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Landscape ecological planning based on change analysis: A case study of mangrove restoration in Phu Long - Gia Luan area, Cat Ba Archipelago

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Abstract. Mangroves play an important role in coastal zones in many aspects e.g. extremely essential habitats for many species, coastlines protection from natural hazards, and so on. However, in Vietnam, like in other developing countries, these mangrove areas have been destroyed and encroached as a consequence of a poorly planned economic development.

The study has been conducted in Phu Long - Gia Luan region, which have the largest mangrove area in the Cat Ba Archipelago Biosphere Reserve, Hai Phong City, Vietnam. The aims of the study are to investigate existing land use conditions, land use changes, as well as driving forces and directions for the changes in order to build a case model of sustainable development; and integrate a mangrove conservation planning into the General Socio - Economic Development Planning Project of Hai Phong City for the period of 2010-2020.

The article presents results obtained from study in the period of 2007-2008 in Phu Long - Gia Luan area, including (a) Mangrove area decreased by 98.9 hectares from 1994 (792.3 hectares) to 2006 (693.4 hectares), in which the largest lost is observed in Phu Long southern region, meanwhile Gia Luan region is less changed; (b) There are 12 species belonging to 10 families and two ecological succession series in these mangroves; (c) Planning the area based on principles of landscape ecology for the priority purposes of mangrove restoration up to 2020 so that a mangrove area restored is equal to the area in 1994. The study area is divided into four functional subdivisions: active use subdivision, ecological restoration subdivision, stable use subdivision, and protective subdivision. The value of restored mangrove in Phu Long - Gia Luan is estimated 15,908.45 USD per hectare for shrimp farms through an environment impact assessment and cost-benefit analysis.

Keywords: Landscape ecological planning; Mangrove restoration; Ecological succession; Functional subdivision; Remote sensing; GIS; Cost-benefit analysis.

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1. Introduction

Mangroves are ecologically important coastal ecosystems, currently cover 146,530 km of the tropical shorelines of the world. This represents a decline from 198,000 km of mangroves in 1980, and 157,630 km in 1990. These losses represent about 2% per year between 1980 and 1990, and 1% per year between 1990 and 2000 [6]. Vietnam has favorable conditions for mangrove development, such as estuaries and inlets long coastline of approximately 3260 km in length, large river systems rich in alluvia and tropical and monsoon climate. However, many mangrove areas have been destroyed to practice aquaculture, especially shrimp rearing over the last years [10]. The consequence is that both ecological services which are provided for local people by these ecosystems and ecological functions are adversely impacted.

The selected study area is the Phu Long - Gia Luan tract belonging to the Cam - Bach Dang estuary, Hai Phong City, which is a northern province of Vietnam (Fig. 1). This area has the largest mangrove area in Cat Ba Archipelago Biosphere Reserve. Hence, it was chosen as a case model of sustainable development. Mangrove reservation planning was integrated into the General Socio - Economic Development Planning Project of Hai Phong City for the period of 2010-2020. This problem arises from that along with the development of aquaculture, shrimp farms have been enlarged and as a consequence, mangrove areas have been destroyed, especially from the beginning of Doi Moi period (1986) up to now. That is a challenge of sustainable development in this area.

Restoration of areas of damaged or destroyed mangroves has been previously discussed. The discussions were about using of system dynamics modeling in design of an environmental restoration banking institution [1], functionality of restored mangroves [2], rehabilitation of mangrove ecosystems [3], ecological engineering for successful management and restoration of mangroves [6], analysis of factors influencing community participation in mangroves restoration [8]. In Phu Long - Gia Luan region in particular, some studies have been conducted, such as studying structure, distribution and succession on mangrove ecosystems in Phu Long area [4]; research on managing the coastal area resources and estimating environmental economic values for mangrove areas [9]. However, there still is a few of studies in this area conducted based on the landscape ecological fundamentals in general. Remarkably, mechanism of primary and secondary ecological succession of mangroves was showed but it is for the Northern - East coastal regional scale and not specific for the selected area [4]. Therefore, this article deals with the supports of remote sensing technology integrated in landscape ecological fundamentals to study specifically on restoring mangrove ecosystems in Phu Long - Gia Luan area.

Fig. 1. The selected area in Cat Ba Archipelago

2. Research methods and applied principles of mangrove restoration

2.1. Research methods

The selected research methods for this study are the followings:

- *Field survey methods:* Investigating 20 quadrates with 10mx10m size per one. The

TOA rapid water quality assessment machine was used to analyze 43 water samples for 6 criteria (dissolved oxygen, salinity, pH, conductivity, turbidity, temperature).

- *Social investigation method:* In March 2008, we conducted 30 household surveys to obtain information on aquaculture development patterns and mangrove management practices. Additionally, we conducted interviews with regional planners in Hai Phong, Cat Ba Archipelago Biosphere Reserve officials, and leaders of Phu Long, Gia Luan communes at multiple administrative levels.

- *Remote sensing and GIS method:* Main data used are topographical map 1:25,000 (edited in 2006) and satellite images (SPOT3 in 1994 and SPOT5 in 2006). All satellite images were rectified, geo-referenced and processed by using ENVI (the Environment for Visualizing Images) software version 4.1 and then these images were interpreted manually based on the platform. These satellite images are rectified by Nearest Neighbor Method (Select GSPs: Image to Map) and classified by Supervised Classification allowing to classify the images based on sample pixels which are identified by analyzers. Finally, the satellite images are used for mapping existing mangroves in 1994 and 2006 years and mangrove changes in this period by using ArcGIS 9.1 software (Fig. 1).

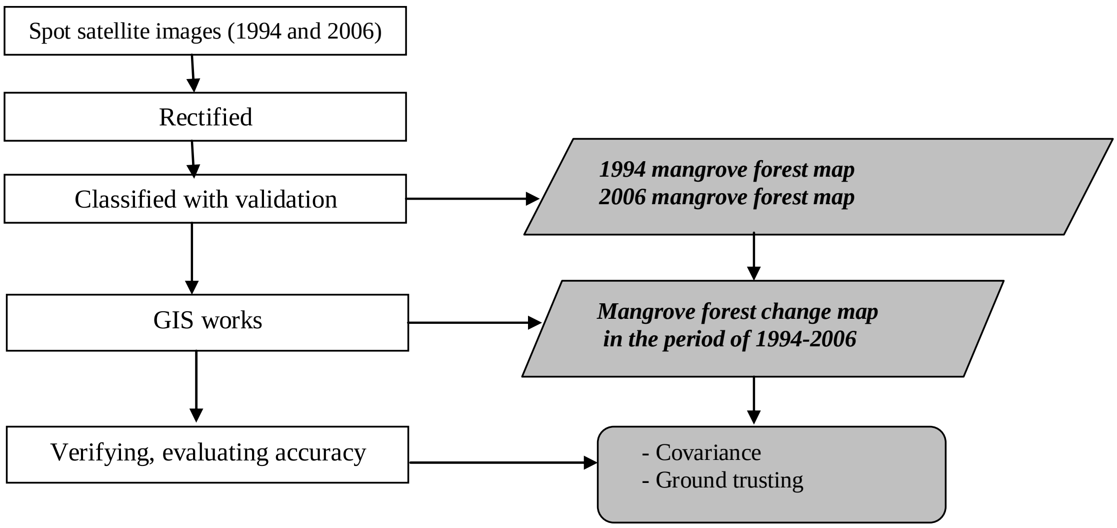

Fig. 2. The workflow for establishing mangrove change map in Phu Long - Gia Luan area for the period of 1994-2006.

2.2. Applied principles of mangrove restoration

The term “restoration” has been adopted here to specifically mean any process that aims to return a system to a pre-existing condition (whether or not this was pristine), and includes “natural restoration” or “recovery” following basic principles of secondary ecological succession. Secondary ecological succession depends upon mangrove propagule availability as “propagule limitation” to describe situations in which mangrove propagules may be limited in natural availability due to removal of mangroves by development, or hydrologic restrictions or blockages (i.e. dikes) which prevent natural waterborne transport of mangrove propagules to a restoration site [6]. Such situations have been described for the U.S. Virgin Islands, a mangrove restoration site in the Mahanadi Delta, Orissa, India, and similar efforts at Can Gio, Vietnam. In addition, the Society for Ecological Restoration (SER, 2002) has defined “ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed", and "the goal of this process is to emulate the structure, functioning, diversity and dynamics of the specified ecosystem using reference ecosystems as models" [11]. However, some others authors think that mangrove may recover without active restoration efforts. Bosire et al. [2] proposed a ten steps scheme presenting possible mangrove restoration pathways depending on site conditions.

With this understanding, a conceptual framework was proposed based on restoration principles in study area, including understanding mangrove ecosystems, involving community ecology of mangrove species (step 1), baseline environmental factors (step 2) and ecological succession of mangrove ecosystem (step 3). Then, using remote sensing and GIS method to analyze the existing and change area of mangrove ecosystem (step 4). As a consequence, a landscape ecological planning is proposed according to the priority purpose of mangrove restoration up to 2020 year (step 5). After assessment of success based on cost-benefit analysis (step 6), when the assessment has a positive outcome the site should be restored, although further monitoring of the restored site can be undertaken as necessary (Fig.3).

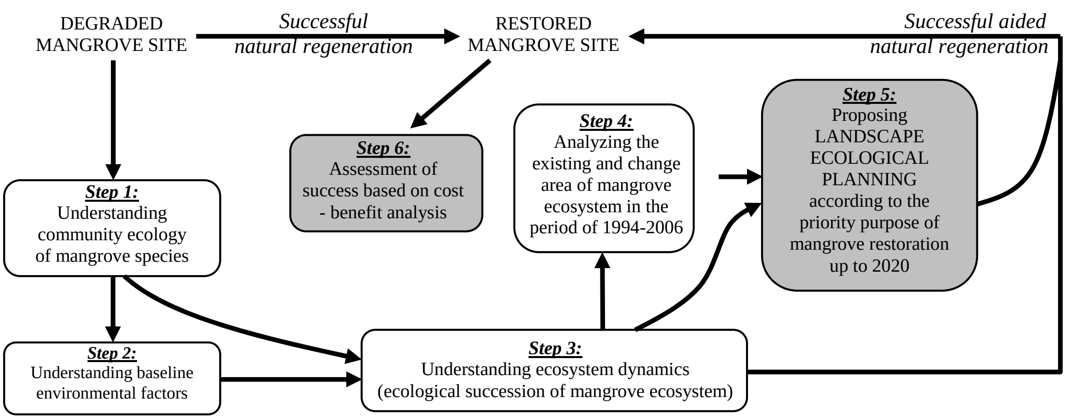

Fig. 3. The conceptual framework on mangrove restoration studying in Phu Long - Gia Luan area.

3. Research results

3.1. Characteristics of mangrove ecosystems

a) Baseline environmental factors

- *Geomorphic conditions:* geomorphic structure of the study area is divided into following types: beach type with 2.5m to 3.5m height above sea level distributed to the south of Phu Long Commune; high-tidal plat type with height over 1.86m distributed to Cai Vieng 1, Cai Vieng 2 marshland and Hai village; low-tidal plat type with height from 0m to 1.86m distributed to Bai Giai 1 and Bai Giai 2.

- *Hydro-meteorological conditions:* the study area has rainfall of 1,600-2,000 mm/year and mean temperature of 23.5^{0}C. In NE monsoon during October - April, the average speed of wind is 3-4m/s and NE and N wind directions which are parallel to the coast reach a frequency of 70-80% from December to January. In SW monsoon during May - September, the average wind speed is from 4 to 5m/s with the prevailing wind of SE, S and E directions. Every year, this area is under the influence of 2-5 typhoons happening from June to September, generally with the wind speed reaching 45-50m/s. Some typhoons occurred in the spring tide combining with typhoon surge have destroyed the coast heavily. As a calculation, the surge range reaches 1m every 2 typhoons, 2m every 5 typhoons and maximum 3m. When the typhoon surge falling in spring tide, the sea level can rise up 5-6m and very strong wave can break out sea dikes and make a deep coastal deformation. The diurnal tide is nearly regular with the maximum range of 3.5-4m. The tide current is 20-30cm/s in average speed, maximum 60cm/s for ebb tide and 50cm/s for flood tide. The coastal circulation is 25-30cm/s and SW ward in dry season, and 15-20cm/s and NE ward in rainy season. The prevailing wave directions are NE and E in winter and SE and E in summer. The mean wave height is 0.88m, maximum 2m during NE wind season and 5m during typhoons. In the NE part of RRE, the sea level rise at rate of 2.24mm/year was measured.

- *Water quality:* results of using TOA rapid water quality assessment machine to analyze the water environmental quality show that it reaches high value of salinity (2.5-3.3$^{o}/_{oo}$) and turbidity (12-86mg/l); BOD_5 value approximately 0.83-1.4 mg/l, average value about 0.97 mg/l; DO value approximately 0.88-2.35 mg/l (Table 1).

Table 1. Analysis of environmental quality of water in the study area

No	pH	DO (mg/l)	Conductivity (S/m)	Turbidity (mg/l)	Temperature (^{0}C)	Salinity ($^{o}/_{oo}$)
1	6.50	1.27	4.79	30	24.8	2.99
2	7.70	1.02	5.01	14	26.3	3.15
3	7.80	1.04	5.01	10	25.5	3.16
4	7.70	0.88	5.12	13	29.5	3.24
5	7.70	0.96	5.07	13	27.8	3.19
6	8.27	1.08	5.03	22	25.6	3.16
7	7.25	0.98	0.93	17	25.7	0.50
8	8.30	0.95	3.19	24	25.9	1.92
9	7.95	1.02	3.85	19	25.4	2.32
10	7.96	1.02	4.92	12	24.8	3.08
11	8.04	1.10	5.10	86	23.4	3.20
12	7.70	2.18	1.17	15	20.4	0.64
13	7.18	1.75	5.18	5	19.9	3.27
14	3.45	1.81	1.90	10	20.6	1.08
15	5.30	1.85	4.54	32	20.2	2.82
16	3.20	1.90	4.27	18	19.6	2.70
17	7.65	2.35	4.03	17	20.6	2.17

Sample survey position and its description: (1) Sea water in the upper tidal basin; (2) Water discharged from shrimp pools; (3) Shrimp pools at the discharged wastewater point; (4) Shrimp pools with some plants; (5) Central point of the shrimp pools; (6) Primary mangrove; (7) Ang Coi; (8) Gracilaria cultivation pools; (9) Mangrove with gracilaria cultivation; (10) New pools near sand bars; (11) Sea water in the lower tidal basin; (12) Unused land with some grasses; (13) Intensive cultivation shrimp pools; (14) Grass pools (No mangrove trees); (15) Shrimp pools with some mangrove plants; (16) Wastewater; (17) Rivulet.

b) Mangrove communities

In Vietnam, there are 106 mangrove species, including 36 true mangrove species and 70 associate mangrove species [4]. In the study area, environmental factors determine the extent and distribution of mangroves. The results of this study have shown that in the Phu Long - Gia Luan area, there are 12 species belonging to 10 families including Pteridaceae (Polypodiophyta), Acanthaceae, Asteraceae, Avicenniaceae, Combretaceae, Euphorbiaceae, Myrsinaceae, Rhizophoraceae, Sterculiaceae and Verbenaceae (Table 2).

Table 2. Mangrove plant species in Phu Long - Gia Luan area (surveyed in March, 2008)

N°	Scientific name	N°	Scientific name
	Polypodiophyta		Euphorbiaceae
	Pteridaceae	6	*Excoecaria agallocha* L.
1	*Acrostichum aureum* L.		Myrsinaceae
	Magnoliophyta	7	*Aegiceras corniculatum* (L.) Blannco.
	Acanthaceae		Rhizophoraceae
2	*Acanthus ilicifolius* L.	8	*Bruguiera gymnorhiza* (L.) Lam
	Asteraceae	9	*Kandelia candel* (L.) Druce.
3	*Pluchea indica* (L.) Less.	10	*Rhizophora stylosa* Griff.
	Avicenniaceae		Sterculiaceae
4	*Avicennia marina* (Forsk). Vierh.	11	*Heritiera littoralis* Dry.
	Combretaceae		Verbenaceae
5	*Lumnitzera racemora* Willd	12	*Clerodendron inerme* (L.) Gaertn.

c) Ecological succession of mangrove ecosystem

There are 2 ecological succession series determined in the study area:

(i) Primary ecological succession: it is an initial colonization of land that has never been colonized before. One of prominent characteristics of mangrove swamps is the belt distribution phenomenon of dominant plant species. And it is somewhat parallel with coastlines. This phenomenon is clearly seen in the areas where the sedimetation process occurs strongly and rapidly. The primary succession characterizing mangrove ecosystems in Phu Long - Gia Luan area takes place and it could be divided into four phases as follows [4]:

- *Initial/vanguard phase (phase 1): Avicennia marina* will appear on places which are higher than the sea water surface at the average low tide. In these areas, the soil is slime mud mixed with sand and sprouts of *Avicennia marina* which are taken by tides from swamps situated there. Due to the characteristics of *Avicennia marina* such as high salinity adaptation, deeply sinked suffering, and high light intensity, they can grow well. Therefore, after a short time, in the mud areas the light-like thin forest patches appear. However, it is not always that *Avicennia marina* will appear as a pioneer. In some places, *Aegiceras corniculatum* will firstly appear. Its stems are capable of shooting roots after the period of living as floatings in the water. As they have fixed in the slime mud areas, they will exist and grow well as a result of the development of their root system. *Aegiceras corniculatum* can suffer a wide salinity range and it can survive in high salinity because of salty adjustment through secernent glands in its leaves. However, in the sea water environment, such mollusca as shipworm or teredo are harmful to its development and growth.

- *Mixed phase (phase 2):* initial communities play an important role in keeping soil. This makes slime mud areas gradually raise. Regularly tidal inundation time in the day will be shorter and mud becomes tighter due to clay mineral and limonite supplement. The stems of *Kandelia candel* are brought to these areas and kept by *Avicennia marina* or *Aegiceras corniculatum*. When they meet suitable living environmental conditions such as soil, wind and wave prevention, as well as limitation on winter adverse impacts of pioneer species. They will develop and grow in the communities of *Avicennia marina* or *Aegiceras corniculatum.* Gradually, they are such a good growth that most of *Avicennia marina* or *Aegiceras corniculatum* are unable to competing about the light and nutrient sources. There is a few of *Avicennia marina* or *Aegiceras corniculatum* surviving. However, the seeds and sprouts of

Avicennia marina or *Aegiceras corniculatum* will be brought to new slime mud areas and new circles will be formed. In the areas, *Aegiceras corniculatum* species exists. Thank to better dark suffering ability of them, it can live and exist under leaf canopy of other species. Hence, in this mixed stage, it is difficult to clearly realize which species are dominant ones. *Avicennia marina* is pioneer species, *Aegiceras corniculatum* always occupies the land near rivulets because they are able to suffer water inundation. *Kandelia candel* can live in low land while *Bruguiera gymnorhiza* distributes in higher land near banks. Soil in tidal basin continues to increase due to sedimentation of suspended solid and litter of mangroves. These materials will be decayed by bacteria and fungi to form a mud layer with rich humus and pyrites (Fe_2S) that is unsuitable for mangrove species.

- *Dominant Bruguiera gymnorhiza phase (phase 3)*: this phase takes place when tidal basin raises and becomes more stable because it only suffers the inundation of high tidal regime. The components of soil changed to become into limonite soil mixing with sand, clay and much organic matters as well as gravels. Then, the river bed gets more slope and the speed of flow is stronger, and the growth of mangrove species such as *Kandelia candel* and *Aegiceras corniculatum* will be slower. *Bruguiera gymnorhiza* is capable of suffering high darkness in the young stage, and its nutrient and respiratory roots are well developed. Therefore, it is a dominant species in competing nutrients and light. As a result, its growing and developing speed is higher than that of other species. Gradually, it will be more dominant than other species left. This leads to higher mortality of weak competing species due to the lack of light, oxygen, nutrients etc. *Bruguiera gymnorhiza* species soon occupies the whole upper tidal basin and pushes other species on places in the sea direction.

- *Final phase (phase 4):* this phase occurs complicatedly and depends on terrain conditions. In the upper tidal basin, it is increasing so much that sometimes only high tidal regime can reach. There is a few of *Bruguiera gymnorhiza* surviving, while almost of other species die because mud becomes hard and soil is rich of pyrites. This pyrites is gradually oxydated to become acid sulphate. A community of halophilic arbors and shrubs will not appear and encroach inundated areas. The component of this community is quite abundant with dominant species such as *Excoecaria agallocha*, *Clerodendron inerme*.

(ii) S<u>econdary ecological succession:</u> it is recolonization of areas after a disturbance such as a fire or when a large tree falls. Given the increasing disturbance of ecosystems by human activity, the concept of succession has dramatic implications for the future of the Earth as we wait to see how it will recover. The secondary ecological succession in different areas occurs complicatedly depending on the component and structure of communities as well as severity of human impacts. In the formerly mixed forests on the sandy mud soil before, when they are exhaustedly exploited many times, *Avicennia marina* will occupy the areas, exist sustainability and create a single dominant community with small arbors and shrubs.

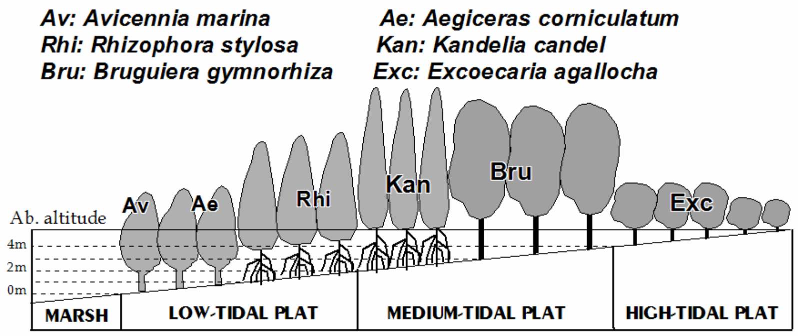

Fig. 4. Primary ecological succession of mangrove ecosystem in Phu Long - Gia Luan area (referred from Hong, 1991 [4]).

3.2. Mangrove change in the period of 1994-2006

Satellite imagery has a potential to provide information for assessment of the effect of environmental treaties. In Phu Long - Gia Luan area, the routine collection of imagery for most of Earth's surface by satellites provides an invaluable historical record covering more than a decade (from 1994 to 2006 year). The analysis result shows that there is a discrepancy between extents of the total areas officially listed as protected versus the area observed from the imageries. The study area is listed as 1,420 hectares or 14.2 km^2. By using the SPOT satellite imageries, the area of mangrove in Phu Long - Gia Luan is identified exactly 792.3 hectares in 1994 year and 693.4 hectare in 2006 year. Land use change area is 98.9 hectares. The largest lost of mangrove area is in Phu Long southern region while Gia Luan region has less change.

In 1986, the Vietnamese government promulgated the Doi Moi policy to increase national productivity, stimulate foreign direct investment and modernize the country's infrastructure. The reforms have led to an increase of agricultural expansion and intensification, with a focus on high value crops, export oriented commodities such as farmed shrimp. In less than one decade, large coastal sections of Phu Long - Gia Luan area have been converted into shrimp aquaculture ponds, leading to destruction of some significant sections of mangroves.

Aquaculture was introduced to the Phu Long - Gia Luan area in the early of 1980s. Prior to aquaculture, the area was exclusively mangrove forests, with a few farmers engaged in fishing activities. Aquaculture ponds were developed either by clear-cutting or selective clearing of mangroves followed by the construction of dykes and pond enclosures. Management styles vary across the ponds, with some farmers maintaining significant mangrove to cover while others prefer no mangroves. The land use history is corroborated by the SPOT satellite imageries (Fig. 5).

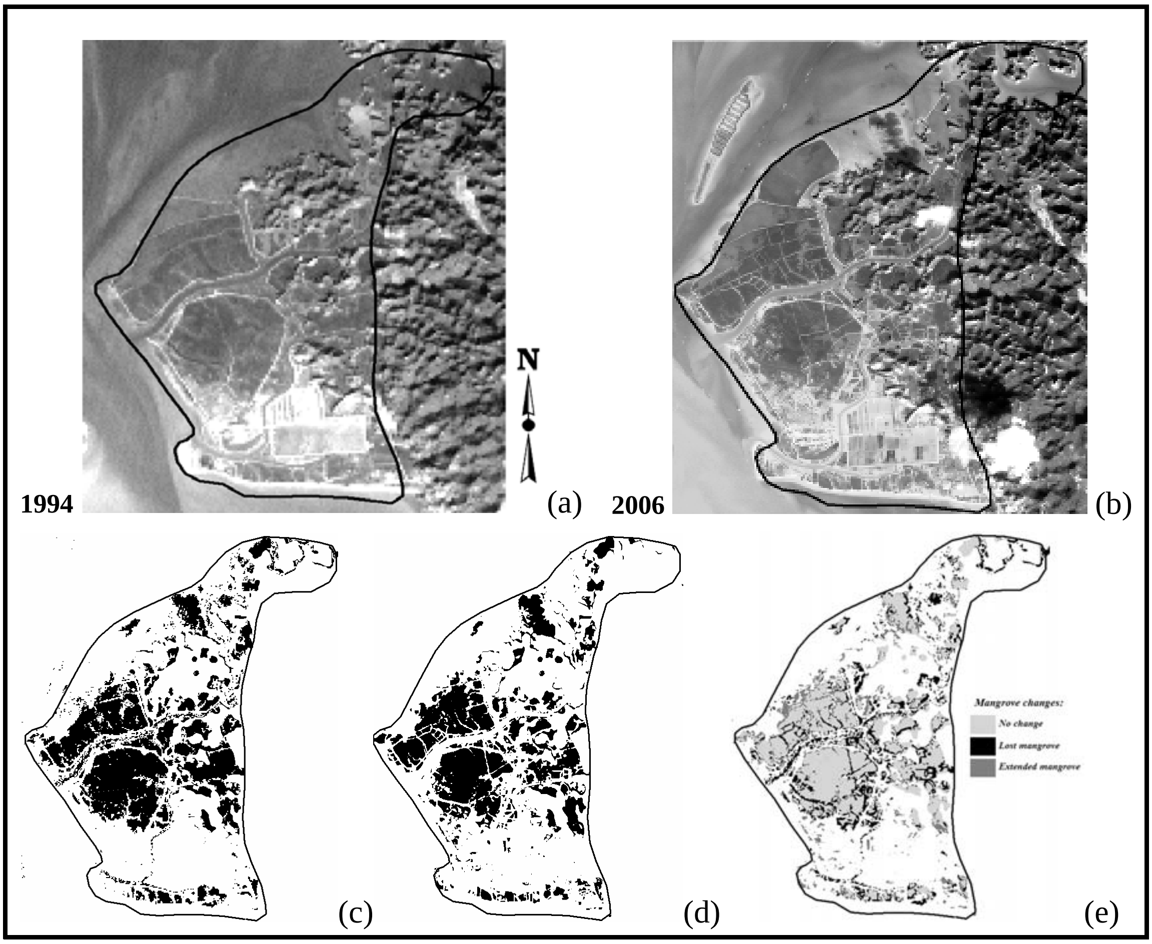

Fig. 5. SPOT satellite imageries of the Phu Long - Gia Luan tract in the years 1994, 2006 (a, b); maps of mangrove distribution in the years 1994, 2006 (c, d); and map of mangrove change in the period 1994-2006 (e).

In the earliest imagery, acquired in 1994, the region is completely absent of intensive cultivative shrimp ponds in Nam Village of Phu Long Commune. The region is dominated by dikes of Cai Vieng 1 and Cai Vieng 2 marshland, which separate the land from the mangroves. By 2006, the entire region was extensively farmed. So that, mangrove extent had strongly decreased in Hai Village and Cai Vieng 1 salt mash, but it had also increased in Cai Vieng 1 salt marsh and Bai Giai 1, 2 area. This phenomenon show that the mangrove ecosystem fragmentation is increased with shrimp pond development in the period of 1994-2006.

3.3. Proposing landscape ecological planning with primary purpose of mangrove restoration up to 2020

a) Functional subdivisions

The study area is divided into four functional subdivisions, including active use subdivision, ecological restoration subdivision, stable use subdivision, and protection subdivision (Fig. 6). According to this planning, the area of mangrove in 2020 will get as large as it was in 1994.

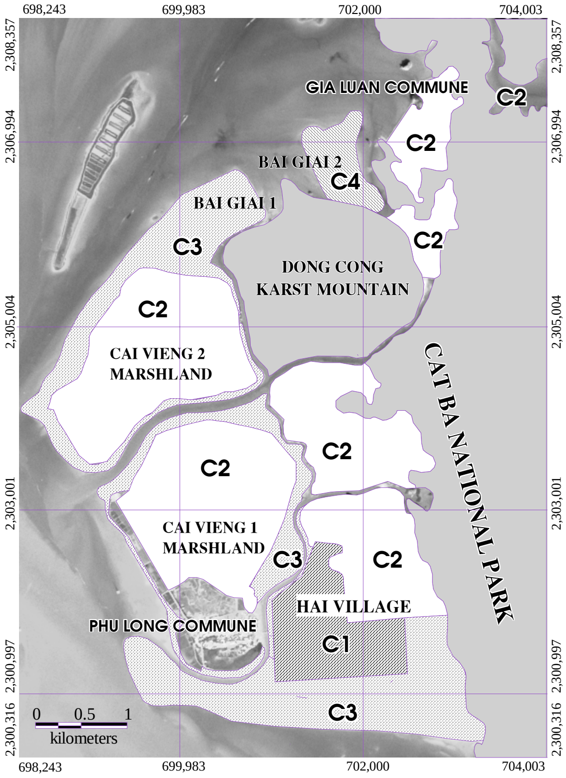

Fig. 6. Map of functional subdivisions in Phu Long - Gia Luan area (C1,…,C4 are the symbols of functional subdivisions).

- *Active use subdivision (C1):* consists of areas in the south of Phu Long Commune (390 hectare). In these areas, shrimp farms have been formed since 1990. From 2004, mangroves have been significantly reduced because of expansion of shrimp farms. The dominant species in the mangrove are *Aegiceras corniculatum*, *Acanthus ilicifolius* and *Kandelia candel* which are left scattered. However, these areas can be re-planned and restored by dividing it into smaller sub-area and increasing ditches to reduce water pollution as well as enhance improved shrimp culture activities to rise its productivity from 270 to 450 kg/ha. At the same time, it is necessary to pay attention to protect secondary forest patches in accordance with the ecological shrimp culture model which has been deployed in some coastal zones in the northern delta in Vietnam (e.g. Tien Hai, Giao Thuy Ramsar areas, etc.).

- *Sustainable use subdivision (C2*): including Cai Vieng 1, Cai Vieng 2 marshland and Hai Village, with total area of 685 ha. The dominant species of mangrove are *Bruguiera gymnorhiza*, *Avicennia marina*, *Aegiceras corniculatum* and *Kandelia candel*. In the past, almost all of mangrove species died leading to the low shrimp productivity. Shrimp farming owners need to change to culturing grabs, or cultivating gracilaria. At present, mangrove area gets more stable due to mangrove protection policies. Through this, the mangrove patches will be restored leading to the improvement of shrimp productivity.

- *Ecological restoration subdivision (C3):* has an area of approx 500 ha including areas outside of Cai Vieng 1, Cai Vieng 2 and in the south of Phu Long Commune with the species component of *Bruguiera gymnorhiza*, *Avicennia marina*, *Kandelia candel* and *Acrostichum aureum*. Currently, mangrove area is increasing because of reforestation. This subdivision should be prohibited from forming shrimp farms and used for low income communities to exploit aqua-products. Therefore, the rich people can form the farms but not in conflict with the low income communities as before. Also, the mangroves have been restored following two ways reforestation and natural succession.

- *Strictly protected subdivision (C4):* includes the whole Dong Cong limestone mountain and Bai Giai 2 area. This area has the function to protect the area from sand encroaching. At the same time, it provides offspring and nutrients for the active and sustainable use subdivisions as well as migrating birds. The species in the forest are *Bruguiera gymnorhiza*, *Avicennia marina* and *Kandelia candel*. This is a primary area which will be increasing thank to sedimentation of tidal basin. Two methods should be used are strictly protected forest area (Bai Giai 2) and reserve area (Dong Cong limestone mountain).

b) Cost-benefit analysis of restored mangrove

Cost-benefit analysis (CBA) is widely used in EIA reports for estimation of benefits and costs of a project on the environment. It is also called the extended benefit-cost analysis. According to proposed landscape ecological planning based on dividing into functional subdivisions, for the restored mangrove forests in Phu Long - Gia Luan area in particular and Hai Phong City in general, they are formed from two origins: natural and reforestation afforestation. The identification of the time for reforestation or afforestation is quite easy. Whereas the identification is quite difficult. To merge this deviation, both for the time of planted forests have been counted. It is a fact that the cost for resforestation is not so different with its afforestation. This method aims at assessing efficiency of projects or economic efficiency of restored mangrove vis a vis the environmental efficiency. That value is expressed by NPV (Net Present Value):

$$NPV = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \left[C_o - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \right]$$

where B_t: benefits of year t; C_t: costs of year t; C_o: initial costs; r: discounting ratio; t: time; n: life-time of the area.

On the view of point, approach, methods of resource economic estimation, the overall economic value of restored mangrove in the Phu Long - Gia Luan includes direct and indirect use values. Direct use values in terms of commodity output and services, such as timber, aquaculture, etc. (Table 3). Indirect use values with regards to erosive prevention, carbon accumulation, bank protection, tourism, etc. In addition, ecological functions, such as source, habitat, breeding, etc. has been concerned with. The overall value is approximately 15,908.45 USD per hectare (Table 4).

Table 3. Value of main aquatic product in mangrove marshland (per hectare)

N°	Aquatic product	Average productivity (kg)	Price (USD per kg)	Value (USD)
1	*Epinephelus sp.*	60	14.70	882.0
2	*Penaeus monodon*	80	7.06	564.8
3	*Scylla serrata*	100	8.82	882.0
4	*Metapenaeus ensis*	110	4.70	517.0
5	*Oreochromis niloticus*	230	1.17	269.1
6	*Lates calcarifer*	50	8.82	441.0
7	*Sparus latus*	20	2.94	45.8
8	*Butis butis*	50	2.94	147.0
9	*Mugil cephalus*	120	1.17	140.4
10	*Bostrichthys sinensis*	20	2.94	58.8

(Source: survey in March, 2008)

Table 4. Cost-benefit analysis of mangrove ecosystems (USD per hectare)

N°	Use	Direct value	Indirect value
	EXTRACTIVE USE		
1	Aquaculture	2405.88	
2	Timber	23.20	
	NON-EXTRACTIVE USE		
3	Bank protection		6211.76
4	Tsunami prevention		3399.52
5	Carbon accumulation		1462.21
6	Cultivation		2405.88
Net Present Value (NPV)			15,908.45 USD

Economically speaking the proposed mangrove restoration planning would be clearly viable. Future reforestation efforts may find this information useful in drumming up funding and resource support from donors, agencies and community members. However, in Phu Long - Gia Luan area, the mangrove expansion in the future will depend on whether the government agencies and local NGOs will be able to organize more communities to carry out such projects and whether community members will have equitable access to attendant benefits.

4. Conclusions and recommendation remarks

Based on the analysis of mangrove change in the study area, some conclusions and recommendation remarks are made as follows:

In Phu Long - Gia Luan area, people have exploited coastal areas, especially mangrove areas, for economic development. The main reason of mangrove loss is conversion of mangrove forests to shrimp ponds and a part of areas resulting from urbanization.

In order to maintain productivity and protect fishery resource and water quality, it is important to make surveys and research programs including compilation of detailed inventories of mangrove resources, impacts statement and more case studies on environmental management issues, on the risk of mangrove loss in the context of increasingly severe natural hazards. Together with aquaculture development, mangrove reforestation and development should be considered. The long term allocation of mangroves for protection and production aims together with mangroves conservation should be completed soon.

We suggest that the FRACTAL model and GRADIENT model can be applied to analyzing mangrove pattern and gradient of mangrove changes in the period of 1994-2006. Through those studies, scientific bases will hopefully be adequately satisfied to contribute to proposing a perfect mangrove restoration planning.

References

[1] S. Arquitt, R. Johnstone, Use of system dynamics modeling in design of an environmental restoration banking institution, *Ecological Economics* 65 (2008) 63-75.

[2] J.O. Bosire, F. Dahdouh-Guebas, M. Walton, B.I. Crona, R.R. Lewis III, C. Field, J.G. Kairo, N. Koedam, Functionality of restored mangroves: A review, *Aquatic Botany* 89 (2008) 251-259.

[3] C.D. Field, Rehabilitation of mangrove ecosystems: an overview, *Marine Pollution Bulletin* 37, No. 8-12 (1998) 383-392.

[4] P.N. Hong, *Mangrove vegetation of Vietnam*, Thesis of Doctor of Science in Biology, Hanoi University of Science, 1991 (in Vietnamese).

[5] C.S. Karen, M. Fragkias, Mangrove conversion and aquaculture development in Vietnam: A remote sensing-based approach for evaluating the Ramsar Convention on Wetlands, *Global Environmental Change* 17 (2007) 486.

[6] R. Roy, Lewis III, Ecological engineering for successful management and restoration of mangroves, *Ecological Engineering* 24 (2005) 403.

[7] M.T. Nhuan, N.H. Ninh et al., Overview of wetlands status in Vietnam, Conference *"Following 15 years of Ramsar Convention Implementation"*, Hanoi, 2003 (in Vietnamese).

[8] K. Stone, M. Bhat, R. Bhatta, A. Mathews, Factors influencing community participation in mangroves restoration: A contingent valuation analysis, *Ocean & Coastal Management* 51 (2008) 476.

[9] N.H. Tri, W.N. Adger, P.M. Kelly, Natural resource management in mitigating climate impacts: the example of mangrove restoration in Vietnam, *Global Environmental Change* 8, No. 1 (1998) 49.

[10] L.X. Tuan, Munekage Yukihiro, Q.T.Q. Dao, N.H. Tho, P.T.A. Dao, Environmental management in mangrove areas, *Environmental Informatics Archives* l (2003) 38.

[11] R.R. Twilley, H. Victor, Rivera-Monroy, R. Chen, L. Botero, Adapting an ecological mangrove model to simulate trajectories in restoration ecology, *Marine Pollution Bulletin* 37, No. 8-12 (1998) 404.

[12] B.B. Walters, Human ecological questions for tropical restoration: experiences from planting native upland tree and mangroves in the Philippines, *Forestry Ecology and Management* 99 (1997) 275.