

Ecosystem Assessment of Cuu Long River Delta Wetland, Vietnam

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ABSTRACT

The Cuu Long river Delta, covering majority of the downstream portion of the Mekong Delta, has four diverse wetland ecosystems in Dong Thap Muoi: coastal, inland, coastal estuarine and special wetland ecosystems. In the past decades, these ecosystems and their services (especially provisioning ecosystem) have been strongly exploited that resulted to its declining ability to meet increasing human demand for natural resources. Based on analysis of trends of change in ecosystems and their services, drivers of change in ecosystems and their services in the Cuu Long River Delta are rapid population growth, economic development pressure and management. Recommendation on management responses at macro-level for the whole region and at micro-level for provinces and environment and natural resource sectors were formulated based on the condition and trend assessment and driver analysis.

Key words: ecosystem, ecosystem services, wetland, Cuu Long river Delta, Millennium Ecosystem Assessment

INTRODUCTION

The Cuu Long river Delta is home to ecosystems most typical in the whole Mekong river basin because biodiversity of ecosystems is very high; this region is most affected both positively and negatively by tidal regime in the Mekong river; and it strongly interacts with sea. The exploitation of these ecosystems in the region in the last decades has led to dramatic changes in their services particularly in terms of declining biodiversity, reduction of forest area, change in habitats, and environmental pollution, among others. These are mainly caused by uncontrolled economic development, the local authority's undervaluation of the ecosystems' functions and values that lead to poor exploitation and management policies.

Many studies that evaluated the biodiversity of wetland ecosystems in the Cuu Long river Delta were carried out in the last 50 years. These studies focused on coastal wetland forest and inland wetland ecosystems. However, there was no comprehensive assessment covering all ecosystems and its contribution to human well-being in the Delta.

Using the Millennium Ecosystem Assessment (MA 2005) approach in ecosystem assessment, the project "Downstream Mekong river Delta wetland ecosystem assessment" of Vietnam – the sub-global ecosystem assessment (SGA) made an inventory of ecosystems and their biodiversity, assessment of condition and trends of change in ecosystems, and analysis of drivers of change in ecosystems in the past 15 years. The results of the assessment led to responses recommended for ecosystem management at macro scale for the whole Cuu Long river Delta and at micro scale for provinces and some departments working in environment and natural resources.

The aim of this study is to assess the wetland ecosystems in the Cuu Long river Delta and investigate changes in ecosystems and the causes of these changes; to suggest some suitable policies and ways to manage ecosystems for each sub-region in identified periods; and to establish a database for managing ecosystems and their services in effective and scientific way.

APPROACHES AND METHODS

The Millennium Ecosystem Assessment (MA) is an international process designed to meet needs of policy makers and the public for scientific information concerning the identification of consequences of ecosystem changes on human well being and responses to these changes. Within the conceptual framework for ecosystem assessment, the MA program has the following concepts (MA Board 2003):

- An ecosystem complex system of communities of species (human, animals, plants and microorganisms) and physical environment with the emphasis that the human being is a component of ecosystem.
- Ecosystems exist in different scales and providing various benefits referred to as ecosystem services.

Ecosystem services are divided into four groups: Provision services refer to products human gain from ecosystems such as food, raw materials, freshwater, gene resources, etc.; Regulating services benefit human through the regulatory processes of ecosystems including air and water purification, water and climate regulation, climate, erosion prevention, disease control, etc; Cultural services that are non-material benefits that help human improve their awareness and spirit and develop their knowledge, creation

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and aesthetic experience; and Supporting services that are necessary to produce all other services such as oxygen and land formation.

The MA framework places human well-being at the center of the assessment while recognizing the intrinsic values of biodiversity and ecosystems. This framework highlights the existing dynamic interactions between human and ecosystems and that changes in ecosystems would result to changes in human well-being. Thus, the assessment process pays special attention to interrelations between ecosystem services and human well-being (**Figure 1**).

Relationship between ecosystems and its services to well-being of specific groups is complex that vary across time and space. Unregulated human activities could lead to unexpected consequences that in turn are harmful to humans.

Provisioning function of ecosystems are goods and services to remain human well-being in different aspects. Human well-being will be badly affected or even destroyed if ecosystems do not provide enough foods, clean water, fiber, etc. for human.

Regulating function of ecosystems also affects human well-being in different ways. The impacts of the regulating function on human are seen in various processes such as air and water purification, water regulation, flooding and drought reduction, climate stabilization and disease control. The changes in this function of ecosystems have influences on human health and other factors of human well-being.

Ecosystems also have influence on human well-

being through their cultural services. Their functions and characteristics affect human activities such as education, aesthetics, culture, leisure activities, spirit of human, etc. The wealth of ecosystems in terms of landscape and habitat, among others to the improvement of the quality of human's life and spirit; and unwise management would result to negative changes in ecosystems such as pollution, degradation, etc.

For supporting services, due to their functions in terms of supporting the provision of other ecosystem services, they have indirect impacts to human well-being.

Humans well-being and sustainable development deeply depend on managing global ecosystems. However, increasing humans consumption of ecosystem services (such as foods, clean water, etc.) has led to the decline of the ability of ecosystems to provide their services to meet human demands. Sound policies and management are important to protect ecosystems from degradation and to strengthen their contribution to human well-being. Besides, good understanding of ecosystems and relevant systems in the society is important to identify when and how to intervene. Better communication may not directly mean that policies and decisions will be improved but it is critical designing to right policies and decisions.

The MA Framework uses a pioneering approach to ecosystems, Among the advantages of this framework include: it focuses on goods and services provided by ecosystems and how their changes affect humans well-being; it covers a comprehensive look at systems such as agriculture, mangrove forest, water and coastal areas that

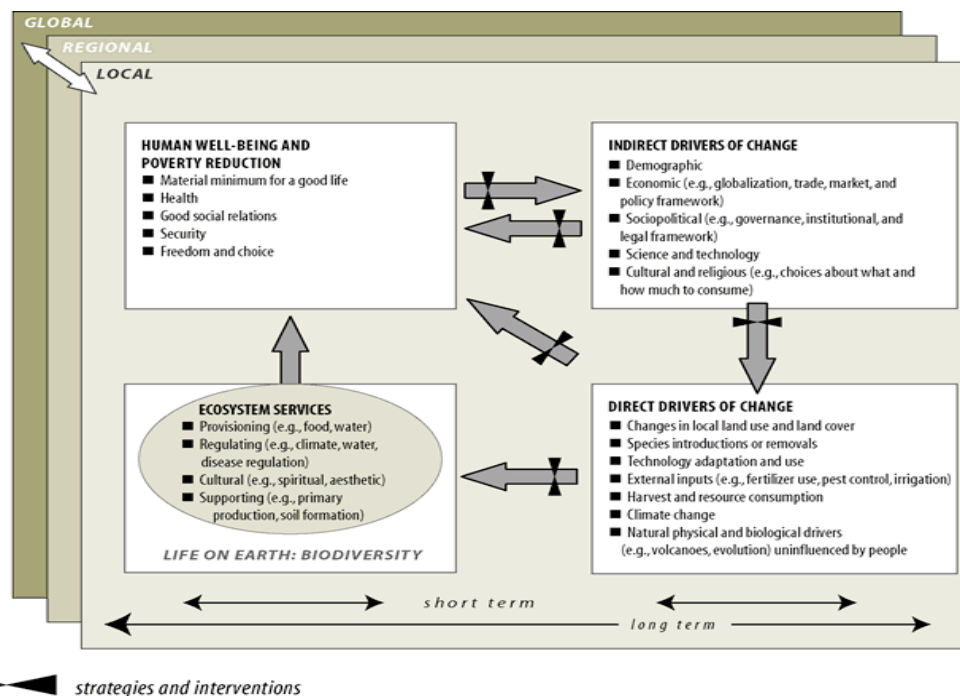


Figure 1. MA Conceptual Framework (MA Board, 2003).

were often assessed separately; it is a multi-scale approach that looks at both direct and indirect drivers that affect ecosystem's services; using interdisciplinary approach; it emphasizes on the consequences of change in ecosystems and the responses. (MA Board 2003).

Condition and trend assessment is used in the MA program and the sub-global ecosystem assessment of Vietnam employing the following approaches:

- Integrated assessment method. It includes multi-sectoral (agriculture, water, energy and environment) and interdisciplinary assessment that combine both natural and social sciences.
- Multi-scale assessment is the method that has active interaction with other assessment at global, regional and local scales.

In addition, some methods were also used for the sub-global ecosystem assessment of Vietnam.

- Field survey and fieldwork, sociological investigation in the study area to collect primary and secondary data.
- Statistical method and comparative analysis.
- Mapping method and GIS (Geographical Information System) to express assessment results and develop database.

Assessment tools include spatial analysis; GIS modules to assess spatial change in ecosystems and their services; and sets of indicators which are suitable for each specific region and scale to make it easy for users especially policy-makers to understand.

RESULTS AND DISCUSSION

The results of assessment of wetland ecosystems in the Cuu Long river Delta presented below were extracted from the synthesis report of the SGA of Vietnam (Thong *et al* 2005).

General Description of Cuu Long River Delta

The Cuu Long river Delta is the downstream part of the Mekong river within Vietnam (8°20' - 11°05' N and longitude 104°25' - 106°50' E), stretching from Long An to Ca Mau province. It is a rich-soil area of 39,000 km², covering 12 provinces of southwestern Vietnam and accounting for 12 % of the total area of Vietnam. The population of this region was 14.6 million people in 1990, 16.4 million in 1999 and has reached 17,330,000 in 2013.

It accounts for 79 % of the area of the Mekong Delta, which is 49,520 km² and stretches from Kratie of Cambodia to coastal provinces in southern Vietnam. The Cuu Long

river Delta is a flat land, except for some rocky mountains in Long Xuyen Quadrangle. The average elevation of the region is 0.8 m above sea level. In the eastern sea, tides occur semi-diurnally with amplitude of oscillation of 25.5 – 3.0 m while in the southern sea, tides occur daily with lower amplitude between 0.4 and 1.2 m. Intertidal zone has an area of 480,000 ha of where approximately 300,000 ha of which is suitable for growing salt-water, brackish water aquaculture. The total area of the inland wetland in the entire region is about 36,000 km², equal to 90 % of the inland area. Two-thirds of the wetland area has been used for agricultural production and aquaculture.

The wetland brings not only ecological and environmental benefits but is also critical for various socio-economic activities. Some portions of the wetlands are fertile and suitable for growing rice. Thus, the Cuu Long River Delta is considered as the "rice bowl" of Vietnam as it produces about 80 % of the volume of exported rice. In addition, for the past decades, Vietnam has been as one among the world's leading shrimp exporters of the world, some of which are produced in the area (Thong *et al.* 2005).

Condition and trend of change in ecosystems and services

Following the Millennium Ecosystem (MA) framework, variables such as biodiversity, areas and functions of different types of forests, agricultural products, fishing and aquaculture biomass, water volume and quality, environmental pollution and types of tourism, were used as key issues and indicators to look into in the case of Cuu Long River Delta.

Wetland ecosystems in the Cuu Long river Delta

There are four ecosystems in the area:

1. Coastal wetland ecosystem, covered mainly by mangroves distributed in coastal Ca Mau, Bac Lieu, Soc Trang, Tra Vinh and Ben Tre provinces. About 46 species belonging to the Rhizophora, the Avicennia, the Bruguiera, and Sonneratia. Before 1943, there were 250,000 ha of mangrove in the region. Due to the destruction during the war, locals' deforestation for timber extraction, and for rice and shrimp production, the mangrove forest area has declined significantly down to its current area of to 88,530 ha. By 2010, natural forest area in Cuu Long river Delta just over 100,000 ha (mainly in Ca Mau: 58 285 ha, Tra Vinh: 8,582 ha, Ben Tre: 7,153 ha, Bac Lieu: 4,142 ha, Soc Trang: 2,943 ha).
2. Inland wetland ecosystem, represented by Melaleuca forests in U Minh (located in Ca mau and Kien Giang) and Dong Thap Muoi (of Long An and Dong Thap provinces). Melaleuca ecosystem is both environmentally and commercially important. It provides habitat for many

wild animals, birds and fishes, etc. Before, the Melaleuca forests has an area of 200,000 ha, but it has decreased to 110,000 ha in 1983. Due to the strengthened afforestation in recent years, the area rebounded to 191,950 ha in 2001. Recently, mangrove deforestation has been rampant due to intensified aquaculture activities. In 2011 mangrove forest area remained about 176,000 ha (mainly in Long An: 64 293 ha, Kien Giang: 49,519 ha, Ca Mau: 38,832 ha, Dong Thap: 10,809 ha, Tien Giang: 8,019 ha). The current policy is to protect and use about 125,000 ha of mangrove forest generation of some products.

3. Coastal estuarine ecosystem is rich in biological resources. The regional aquatic communities are complex and include species from freshwater, brackish water and saline water (e.g: mangroves, water birds, shrimps, fishes, amphibians, reptiles, mammals, etc.).
4. Special ecosystem in Dong Thap Muoi. This ecosystem covers 700,000 ha, of which 370,000 ha is aluminous. This ecosystem is located in a low-lying area, thus it is flooded in rainy season (July to October). It is rich in biodiversity. Reports have listed the existence of 61 fish species in Vam Co Dong and 15 in Vam Co Tay. During flooding season, a lot of fishes and shrimps migrate into the area from upstream to reside and breed. In Dong Thap Muoi some water birds, including migratory species, recognized as rare species at the global level, could be found in the area. However, the ecosystems in Dong Thap Muoi have likewise been intensively used for rice production and fish/shrimp farming.

In addition, other bodies of water such as tidal flats, canals, arroyos, ponds, marshes, rice fields and peat swamps, etc., can also be found in Cuu Long river Delta. These ecosystems benefit locals and play important role in water regulation.

Biodiversity

A large number of different species of land and aquatic fauna and flora could also be found in Cuu Long River Delta. For fauna, there are 219 species of birds within 57 families, 75 species of insects, 32 species of reptiles and 42 species of amphibians. There are 50 fishes migrating into freshwater from both brackish and saline water which are beneficial to both fishing and farming. Water birds are the most abundant, reflecting the typical species composition of wetland ecosystems. There are nine plant species and 23 species of rare birds and animals, including 14 species of birds in danger of extinction.

High biodiversity is also found in aquatic communities, e. g: seaweed: 28 species of crustacean: 98 species of mollusk: 66 species of water larva and insects; and 27 families of fish, with 280 species. The diversity of habitats of the wetland in the Cuu Long river Delta is an important factor

contributing to creating abundant services of ecosystems.

Conservation

In the Cuu Long river Delta, five conservation areas have officially been established, including the Nature Reserve of Dat Mui of about 40,000 ha (of which the actually managed area is about 7,239); Vo Doi nature Reserve (which is the Melaleuca forests and seasonally flooded grasslands in the peaty swamps of U Minh-- covering an area of 3,724 ha); U Minh Thuong Nature Reserve of 22,918 ha of which the core area includes 8,468 ha (mature Melaleuca forest, seasonally flooded grassland and open swamp in Kien Giang); Tram Chim National Park (considered as the remaining part of the wetland ecosystem in Dong Thap Muoi and covering an area of 10,028 ha). There are also other areas with high potential to be declared as natural reserves in the future, such as the alluvial ground in Ca Mau (Bai Boi Ca Mau), Lung Ngoc Hoang of Can Tho, Tra Su of An Giang and Ha Tien Plain in Kien Giang (*Kim Son 2013*).

Exploitation of ecosystem services and trend of change

Current exploitation of ecosystem services

In the Cuu Long river Delta, ecosystems give locals a wide-array of important services contributing to improvement of their well-being. Due to unregulated exploitation of natural resources and insufficient management policies, local residents have contributed to significant changes and significant declines in ecosystems and their services. that in turn has reduced human well-being at present.

Provisioning services are seen as the most important benefits of ecosystems in the Cuu Long river Delta. Rice expansion has lead to changes in wetland habitats in the Delta. The rice area increased from 3.19 M ha in 1995 to 3.79 M ha in 2002. After 12 years, the rice production doubled compared to that in 1995, raising average food per capita to over 1,000 kg yr⁻¹. In 2011, rice field area has risen to more than 4 M ha with production reached 23 MT. However, due to increasing saltwater intrusion, about 2.5 M ha are threatened.

Aquaculture is the main ecosystem service of the Cuu Long river Delta. Area and production of aquaculture is constantly increasing over the past 18 years. (**Table 2**).

Species growing in the salt and brackish are *Penaeus monolon*; and *Litopenaeus vannamei* and *Pangasius hypophthalmus* in the freshwater region. In 2011, *P. monolon* covered 575,997 ha with production reaching to 280,600 t. *L. vannamei* shrimp production areas reached 15,727 ha with a production of 77,800 t while *P. hypophthalmus* occupied 5,140 ha with production of 1.1 MT. In the Cuu Long river Delta, shrimps are growth in many models such

Table 1. Wetland habitats in the Cuu Long River Delta.

Type	Habitat	Type	Habitat
Marine/coastal	coastal mudflat	River	perennial rivers and canals
	coastal aquaculture		floodplain grassland
	coastal mangrove plantation		floodplain paddy rice
	coastal paddy rice		floodplain other crops
	coastal non-tidal grassland		seasonally flooded Melaleuca plantation
Estuarine	estuarine mudflat	Lacustrine	permanent Melaleuca forest reservoir
	estuarine salt works	Palustrine	seasonally-flooded grassland
	estuarine aquaculture		seasonally flooded Melaleuca plantation
	estuarine mangrove plantation		seasonally flooded paddy rice field

as: Extensive, extensive improvements, industrial shrimp farming. Shrimp farming under the forest canopy is now considered sustainable model. Shrimp revenue from this model achieved 25 M VND ha crop⁻².

Area and output of fruit trees are increasing as wetland are converted and dams are constructed. In recent years, development of fruit trees has been popular in the Delta.

The area of fruit trees increased from 175,700 ha in 1995 to 211,400 ha in 2001, and reached 288,000 ha by 2013. The reclamation of wetlands into fruit tree lands has undertaken in following modes such as making beds to higher ground and constructing surrounding dams. Present rice fields are also expected to be converted into fruit tree lands.

Forests are decreasing in terms of area and quality, leading to the reduction of timber stock. Timber is mainly from Melaleuca forests and mangrove forests. Due to the large decrease in the forest area and their poor quality, its capacity to provide timber and wood is very limited. The timber stocks of recently planted forests are not significant. For 2007, Production of timber from the forests reached 604,000 m³.

Provision of natural materials is necessary for handicraft production, which include rattan, bamboo, coco leaf and eichnorria, etc. The large area of permanently flooded lands has a big potential for the production of these type of materials.

Essential oils and other biochemical products are also decreasing due to reductions in input materials. The Melaleuca oil contains high contents of pinene and terpinene, which are good for pharmaceutical industry. In recent time, the area of Melaleuca has sharply decreased, thus the oil stock has reduced by 40 % over the past 26 years down to 4,356 t yr⁻¹.

Natural pharmaceutical material is declining due to changes in ecosystems. There are 280 species of medicinal plants existing in Cuu Long River Delta, 150 species of which have been used. Some species that used to be seen with large reserves in the past (*Cyperus stoloniferus* Retz

Table 2. Changes in the area and production of aquaculture in the Cuu Long river Delta.

Year	Area (thousand ha)	SL (thousand tons)
1995	289,4	266,98
2000	445,3	365,1
2005	680,2	1.001
2010	739,7	1.014
2012	795,0	2.400

and *Aurelia aurita*) are in danger of extinction. Many species of medicinal plants from Melaleuca forests have declined due to deforestation.

Natural food items are changing in composition and quantity due to alternation of natural habitats. There are 62 plant species used as vegetables for human consumption. Due to human exploitation the wild wetland area in the Delta has considerably reduced, that is, the habitats for many vegetable species are getting limited and they are degraded in distribution and stock.

With diverse species composition of wild animals in both land and water, the Delta used to be home to a numerous wild animals which were available for human consumption. Recently, these species have been reduced and the stocks are so limited that they are too scarce to be used as food.

Also, the fresh water in the Cuu Long river Delta comes from three sources: rain water (estimated 80 B m³ yr⁻¹), river water (508 B m³) and groundwater (the groundwater stock with salinity of less than 1 g L⁻¹ can afford the extraction rate of 1.5 M m³ d⁻¹), which are sufficient to meet the demand in 2010 and the rural drinking water needs for coming decades. Water quality is high without alum contamination but most water sources contain an elevated content of alluvia requiring treatments before use.

The use of provisioning services led to increase of human welfare in the Cuu Long river Delta, that in turn increased the amount of basic material for a better life. Provisioning

ecosystem services in the Cuu Long river Delta, especially the ability to grow rice, fruit trees and aquaculture in different habitat conditions, have made human welfare increased and contribute to poverty reduction average income of the farmer effects increased from 29 M VND in 1995 to 4.4 M VND in 2002 and 4.8 M person yr⁻¹ in 2011. The poverty rate decreased from 15.3 % (2004) to 8.9 % (2010). However, negative consequences to the environment and ecosystems have been observed and more and more degradation in their ecosystem services (1.00 US\$ = 21,105.00 VND).

Benefits from ecosystems and the importance of equitable distribution. Alum regulation is limited in some areas due to incomplete irrigation. The area of alum soil in the region accounts for 40 % of the entire region. In the past, seasonal flooding process is an effective natural alum washing process, where flood water freely flows, dissolving and bringing alum with its course. But recently, constructed irrigations have played their role in flood control, as well as expanding cultivated area. However, on the other hand, it prevented the land from the natural washing processes and soil become more and more aluminous, which decreases cultivated crops. In some areas, local residents does not have enough freshwater for daily use.

Water regulation is limited due to narrowed water storage bodies, especially in Melaleuca forests. In effect, the water regulation capacity of ecosystem in the Delta is weak and much dependent on rains and irrigations.

Cultural services. Eco-tourism has grown rapidly based on advantages of typical habitats. Types of eco-tourism include tours in rivers, traditional orchards, mangrove, Melaleuca forest, trade villages and bird sanctuaries, etc. Eco-tourism was initiated in the past, but at small scale due to poor traffic conditions. Recently, the provinces here have been making efforts to build eco-tourism sites, enabling it to become a key industry in the Delta.

Cultural tourism could blossom by capitalizing on ethnic identities and cultural vestiges. The Cuu Long River Delta is home to the Kinh, Khmer, Hoa and some other minorities with and traditional culture. Visitors could enjoy traditional music of the Kinh, charming dancing of Lan, Chinese traditional songs of overseas Chinese community, watching Ngo junk competition, drumming performance and traditional dances of the Khmer. Furthermore, the architecture of Khmer's pagodas which is a combination of Buddhism and Ba La Mon is unique in Vietnam.

Limited inspiration is due to change in wetland ecosystems. In the past, such scenic landscapes of wetland ecosystems are sources of inspiration for many immortal art pieces. The riverine life resulted in the Ferry and Tai Tu singing. The region is also the birthplace of various literature

masterpieces.

Trend of change in these services. The trend of change in ecosystem services has been assessed through analyzing development dynamics of ecosystems and natural and social resources in the past and near future (10 to 15 years back and onward from the assessment time), complemented with the investigation of the specific change trends in selected issues that might occur in the near future (increase or decrease) based on the current products of ecosystem services in each ecological sub-region (**Figure 2**).

Drivers of changes in ecosystems and ecosystem services

Multiple drivers and interactions between drivers affect changes in ecosystems and their services. Assessing interaction between drivers of changes in ecosystems in the Cuu Long river Delta is very complex. Following the MA Framework, the following are the identified drivers of changes in the wetland ecosystems in the Cuu Long River Delta:

1. Rapid population growth;
2. Economic pressure (poverty reduction, changing livelihood activities based on market signals: export-led rice and fish and shrimp production);
3. Poor management practice (overlapping management systems, irrelevant management policies: temporary and reactive policies);
4. War (destroyed forest and natural habitats);
5. Rice intensification (after 1975);
6. Shrimp farming intensification in coastal areas (since 1983);
7. Rapid construction of irrigation systems;
8. Intensive use of chemicals (fertilizer, insecticide, herbicide, etc.) in cultivation; and
9. Changes in land use and land cover; removal of species

Drivers (2), (3) and (4) are considered indirect while the remaining six are direct drivers of ecosystems and their services.

The pressure of population growth and economic development

Population and economic pressures are drivers that resulted to change in ecosystems and their services. The rapid population growth (12 M in 1990 to approximately 17 M in 2003) led to increasing demands for food, fresh water, etc. and forced inhabitants to collect and extract anything possible that helps them survive, get out of starvation and/or poverty. On the other hand, under the impact of the trade liberalization and globalization, some agricultural and aquaculture products including rice, fish, shrimp appear to make great benefits in international market. This has led to some extent to the intensification of rice, shrimp and fish that uncontrolled.

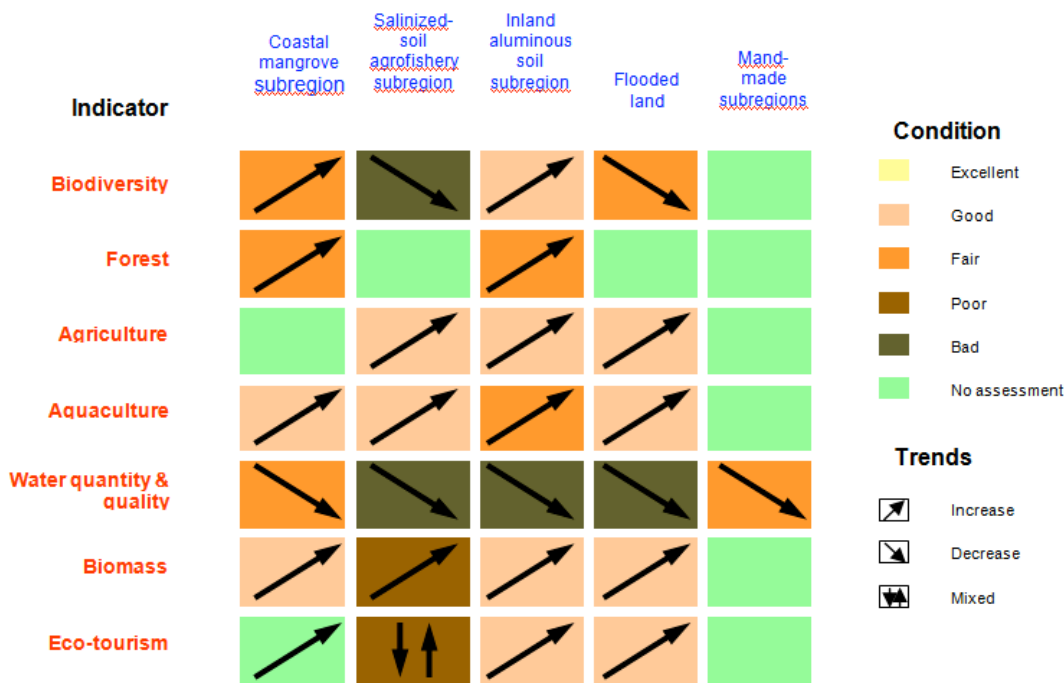


Figure 2. Conditions and trends of ecosystems (Thong, 2003).

Management policies of the local authorities at different levels is also an indirect driver of changes in ecosystems and their services. Ideally, government management policies are developed based on political and socio-economic context of the nation, region and the world as well as for specific political and socio-economic objectives in each specific period. The implementation of these policies produces direct drivers of changes in ecosystems and their services (drivers of changes in land use, ways and technology of production, etc.). Sound policies will contribute to positive changes in ecosystems and in contrast, unsuitable policies will lead to negative change. In addition, law implementation is also considered as a driver. In many cases although policies are good, the effects are not adequate because of poor law implementation.

Under the rapidly increasing population and changes in socio-economic situation, especially the uncontrolled production conversion of local people during the last decades in many areas, the local authorities at different levels gave some inconsistent, unsuitable and run-after- event policies and some policy adjustments that were not suited with the actual situation. Some policies on natural resource

management and exploitation (by province, district, region) are only interested in local interests but failed to recognize the impacts on surrounding areas that cause bad consequences to ecological ecosystems and their services in the whole Cuu Long river Delta.

Changing land use as a direct cause altering ecosystems and their services

In the Cuu Long river Delta, change in land use is the most important driver, which has occurred dramatically over the last ten years as manifested in the conversion of flooded grassland and parts of mangrove and Melaleuca forests into rice cultivation and aquaculture. This change considerably affected ecosystems, natural resources and environment, resulting in decrease in forest land and estuarine tidal-flats, which narrowed habitats of forest species and reduced biodiversity (changes in dominant species, structure and density of fauna and flora communities) and eco-balance (regeneration, growth, habitats and food chain (Table 4). The statistics show that Cuu Long river Delta has lost 72,825 ha of forest during the period of 1980-1995 and 11,785 ha of forest during the period of 2000-2010 (Don 2011).

Table 3. Changes in area of natural forest in Cuu Long river Delta (thousand ha).

Year	Melaleuca forest area	Mangrove forest area
1975	200	200
1983	110	130
2001	115	90
2011	176	100

The expansion of shrimp-farming has caused pollution, especially in coastal salinized wetlands with blooming shrimp farming leading to the overwhelming alumnfection. Extensive and improved extensive shrimp culture with poor technology, facilities, irrigational conditions contribute to water pollution and disease outbreaks at large scale.

The conversion of wetland ecosystems has led to the

migration of some alien species, which strongly affects native species and environment. Some wild plants that were imported into the Cuu Long river Delta from other countries (such as *Mimosa* sp., *Mimosa pigra*) have increased dramatically and dominated native species and environment in the region. The *Mimosa pigra*, for example, was sporadically seen in the national park of Tram Chim but now it accounts for 25 % of the park's area, in which narrows the habitat of *Grus antigone* – a globally-recognized rare species. The impacts of shrimp culture on mangrove forests in Ca Mau is also an example (Table 4).

Rapid development of infrastructures and society are also direct drivers of changes in ecosystems and their services. In many recent years, implementation of irrigation projects were considered as a major local achievement. However, these irrigation works also have negative impacts on the environment. The system to drain floodwater into the Tay sea partially flooding in lowlands but affects strongly on ecosystems in coastal wetlands. Flood water from the Dong Thap Muoi pouring into channels to bring alum to pollute thousands of hectares of land in the western Delta, threatening thousand hectares of shrimp culture land and coastal coral reef ecosystems.

Responses for management of ecosystems services

Identification of responses in the Cuu Long river Delta

Condition and trend of change in ecosystems and services in the Cuu Long river Delta reveal inconsistent management and exploitation in the whole region, different provinces are not the same in these regard, dependent on awareness level and demand for development (Thong 2004). As a consequence, the natural functioning of ecosystems has been negatively affected and their services have been degraded. The following multidisciplinary responses are identified:

- To intervene in unsustainable use of resources with regulations for sound wetland management.
- To intervene using socio-economic development, management, resource exploitation and utilization policies.
- To intervene using financial and technological support to enhance technical and material facilities in farm cultivation in order to minimize environmental impacts.
- To intervene by increasing the awareness of managers and the community about the ecosystems and their services.

Suggested specific responses are as follows:

1. A need for an institution/regulation of wetland management that is consistent nationwide to support the government in making policies, regulations

2. To adjust production mechanisms and land use schemes in agriculture, forestry and aquaculture in the Cuu Long river Delta - this is a macroscopic scale and the most important response.
3. Adjusting unsuitable policies on management and exploitation of ecosystems and their services in the Mekong River Delta.
4. Responses at micro level:
 - Adjusting development and land use planning of each province, district and commune to fit the land use planning of the whole Cuu Long river Delta.
 - Adjusting and adding policies on natural resource management and exploitation (especially for land and water resources) towards proper use of natural resources and ecological environment protection.
 - Adjusting policies on credits and agricultural encouragement for farmers in order to encourage agricultural production methods that are sustainable and help maintain the resources and minimize impacts on ecosystems.
 - Adjusting policies on credits and agricultural

Table 4. Loss of forest and biodiversity caused by shrimp expansion in Ca Mau.

Area of forest to have been destroyed for shrimp production in Ca Mau	
Year	Area (ha)
1983	3,000
1988	28,701
1990	45,701
1991	47,480
1993	67,072
1995	76,036
1998	120,000
Over 120,000 ha of shrimp land, where:	
- Forested: 72,539 ha.	
- Pond edge area: 41,204 ha (50 % is water surface and 50 % is ground edge) and, 25,000 ha of ground edge are impossible to afforest with mangrove species.	
Species with declining population:	
- <i>Hunuitzera littorea</i>	
- <i>Scyphiphora hydrophyllacea</i>	
- <i>Aegiceras floridum</i>	
- <i>Instia bijuga</i>	
- <i>Avicenia lanata</i>	
Some rare species suffer risk of extinction:	
- <i>Aegiceras floridum</i>	
- <i>Bruguiera gymnorrhiza</i>	
- <i>Heritiera littoralis</i>	
Declining of rare birds:	
- 10 bird sanctuaries vanished	
- Some rare bird species are extinct such as <i>Placanus onocrotalus</i> , <i>Ibis leucocephalus</i> and <i>Leptoptilos dabius</i>	

(Source: Dang Trung Tan, 2001; Dang Cong Buu, Do Xuan Phuong-Minh Hai Centre for Mangrove Research, 1999)

encouragement for farmers in order to encourage agricultural production methods that are sustainable and help maintain the resources and minimize impacts on ecosystems.

CONCLUSION

Using the new approach of the MA conceptual framework to assess ecosystems through some selected issues and indicators suitable for wetland ecosystems, Vietnam's sub-global assessment (SGA) focuses on identifying some main wetland ecosystems, analyzing condition and trend of ecosystems, drivers of change in ecosystem services and its impacts on human well-being in the Cuu Long river Delta. Based on the assessment, some interdisciplinary responses have been identified and some specific responses in effective management of ecosystems have been proposed for the whole Cuu Long river Delta at the macro scale, as well as for the provinces, districts, environment and natural resource sectors at the micro scale.

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