people to expand coastal areas and waterfronts to undertake shrimp and crab farming. Households that cleared mangroves for shrimp ponds did not pay any tax to the cooperative for the first 5 years. During that period, those who cut down mangroves for shrimp aquaculture were called heroes of the "uncultivated land encroachment" movement. This policy

also encouraged people to clear mangrove forest for shrimp culture (Hue 2008). In recent years, urban expansion has increased around coastal cities such as: Hai Phong, Quang Ninh, and Ho Chi Minh. New industrial factories for seafood products and port infrastructure have been constructed.

Mangrove conservation and management have been implemented in many nations in Asia to promote the establishment and maintenance of mangrove to defend against natural disasters; especially countries that suffer from typhoons such as the Philippines and Vietnam (FAO 2007). Numerous mangrove plantation activities and regulations to protect remaining mangrove areas have taken place in many Asia nations. However, a lack of financial and human resources hamper effective enforcement of legal frameworks. Several Asian countries have ratified the Ramsar Convention on Wetlands and have designated mangrove areas as Ramsar sites or as national parks, reserves and wildlife sanctuaries (Ramsar 2006). In Vietnam, important international documents signed by the Government of Viet Nam such as RAMSAR Convention on Wetlands 1971; Biodiversity Convention 1992 clearly reflects the Government's concern about conservation of biodiversity and environment (Torell et al. 2003, Ramsar 2006). The Government of Vietnam has also taken into consideration the establishment, and management of nature reserves, and national parks. At present, Vietnam has six mangrove nature reserves and two national parks namely Xuan Thuy and Ca Mau. Nevertheless, no specific laws on mangrove management at the central level exist. The legal documents for mangrove protection and management have only been integrated into legal laws on environmental protection (UNEP 2008).

In many localities such as Hai Phong and Quang Ninh, mangrove forests were not included in the official list of forest systems; therefore the forestry sector had no written legal document on mangrove management during the 1990s. Since NGO projects of mangrove planting and protection took place in Vietnam, mangrove management and protection activities have been taken into consideration. Due to the close coordination between donors and local governments, local people have asked for the implementation of the projects through fairly strict local commitments. The People's Committee and a local household signed an agreement to allocate land (2−5 hectares) to the household for planting and protecting mangroves for a 10 year period (Hong 2003). Each project commune set up two groups of forest guards responsible for forest protection 24 hours/day. The groups were equipped with a guard tent for sheltering from rain, storms and resting, motorized boats to patrol at high tide, shoes (for walking in mud), raincoats, flash-lights, handheld loudspeaker, binoculars and so on. The guard team would only receive a full salary when they fulfilled their work responsibilities. If plantations were invaded for any reason, they were fined via salary reduction. All the stakeholders as well as household members involved in the project were invited to attend training courses on mangrove planting techniques. Another strategy was the allocation of land and forestland to some planting households or some prestigious mass organizations such as the Women's Association, or the Red Cross for management and receipt of benefit from seafood products or thinning products (ACTMANG 2006). When the project ended, the Project Management Board would assign the plantation to local authorities for long-term management. In some communes, the local authorities allocated the guard team an area of shrimp ponds to create a stable income for them so that the team would apply themselves to forest protection work. However, in other communes, mangrove forests were cut down due to the high benefits received from shrimp farming and urbanization. Two case scenarios occurred in Hai Phong city, which was the reason this research area was chosen.

Hai Phong is located in the Northern coast of Vietnam, where the mangroves are distributed within zones I and II among four mangrove zones in Vietnam (Hong and San 1993). This city is vulnerable to rising sea level and big storms possible associated with climate change (Mai et al. 2009, Neumann et al. 2015). Mangrove conservation and management has been implemented in the city; however, weak policies and practices have led to mangrove deforestation and degradation. An understanding of mangrove change is crucial for coastal environmental management towards sustainability.

Understanding the driving forces of mangrove deforestation and degradation is important; however, limited research has been undertaken on the main driving forces of mangrove deforestation and understanding the interaction among these causes. This research examines the driving forces of mangrove change and proposes better mangrove management system to archive sustainable conservation and guarantee local livelihoods.

METHODS

Study site

Hai Phong is located at between 20°30' to 20°01' N latitude and 106°23' to 107°08' E longitude, respectively. This city belongs to the Northern coastal zone of Vietnam and
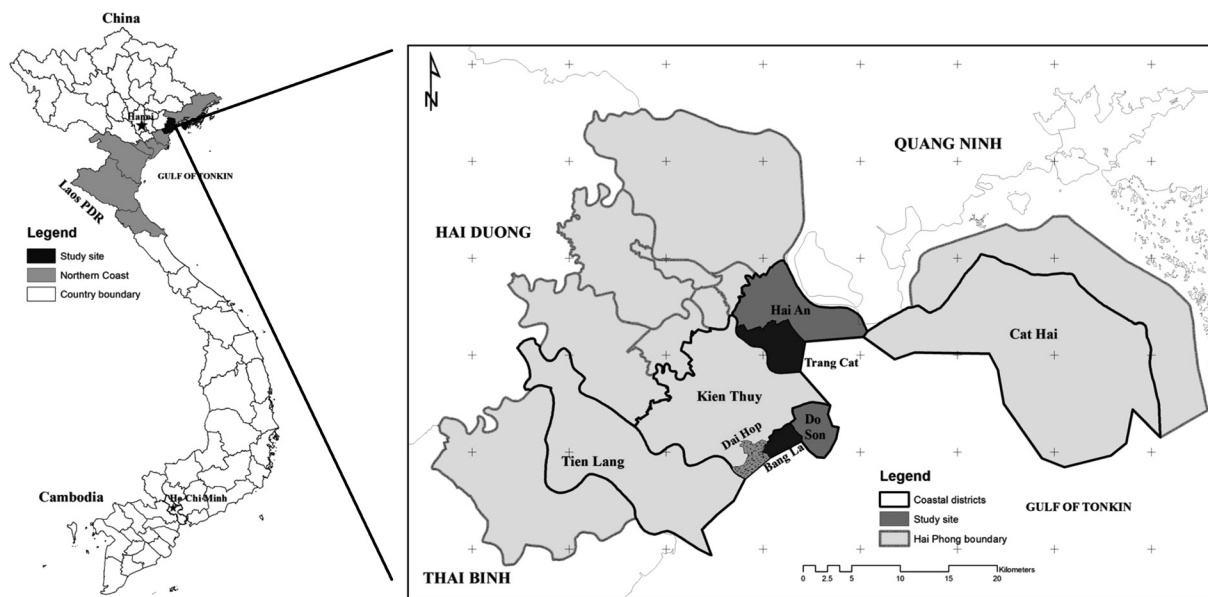
Fig. 1. Location map of study site.

lies within the tropical monsoons belt of Asia. It borders Quang Ninh province to the north, Hai Duong province to the west, Thai Binh province to the south, and the Gulf of Tonkin to the east. It is about 120 km from the capital Hanoi. The length of the sea coast of Hai Phong is 125 km including the length of coast surrounding the offshore islands (Fig. 1).

Hai An and Do Son are urban coastal districts of Hai Phong city. There are eight communes in the former district and seven communes in the latter district, of which mangrove forest are found mainly in Trang Cat commune, Hai An district and Bang La commune, Do Son district. There are many similarities between the two districts. In 2002, Hai An was separated from the An Duong suburban district and became one of seven urban districts of Hai Phong following National Decree 106/CP while Do Son became an urban district in 2007, following National Decree 145/CP. The population of Hai An was about 103,300 and 46,200 in Do Son district in 2010.

There were some mangrove plantation programs supported by both international funding agencies and the State undertaken in the two districts in particular and in Hai Phong in general. The Japanese Red Cross (JRC) was the main international organization taking care of mangrove plantations program in these districts (ACTMANG 2006). The 327 program was a national afforestation program related to mangrove plantation on bare land and coastal sand in order to reduce poverty and promote fixed cultivation and settlement.

Sampling

We selected two typical communes from two coastal districts that have similar mangrove rehabilitation programs funded by the State and international organizations (ACTMANG 2006) mainly the Japanese Red Cross and ACTMANG. Primary data was obtained from interviews with local people and key informants as well as group discussion. We selected a random sample from 34 households in the former commune and 36 households in the latter commune based on different social well-being: rich, middle and poor families for the in-depth interviews. We conducted a survey during July and August 2011 and interviewed the chairpersons of the People's Committee in Trang Cat and Bang La.

Mangrove change detection

Remote sensing was the practical approach used to map and observe the extent and the change of mangrove forests along the coast of Hai Phong. In this research, we applied a hybrid approach to generate land cover maps of Hai Phong from 2001 to 2010. The details of optical image classification could be found in (Tien Dat and Yoshino 2012).

Mangrove change detection technique is employed by ENVI (Environment for Visualizing Images) software version 4.8 though a matrix table, which represents the mangrove forest change between 2001 and 2010. The

Table 1. Mangrove change detection from 2001 to 2010

No.	Land cover		Regrouping
	2001	2010	
1	Mangrove	Aquaculture Rice paddy	Mangrove deforestation
2	Tidal mudflat Water Aquaculture	Mangrove	Mangrove gain
3	Rice Paddy Water, Tidal mudflat	Aquaculture	Aquaculture expansion
4	Rice Paddy Cloud, Forest, Settlement, Bare land	Other land use types	Not considered or unidentified

Table 2. Explanatory variables in the logistic regression model from 2001 to 2010

Independent factors (unit)	Source
Slope (Degree)	ASTER GDEM 30 m
Elevation (M)	
Population density (People km^2)	Statistical data
Aquaculture (Ha)	Land cover statistic
Distance from river (M)	Topographic map 1:25,000
Distance from road (M)	Topographic map 1:25,000
Distance from dyke (M)	Topographic map 1:25,000
Distance to settlement (M)	Topographic map 1:25,000
Mangrove management implementation (Binary 0−1)	Secondary data Official interviews

matrix table was then used to calculate the rate of change under the land cover types. The rules are set as in Table 1.

Logistic regression model

The logistic binary regression technique was utilized in this research to ascertain the relationship among geophysical, institutional and socio-economic factors and mangrove forest changes. The selected variables include geophysical, accessibility and socio-economic data (Table 2). In addition, institutional factors are also included in the logistic regression model. The mangrove forest cover change variables were considered to be binary change or no change. They formed the dependent variables in the analysis while biophysical, institutional and socio-economic factors were considered as independent or explanatory variables. The institutional variable called *Mangrove management* was recoded into binary 1 and 0 representing area where community-based forest management was associated with local authorities, and for area managed by local people. Dependent variables were acquired from the land cover change maps from 2001−2010.

Spatial data were acquired from the ASTER Global Digital Elevation Model (GDEM) with 30 meter spatial resolution available at http://gdem.ersdac.jspacesystems. or.jp/ and topographic map 1:25,000 obtained from the Centre for Agricultural Research and Ecological Studies (CARES), Vietnam National University of Agriculture, Vietnam. Analysis was carried out to examine if the association between underlying factors and mangrove forest change were consistent over time. The analysis was done by the SDM2009 (Spatial Data Modeller) in the ArcGIS environment.

The regression model is specified in equation below:

$$Ploss = \frac{\exp\left(\sum \alpha + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn + \varepsilon\right)}{1 + \exp\left(\sum \alpha + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn + \varepsilon\right)}$$

(1)

Where **Ploss**: the probability of mangrove deforestation ($0 \leq Ploss \leq 1$)

X = (X_1, X_2, $\cdots$, X_n): independent variables

α, β, ε: Regression coefficients.

In order to use the logistic regression model effectively, one thousand five hundred random points were selected in the study site. In the end, 558 points that satisfied the requirements were utilized in the logistic regression model. The training points were divided into two groups. The first group was used to create a logistic regression model and the second group is used to validate the model by accessing the accuracy of predicted pixels which was created by the first group.

The logistic regression model used in this research was present in the SDM2009 (Spatial Data Modeller) (Sawatzky et al. 2009) supported by ArcGIS version 9.3. In order to generate weights for each independent variable, integer raster is required. All raster layers were converted from floating values into integer values by the reclassification function in the ArcGIS environment. This step was applied for slope data generated from GDEM 30 m and population density. For the latter dataset, we used the criteria for urban classification in Vietnam recommended by the General office for Population Family Planning (Tung 2004).

In order to validate the logistic regression model, we

calculated the R^2 for the model. For each independent variable, the coefficient was generated by SDM tools (Sawatzky, Raines et al. 2009). The significance of the coefficients was calculated for all independent variables (explanatory variables) including free or categorical variables (Long and Freese 2005) as well as for ordered variables. We also used a sensitivity test, which can be calculated by the Area Frequency tool in SDM. This tool measures the efficiency (accuracy assessment) of classification of the first training set and the second set of training not used in the model (Sawatzky, Raines et al. 2009).

Statistical analysis

We compare two typical coastal districts in Hai Phong based on results from in-depth interviews via questionnaires to local households. The sample of each commune and the method used to select random households based on different social ranking. The questionnaire data were analysed by Microsoft Excel.

General statistics and descriptive analysis were used to describe characteristics of the situation in the study site. For in-depth interview and Focus Group Discussion (FGD) results, we also used description statistics to examine household income sources and the relationship between aquaculture and mangrove change.

RESULTS AND DISCUSSION

Driving forces of mangrove change

There are several driving forces associated with mangrove deforestation and degradation. On the other hand, mangrove reforestation or mangrove gain was due to other different important factors. Independent variables of mangrove change were selected based on the availability of reliable data. We utilized a logistic regression model covering the period 2001−2010 in the study site to determine main driving forces of mangrove deforestation and degradation. Regression coefficients represent the direction and strength of the impacts of the independent variables on the probability of mangrove deforestation and degradation. All coefficients are significant at the 99 % level (Table 3).

Table 3. Logistic regression results for mangrove changes from 2001 to 2010

Variables (unit)	Coefficient
Slope (Degree)	− 3.88
Elevation (M)	− 3.71
Proximity to rivers(M)	− 0.85
Proximity to roads (M)	1.84
Proximity to dykes (M)	− 5.05
Proximity to aquaculture (M)	5.29
Proximity to settlement (M)	0
Population density (People km^2)	− 3.26
Mangrove management implementation (Binary 0−1)	7.65

The model for mangrove loss is:

$$Ploss = \frac{\exp\begin{pmatrix} -16.24 - 3.88X1 - 3.71X2 \\ -0.85X3 + 1.84X4 - 5.05X5 \\ +5.29X6 - 3.26X8 + 7.65X9 \end{pmatrix}}{1 + \exp\begin{pmatrix} -16.24 - 3.88X1 - 3.71X2 \\ -0.85X3 + 1.84X4 - 5.05X5 \\ +5.29X6 - 3.26X8 + 7.65X9 \end{pmatrix}}$$

Where: *Ploss*: the probability of mangrove deforestation
X1: the slope (degree)
X2: the elevation (meter)
X3: the distance to rivers (meter)
X4: the distance to roads (meter)
X5: the distance to dykes (meter)
X6: the distance to aquaculture (meter)
X7: the distance to settlement (meter)
X8: the population density (people/km^2)
X9: the management (for Mangrove Conservation Policy)

From Table 3, it can be seen that there are eight factors associated with mangrove loss. The distance to roads, aquaculture and the implementation of mangrove management contributed positively to mangrove deforestation. The most effective factor in reducing mangrove deforestation is the implementation of mangrove management. Deforestation occurred in Hai An district where management and conservation policy has not been implemented. On the other hand, five remaining factors are all negatively related to mangrove deforestation. Dyke systems, especially concrete sea dykes near coastline can reduce mangrove deforestation after they are constructed, since local residents are not able to construct sluices to carry out extensive shrimp culture. When sea dykes are built in Bang La, locals began the improved-extensive shrimp farming instead of extensive farming and they fed extra food to shrimp and crab. This means shrimp farming in Bang La is carried out only behind the sea dykes. On the contrary, in Trang Cat where there are no the sea dykes, shrimp aquaculture is carried out in the tidal in-

undation. Therefore, locals in Trang Cat are able to enlarge their ponds in the tidal inundation. Moreover, the high elevation and slope also can reduce the mangrove deforestation rate since extensive aquaculture farming is difficult to construct and costly.

A logistic regression model was used to generate a probability of mangrove change. The pseudo R^2 is 0.73 and the overall accuracy of the model (efficiency of the probability) is 73.40 %. The probability of mangrove deforestation and degradation completely occurring in Hai An district ranges from 0.0001 to 0.99204. The highest probability happened mainly in the area where aquaculture expanded and in vulnerable areas with dyke systems. Distance to a dyke system can reduce the profitability of mangrove loss. Moreover, slope and elevation factors also influence the probability of mangrove loss.

A multiple regression model can provide a better understanding of the drivers of mangrove deforestation not only by using geographical and socioeconomic factors but also institutional factors. The results of the logistic regression analysis for mangrove change in Hai Phong city is somewhat contrary to a case study in Kenya where road accessibility contributed to deforestation (Serneels and Lambin 2001); even with a case study in the coastal land use change in Malaysia where urbanization play a main role to the coastal land use change. It is common sense since the latter research considered biophysical and socio-economic data, however, it did not consider institutional factors (Olaniyi et al. 2012).

In order to confirm the driving forces of mangrove changes in Hai Phong and understand mangrove conservation and management in the Northern coast of Vietnam, we analysed a comparative case study in Trang Cat commune,

Hai An district where mangroves have declined dramatically and Bang La commune, Do Son district where mangroves have been successfully conserved and managed.

A comparative case study

Sources of household income in the two communes

Table 4 compares the average shrimp ponds size per household of aquaculture farming types. On average, the shrimp pond size per household in Trang Cat commune is 12.81 ha. The same situation occurs in Northern Vietnam. Pond sizes in the North where they use the tidal cycle to feed shrimps and sea crabs are huge and larger than in the South (Lebel et al. 2002). Pond size in Trang Cat commune is fifty three times larger than that of Bang La commune. The pond size in Bang La is tiny with only 0.24 ha per household on average (Fig. 2).

Moreover, shrimp ponds in Trang Cat have utilized an extensive farming method while people in Bang La used the improved-extensive farming method. In extensive farming, breeding sea crabs and shrimps are purchased in the market and are then bred in February following the lunar calendar. After about 4 months of feeding for shrimp and 5 months for sea crab, they can be harvested and sold

Table 4. The average size of ponds per household in 2010

Households	Min	Max	Mean	Std	No. of observation
Trang Cat	1	50	12.81	14.09	34
Bang La	0.07	1.08	0.24	0.23	36

Extensive shrimp pond in Trang Cat

Improved-extensive shrimp pond in Bang La

Fig. 2. Illustration of shrimp pond type between the two communes in 2010.

to the markets. In extensive shrimp aquaculture, water is exchanged based on the tidal cycle. The flows also provide natural food for feeding sea crabs and shrimps as well as seaweed (Lebel, Tri et al. 2002). However, only one kind of brackish fish named *Oreochromis niloticus* was found in Trang Cat. In order to establish the extensive farming system, each household has to construct their own sluices. The cost is about 100 million VND.

On the other hand, people in Bang La, due to the limited area for aquaculture, have to use the improved extensive farming method. In this farming system, shrimps and sea crabs or fish are fed extra food. According to the interviews with local people, the most suitable extra food for feeding shrimp and sea crab is *Corbicula spp.* whilst small fishes are used for feeding brackish fish *Latescal carifer.* In some households, industrial food is also used to feed shrimp and sea crab (Dat and Yoshino 2013).

Net benefits from extensive farming in Trang Cat commune were very low in 2010. In other words, shrimp culture was ineffective. According to the in-depth interview with households, the main reason was that water quality had deteriorated through pollution since Trang Cat has an open dumping station for collecting municipal solid waste. Many households in 2010 did not receive any benefits from aquaculture activities. On the other hand, improved extensive farming in Bang La can provide higher benefits than extensive farming in Trang Cat despite a higher investment in shrimp farming (Dat and Yoshino 2013).

Shrimp pond area is one of the main driving forces leading to the loss and degradation of mangroves. Local people in Trang Cat made their own shrimp ponds. Shrimp and sea crab ponds are located outside the dykes system and close to the sea or river mouths where mangroves are found. Mangrove areas were converted to shrimp aquaculture by local people. In contrast, the tiny shrimp ponds in Bang La were converted mainly from salt ponds.

According to the interview with local people in Bang

La, their shrimp ponds were converted from salt ponds during the period 1998−2003. Moreover, some areas remained fallow since all the salt ponds could not be converted to shrimp aquaculture and salt processing was not able to provide enough income for local livelihoods.

Our research showed that during the year 2010, there were significant differences in terms of average income per month and its sources between the two communes. In Trang Cat commune, Hai An district, the average money income in 2010 was about 6.3 million VND while this figure was approximately 3.4 million VND in Bang La commune, Do Son district. In addition, the maximum monthly income in the former commune was two times and a half higher than that of the latter commune. These numbers represent considerable differences among the rich, the middle, and the poor classes between the two communes.

Moreover, the main income source from aquaculture activities accounts for over 77 % of the total in Trang Cat. This figure was nearly twice of that in Bang La. Nevertheless, agricultural activities play a rather important role in Bang La with 24.4 % while in Trang Cat these activities did not provide any household income. According to the interviews with local people in Trang Cat, spinach cultivation was undertaken; however, this spinach was only for their consumption. Noticeably, in Bang La many people work as hired labour. The people, who worked as hired labour in Trang Cat, on the other hand, were mainly poor people since they could not borrow money from the banks to undertake aquaculture (Fig. 3).

The average agricultural area for cultivating tomato *Lycopersicon esculentum* and jujube *Ziziphus mauritiana* in Trang Cat commune is approximately 565 m^2 and in Bang La commune is 1600 m^2. Paddy rice cultivation (average area of 0.13 ha) was undertaken previously in Trang Cat; however this area became fallow when the water for paddy fields became salty and polluted.

Our survey indicated that agricultural activity brings

Trang Cat
N=34

5.3%
17.5%
77.2%

Bang La
N=36

29.2%
40.3%
6.1%
24.4%

□ Aquaculture

⊠ Agricultural activities
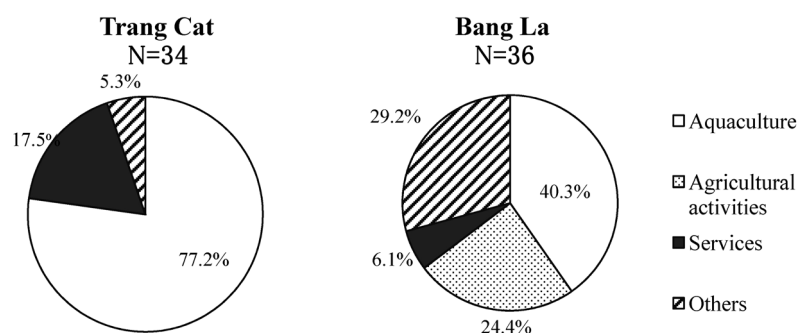
■ Services

▨ Others

Fig. 3. Sources of household income in the two communes in 2010 (%).

high benefits for local people in Bang La commune, Do Son district due to low investment and high productivity. According to the in-depth interview with households in Bang La, this has become the main agricultural activity since aquaculture deteriorated due to the water quality problem. In addition, comparing the net benefits between aquaculture and agricultural activities, the net benefit per hectare of agricultural cultivation is higher than those of aquaculture. However, the average area for planting jujube and tomato in each household is small just about 0.16 hectares. Thus, the total benefit each household receives from cultivation is not enough to guarantee their livelihoods.

According to the interview with headmen of the People's committee and farmer associations, in recent years many households could not receive any benefit from aquaculture in Bang La commune. Only a few households with sufficient experience in terms of shrimp and sea crab feeding are able to get benefits. Some people in Bang La have to work as hired labour in order to guarantee their livelihood.

Mangrove conservation and management

There were different types of management systems for mangrove forest in Hai Phong City. Some coastal districts including Do Son and Kien Thuy (Fig. 1) established community-based forest management after mangrove plantation programs took place. In two coastal districts, according to the interview with chairpersons of the People Committees, they also have guard teams who were responsible for taking care of mangrove forests. Every year, the groups received support funds from the central government of about 10,000 VND per hectare. In Bang La commune, Do Son district, the Japanese Red Cross constructed a house for the security group. On the other hand, in other

coastal districts such as Trang Cat, half of interviewed families said that mangrove forest has been managed by themselves and many households do not know who is responsible for mangrove management (Fig. 4).

There was a different response between local people at the two communes regarding the role of mangrove forest management systems. In Bang La, interviewed families responded positively about the roles of mangrove forests managed by community-based forest with local authorities. Mangrove forests play an important role to guarantee their livelihood and to defend against tropical cyclones. According to the interview with key informants, in Bang La their commune has been well protected from tropical cyclones. In 2005, for instance, three big storms hit the Northern coast of Vietnam (Neumann et al. 2015); there was no damage in settlement areas. On the other hand, due to the destruction of mangrove in Trang Cat, when the typhoons hit in 2005, all shrimp ponds area were devastated and many owners of shrimp aquaculture farms fell deeply in debt; they had to borrow money from the bank to re-start their aquaculture activities. Thus, our findings may conclude that mangrove rehabilitation programs in Bang La have been successfully managed by community-based forest management in cooperation with local authorities. Nevertheless, the mangrove deforestation by shrimp conversion is recorded clearly in Trang Cat and this commune should replant mangrove trees in abandoned shrimp ponds and follow the mangrove management system practiced in Bang La.

Recommendation towards sustainable mangrove conservation

Based on our findings, it is clear that the conversion of mangrove areas to shrimp aquaculture, mainly tiger prawn (*Penaeus monodon*) has occurred in coastal districts in Hai Phong, particularly in Trang Cat commune. In order to control the expansion of shrimp aquaculture in mangrove forests in Hai Phong and manage sustainable mangrove conservation, it is necessary to establish policy and man-
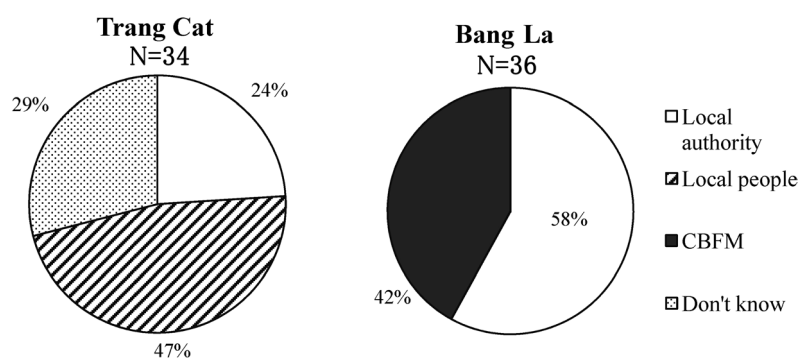

Fig. 4. Mangrove forest management systems in Hai Phong from 2001 to 2010.

agement practices in line with the co-existence of mangroves with shrimp farming (Vannucci 2004).

According to the key informant interview with chairpersons of farmer association in coastal communes, their experience showed that the ratio of mangrove coverage to extensive and improved-extensive shrimp ponds should be 7:3 to ensure mangroves well grow and can provide food for feeding shrimp and crab. Another potential action could be development of eco-tourism which follows the suggestion of UNESCO. A typical successful case can be found in the Southern part of Vietnam in Can Gio mangrove biosphere reserve which was adopted by UNESCO in 2003 (Tuan, Oanh et al. 2002).

We propose a number of recommendations for sustainable mangrove conservation as follows:

1. Issuing land use certificates (*Red Book*) to households who are involved in aquaculture and fishery activities following proper policy (UNEP 2008). The central government should take it into consideration to make local people felt secure about their aquaculture activities coexistence with mangrove protection plan.

2. Community-based forest management needs to be extended (UNEP 2008) to all coastal districts and follow the practices of successful operations such as in Bang La commune, Do Son district. The community mangrove forests should be co-managed by the government and the local community. An effective co-management strategy is required for the active involvement of coastal community organizations and will allow the representatives of such organizations to have the right to make decisions in terms of management plans and regulation needed in the use of mangrove resources (Edward and Suthawan 2004). In Bang La, the co-management between community-based mangrove forest management and local authority is a typical example of successful implementation.

3. Development of conservation and economic zones

Economic analysis, based solely on economic returns from shrimp culture showed that farming systems with a mangrove coverage of 30–50% of the pond area gave the highest annual economic returns (Binh et al. 1997). According to Binh, this is a better economic return for farmers who maintain mangroves in their farming systems. Expansion of shrimp aquaculture without permission from the central government has to be prohibited. Mangroves should be replanted in the abandoned shrimp ponds. The remaining mangrove area should be designated as the conservation and economic zones. Moreover, community-based forest management should be established in both the economic and conservation zones (Barbier and Cox 2004) in other coastal districts in Hai Phong beside the successful cases in

Bang La.

4. Mangrove conservation management from central, provincial to district and commune levels

At the central level, the Ministry of Agriculture and Rural Development is directly responsible for forest resources in general and mangroves in particular (MARD 2009). The Ministry has two specialized departments: Forestry Department and Forest Protection Department. The Forestry Department has the function of governing the forestry sector throughout the country (FIPI 2006). The Forestry Department is authorized to implement the tasks of governing forestry matters on forestation, forest resource development and forestry resource exploitation (MARD, Decision No 91/2003/QD - BNN). The Forest Protection Department executes state management functions of forest resource protection, implements legal acts on forest management, protection and forestry product management throughout the country (MARD, Decision No 92/2003/QD - BN) (MARD 2009).

At a provincial level, the Department of Agriculture and Rural Development (DARD) and Forestry Sub-department and Forest Protection Sub-department are responsible for forest resources including mangrove forests under DARD. National Parks on Mangroves and Nature Reserves, Species/Habitat Reserves, Protection Mangrove Areas have established their own Management Boards.

At district and commune levels, forestry rangers under the District People's Committee and Commune People's Committee are in charge of forest management and protection. For instance, the locality with the most effective and closest organizational structure for mangrove management is Can Gio district (Ho Chi Minh city). The consideration and foresight of the city leadership, the Department of Agriculture and Rural Development (DARD) and authorities at grassroots, level worked to make the management of mangroves in Can Gio is highly effective as shown in Figure 5. In addition, in Can Gio each household was allocated with 80–100 ha of mangroves for protection. In fact, mangrove forests could gradually help numerous poor households to save capital for shrimp and crab farming along the forest edge or rearing of fishes, pigs, and chicken. By 2005, there were about 167 local households protecting 14,198 ha of planted and natural mangrove forests. The remaining forests were assigned to different forestry units belonging to the Forest Protection Sub-department for protection (Tuan 2006).

Finally, the government has to provide technical, educational and financial support for local community organizations joining in management activities for mangrove forest (Barbier and Cox 2004).The case study in
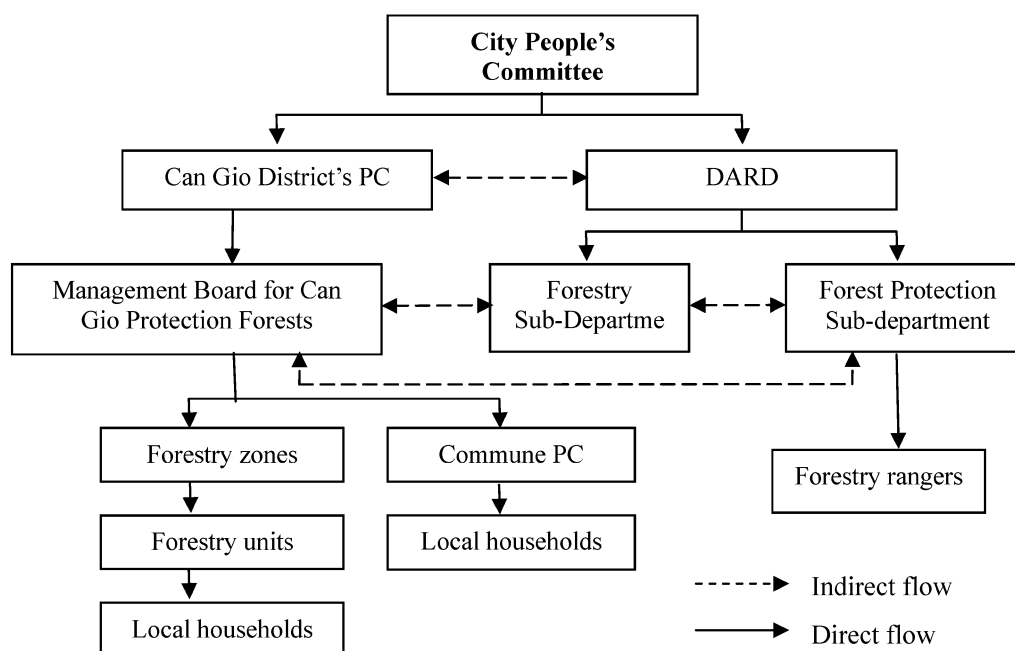
Fig. 5. Mangrove management system in Can Gio district, Ho Chi Minh city.

Hai Phong illustrated that the support funds from the central government for local community organizations such as the guard groups need to be taken into consideration. Up to now, the guard teams at these two coastal districts including Do Son received small support funds from the central government. The amount of money received as salary is not enough to support each member of the guard group. Therefore, the central government has to reconsider the current situation in Hai Phong. The guard team at Can Gio mangrove biosphere reserve has a salary five times higher than the team at Hai Phong. Their salary increased significantly from 185,000 VND to 316,000 VND; and then the figure reached 445,000 VND per hectare in 2006 (Tuan 2006).

CONCLUSION

A logistic regression model and field survey data were used to determine the driving forces of mangrove change. The results indicate that the main driving force of mangrove loss in Hai Phong is over expansion of shrimp aquaculture. Trang Cat commune in Hai An district is a typical example where the average size of shrimp ponds, was approximately 12.81 ha. This number is over 53 times higher than that in Bang La, where shrimp ponds were mainly converted from salt ponds. Expansion of shrimp aquaculture in Hai An district without permission from the central government has to be prohibited.

Mangrove plantation programs funded mainly by Japanese organizations can help the poor and guarantee their lives in Bang La. Mangrove rehabilitation programs in Bang La have been successfully managed thanks to community-based forest with local authorities whilst mangrove deforestation by shrimp pond conversion is recorded clearly in Trang Cat. This commune needs to replant mangrove trees in abandoned shrimp ponds and follow the mangrove management practiced in Bang La.

The government has to provide technical, educational and financial support for local community organizations joining in mangrove forest management activities. The central government has to consider the current situation in Hai Phong and should pay more attention to support funds from the central government for local community organizations such as the guard groups.

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