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Economic Valuation of Regulating Ecosystem Services of Thai Thuy Wetland in the Red River Delta of Vietnam

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Abstract: *The ecosystem in Thai Thuy wetland plays a significant role in providing goods and regulating services such as disaster risk reduction, carbon storage and water purification. This study aims to estimate the value of the major regulating ecosystem services of Thai Thuy wetland. The key regulating ecosystem services of Thai Thuy wetland that were identified for estimating their economic value include the disaster risk reduction (sea dyke protection, aquaculture pond protection and provision of typhoon shelter for fishing boats), carbon storage and water purification. The main methods used for valuing these services are the benefit transfer and replacement cost methods. The total economic value of regulating services in Thai Thuy wetland is estimated at US$6.1 mil. per year. This could help to raise the awareness of the wetland importance for local people and policymakers so that more consideration should be given to better wetland conservation and management.*

Key words: *Economic Valuation, Regulating Service, Wetland, Vietnam.*

JEL Code: Q51, Q56, Q57

1. Introduction

Wetlands are considered one of the most productive and biologically rich ecosystems. They provide a variety of ecosystem services such as provisioning, regulating, supporting, and cultural services (MEA, 2005). In Vietnam, wetlands cover an estimated 30% of the country's land area (around 10 mil. hectares) of which coastal wetlands are significant given Viet Nam's long coastline of 3,260 km. Wetland in Vietnam is extremely diverse in terms of type, morphology, resources, biological value, and functions. Wetlands generate innumerable direct and indirect benefits that have contributed significantly to human wellbeing and economic development across the country.

Covering 13,100 ha (with 1,759 ha of mangrove forest), the wetland in Thai Thuy has been identified as one of seven key wetland sites within the Red River delta. The ecosystems in the Thai Thuy wetland play a significant role in providing goods and services for the coastal communities in Thai Thuy district. It not only offers valued products (fish, shrimp, clam, crop products) for sustaining the everyday needs of local people but also supports many other ecosystem services such as shielding disasters, water purification, and climate conditioning, etc.. (MOE, Birdlife and Viet Nature, 2016; Viet Nam Environment Protection Agency, 2005). Despite a common understanding of the multiple benefits and general commitment to conserving wetlands in Vietnam, the wetlands in general and Thai Thuy wetland in specific currently face many threats and seemingly

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continue to be degraded as the result of a multitude of human development activities. The conversion of the wetland to agriculture (especially to aquaculture ponds), the pollution from agricultural production and industrial facilities, the over-exploitation from fishing, and bird hunting threaten the wetland seriously. This is mainly because the ecosystem services provided by the wetland, especially the regulating are not valued in economic terms, as a result of which the values of the wetland are largely ignored in decision-making on land use planning. Under such a circumstance, this study is conducted to undertake the economic valuation of regulating ecosystem services of Thai Thuy wetland for demonstrating the economic importance of the wetland, then propose the implications for effectively mainstreaming the wetland conservation into the development plans in the coming time.

2. Literature reviews

2.1. Regulating ecosystem services of the wetland

MEA (2005) attempted to create an ecosystem service framework that links ecosystem services to human welfare. Similar to the classification of De Groot *et al.* (2002), MEA (2005) proposed a genetic typology of ecosystem services' classification based on ecosystem functions. They classified ecosystem services into four main groups of provisioning, regulating, cultural, and supporting services (see Table 1). Of those, the regulating services are defined as the benefits of regulation of ecosystem processes. The examples of regulating services and others are described in table 1. Regulating services provide many direct and indirect benefits to humans, including clean air and water, pollination, climate regulation, and natural hazard control.

Table 1. Categories of ecosystem services and examples of related services

Type of services	Service	Type of services	Service
1. Provisioning services	Food Fiber Genetic resources Biochemicals, natural medicines, etc. Ornamental resources Freshwater	3. Cultural services	Cultural diversity Spiritual and religious values Aesthetic values Educational values Inspiration Social relations Cultural heritage values Recreation and ecotourism
2. Regulating services	Air quality regulation Climate regulation Water regulation Erosion regulation Water purification Pest regulation Pollination Natural hazard regulation	4. Supporting services	Soil formation Photosynthesis Primary production Nutrient cycling Water cycling

*(*Source: Adapted from Box 2.1 in the Millennium Ecosystem Assessment, 2005)

According to the Common International Classification of Ecosystem Services (CICES, 2011) ecosystem services are defined as the contributions to the "final output" that ecosystems make to human well-being. The

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classification recognizes these outputs to be provisioning, regulating, and cultural services, but it does not cover the so-called 'supporting services' originally defined in the MEA. The supporting services are treated as part of the underlying structures, processes, and functions that characterize ecosystems.

TEEB (2010) proposed an updated typology of ecosystem services that is mainly based on the classification system initiated by MEA. TEEB provided 22 specific ecosystem services and categorized them into 4 main groups: provisioning, regulating, habitat and cultural and amenity services. The important revision of TEEB in comparison with the MEA is the omission of supporting services and the initiation of habitat services. The habitat services include those that relate to the maintenance of life cycles and genetic diversity.

2.2. Economic valuation techniques for regulating ecosystem services

Economic value refers to the quantified net benefit that humans can derive from a good or service, whether or not there is a market and monetary transaction for the goods and services. Economic valuation is an effort to allocate quantitative values to the goods and services provided by wetland ecosystems (Costanza *et al*., 1997; Daily, 1997). Economic valuation of wetland ecosystems can be useful in indicating the opportunity cost of other land-use practices. The range of value may vary according to the specific approach used, but it can help in land-use decision-making.

Most of the provisioning and cultural services like timber, fish, and recreation are services that the economics profession has long been adept at estimating the economic value of. However, regulating services present much greater challenges (Kumar and Wood 2010). Generally, regulating services are not sold and bought in markets, so people do not pay for these services directly. Valuation of regulating services can provide a powerful instrument for placing this issue on the agenda of decision-makers. The basic aim of valuation is to determine people's preferences: how much are people willing to pay for regulating services, and how much better or worse off would they consider themselves to be as a consequence of changes in the supply of these regulating services. By reflecting these preferences, valuation aims to make regulating services comparable with other economic sectors when decisions are taken regarding land and resource use.

Environmental economists have divided valuation methods into three primary main groups including revealed preference methods, stated preference methods, and other valuation methods (Freeman, 2003; Pearce *et al.*, 2006). Revealed preference methods make use of linkages between non-market ecosystem services and one or more market goods. These methods are well-suited for capturing direct use-values. The four most important valuation methods within this group are production function methods, travel cost methods, hedonic price method, and defensive expenditure method. Stated methods can estimate the WTP for the ecosystem services directly by creating a hypothetical market scenario and presenting this in a survey to a representative sample of the population. This is particularly useful when we suspect that the existing value may be particularly relevant for given resources which cannot be captured using the revealed preference methods. Two main stated preference methods include the contingent valuation method and choice experiment. Other primary methods include the replacement cost method and the human capital method. In addition, the "benefit transfer" method is usually used to transfer primary valuation estimates developed at one location to another location with similar attributes (the transfer site)

3. Research methodology

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3.1. Research site

The coastal wetland of Thai Thuy district covers 13,100 ha including the 1,759 ha of mangrove forest, 4,700 ha of the intertidal zone without mangroves, and 1,429 ha of aquaculture ponds. Thai Thuy wetland has been identified as one of seven key wetland sites within the RRD Biosphere Reserve, approved by UNESCO in 2004. The area includes 16 km of coast bounded by the Thai Binh river to the north and the Tra Ly River to the south. In 2014, Thai Thuy wetland area is included in the list of potential Nature Reserves (for wetland) according to Decision No. 45/QĐ-TTg issued on January 8th, 2014 by the Prime Minister of Vietnam.

The wetland ecosystems of the Thai Thuy coasts are of vital importance as they provide significant ecosystem services to support the well-being of the local communities. The wetlands provide habitats for fish, crustaceans, behalves and other species, which are the main source of income for thousands of local people who daily collect them from intertidal and mangrove areas. The wetland ecosystems also support emergent seafood production systems such as shrimp, fish and clam aquaculture in the area, by providing food inputs, seed, and water purification services. In addition, the wetlands also serve multiple functions such as shore stabilization and erosion reduction, storm prevention, climate regulation and water quality maintenance, which are all essential for the security and well-being of local people.

Key habitat types found in Thai Thuy wetland include mangrove forests, intertidal mudflats, sandy beaches and aquaculture ponds. The mangrove forests found around the Thai Binh and Tra Ly river mouths, which cover some 30 ha dominated by *Sonneratia caseolaris* (mainly located in Thuy Truong commune), represent the largest remaining tracts of old-growth mangrove in the RRD. Other patches of mangrove found here were replanted since 1990s with *Kandelia candel*. Most of the Thai Thuy district's coastal land has been converted to aquaculture ponds, which cover some 1,039 ha. Aquaculture ponds dominate on the landward side of a sea dike that runs parallel to the coast, and around the Tra Ly river mouth.

Like other wetlands with mangrove forests in the world, the Thai Thuy wetland provides a variety of ecosystem services at local, national and global levels. According to Merriman and Murata (2016), the Thai Thuy wetland can provide food for local communities living in five villages next to the wetland and the mangroves in the wetland can provide a protective function from storms for local communities and the global benefit of climate regulation. The wetland also conducts water purification and it provides a home for wildlife such as migratory and residential birds, amphibians, fish, insects, and aquatic plants, etc

3.2. The data collection

This study is conducted in 2017. The secondary data for the study include the statistical data on the aquaculture production from the Department of Agriculture and Rural Development in the Thai Thuy district and the information from the related studies. In addition, the focus group discussions with the local staff and aquaculture households were held to get the assessments on the cost and revenues of aquaculture production, the probability of typhoon occurrence, and the major regulating ecosystem services of Thai Thuy wetland, etc..

3.3. The valuation methods

The main methods used for the valuation of the above-regulating services of the Thai Thuy wetland are replacement cost method and benefit transfer. Replacement cost is the cost that is relevant to determining the price that a market participant would pay as it is based on replicating the utility of the asset, not the exact physical properties of the asset. Usually, replacement cost is adjusted for physical deterioration and all relevant

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forms of obsolescence. Meanwhile, benefits transfer is the valuing methodology employed to estimate ecosystem economic values by transferring available information from a site where a study was realized to a place where the valuation has to be performed under the assumption that characteristics in both sites are similar. Benefit transfer usually is employed when is too expensive or time consuming to produce primary economic valuation studies. Is for this reason that the method has triggered an increasing interest and the literature has expanded rapidly in the last years. This method is more reliable when the original site and the site object of the transfer are similar in quality, location, and population characteristics, when the environmental changes are similar, and when the original study was soundly realized and used appropriate economic valuation methodologies (King *et al.*, 2007). In this sense, it would have to be taken into consideration that the maximum exactitude and reliability attributable to the benefit transfer method are those of the original study.

4. Estimating Economic Value of Regulating Ecosystem Service of Thai Thuy Wetland

4.1. Identification of Regulating Ecosystem Services of Thai Thuy Wetland

Like other wetlands with mangrove forests in the world, the Thai Thuy wetland provides a variety of ecosystem services. According to Merriman and Murata (2016), the Thai Thuy wetland can provide food for local communities living in five villages next to the wetland and the mangroves in the wetland can provide a protective function from storms for local communities and the global benefit of climate regulation. The wetland also conducts water purification and it provides a home for wildlife such as migratory and residential birds, amphibians, fish, insects and aquatic plants, etc.

Based on the previous studies, and the assessment of the importance of the ES services of local people and staff through the focus group discussion, the key regulating services of Thai Thuy wetland selected for valuation include disaster risk reduction (sea dike protection, aquaculture pond protection, typhoon shelter for boats), carbon storages and water purification.

4.2. Valuation of disaster risk reduction of Thai Thuy wetland

Coastal lands are subject to multiple natural hazards such as storms, tsunamis, and over the long-term, rising sea levels. Such hazards and their impacts (such as erosion, wave damage, flooding) may threaten lives, livelihoods, property, health, and economic development. Mangroves are found on the front line in terms of their position relative to many coastal hazards. Mangroves can reduce the height and energy of wind and waves passing through them, reducing their ability to erode sediments and to cause damage to structures such as dikes and sea walls, industrial and private real estate and property. During rising tides, as the sea comes in, waves enter the mangrove forests. They lose energy as they pass through the tangled above-ground roots and branches and their height is rapidly diminished. As this happens, waves lose their ability to scour the sea bed and carry away sediments. Mangroves also reduce winds across the surface of the water and thus prevents the propagation or re-formation of waves, etc.

Realizing the important role of mangrove forests in mitigating natural hazards such as typhoons and tides, the authorities of Thai Binh province and Thai Thuy district had launched many campaigns to plant the mangrove forest since the 1990s. As a result, thousands of hectares of mangrove forest were planted along the coastlines of the Thai Thuy district. The total area of mangrove forest in Thai Thuy was 1,759ha in 2016 and its belt was between 0.7-3.5km wide.

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a. Value of Sea Dike Protection

According to Mazda *et al.* (1997) the height of the sea wave in Thai Thuy would reduce by 20% if it goes over 100 m of mangrove forest. If the wave 1 meter high goes over a mangrove forest (of 6 years old) with 1.5km wide, the height of the wave would remain only 0.05m. This is reconfirmed by Vu Doan Thai (2011) in his study on the role of mangroves in reducing high waves during a typhoon in Dai Hop commune (Kien Thuy district, Hai Phong province) which was very close to and had a similar condition of mangroves to Thai Thuy district.

Dinh Duc Truong (2012) also compared the damages of sea dikes in Giao Thuy district (Nam Dinh province) between two areas: one with mangroves and another without mangroves. When the Damrey typhoon (also called typhoon no. 7) came to the areas in 2005 with the wind gust over 73 miles per hour, the dike in the mangrove area was safe while the dikes in the area without mangroves was seriously broken or blown off parts and needed the urgent maintenance. Based on the data on maintenance costs for the 27km dikes without mangroves, Truong estimated the average maintenance cost for 27 km of sea dike in Giao Thuy (during 1997-to 2006) was around VND3 billion per year or VND144.9 mil./year/km (with the price in 2006). This figure was the avoided maintenance cost for the dikes in the area with mangroves or the contribution of mangroves to the dike protection was equivalent to VND 144.9 mil/year/km at the 2006 price or VND285 mil/km/year at 2016 price (with a discounting rate of 7%/year). It should be noted that during 10 years (1997-2006), there was only one strong typhoon attack Nam Dinh province and the probability of strong typhoon occurrence was just 10%/year.

Thai Thuy had 27km of sea dike which was fully protected by mangrove forest. The FGD with Thai Thuy district staff revealed that the maintenance cost for the Thai Thuy sea dike was nearly zero thanks to the protection of the mangrove forest. Using the benefit transfer methods with the assumption that the avoided maintenance cost of the dike in Thai Thuy was the same in Giao Thuy (for the area with mangroves), and the probability of strong typhoon occurrence was also 10% per year, the contribution of mangroves to dike protection in Thai Thuy district was therefore estimated at VND7.7 billion per year or US$0.345 mil.

b. Value of Aquaculture Pond Protection

- Avoided Loss of Aquaculture Production

The total aquaculture areas between mangroves and dikes in Thai Thuy (including the river estuaries) in 2016 was 1,039 ha and the total value of aquaculture production in this area reached VND107.05 billion in 2016 (Table 2). If there were no mangroves, the aquaculture production would be seriously damaged when the big typhoon came since the sea wave and gust wind due to big typhoons could destroy the pond banks seriously. However, the existence of the mangroves could significantly reduce the height and energy of the coming waves and the power of the winds, thus saving the pond. According to IFRC (2012), the damages by the huge typhoon to the aquaculture production would reduce from 90% to just 25% of total aquaculture production thanks to mangroves. The mangrove forest in Thai Thuy could therefore save up to 65% of total aquaculture production.

Table 2. Total Value of Aquaculture in pond outside the dikes of Thai Thuy wetland in 2016

Items	Total areas (ha)	Total production (ton)	Total Production value (bil. VND)
- Giant tiger prawn	853	185	46.25
- White Leg shrimp	18	36.5	4.02

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-	Greasy back shrimp	45	6.8	0.65
-	Fish	75	337	50.55
-	Crabs	33	23.1	5.08
-	Others (natural harvest)	15	11.25	0.51
	Total	*1,039*	*563.15*	*107.05*

(Source: Authors' calculation based on data from Thai Thuy DARD)

With the assumption of the probability of huge typhoon occurrence is 10% per year, the annual net benefit of mangroves to the aquaculture production (or amount) would be VND6.96 billion or US$0.312 mil. (*107.05 bil. VND x 10% x 65% = 6.96 bil. VND).*

- Avoided Cost for Restoring Pond Banks and Watchtowers

In addition to benefits from the avoided loss of aquaculture production thanks to safe of pond banks, the aquaculture households did also not have to pay the restoration cost due to the devastation of banks and watchtowers (or sentry boxes) in the ponds as well as to collect the garbage in the ponds after a typhoon. This was because during the typhoon, mangrove forest can help to protect the pond banks and watchtowers which are usually established in the pond so that the owner can stay in and watch the pond to prevent aquaculture stealers, observe the situation of the fish and water quality (through watercolor) for proposing right action, and sometimes to keep the feeds inside. Moreover, the mangrove forest also significantly helps prevent the pond from the garbage during the typhoon

According to the household discussions, the restoration cost for the pond banks and watchtowers and garbage collection would be around VND15 mil. per pond of 0.5 ha. Assuming the probability of huge typhoon occurrence was 10% per year, the annual avoided cost for restoring pond banks and sentry boxes and garbage collection would be VND3.12 billion or US$0.14 mil.

In summing up, the annual total value of aquaculture protection from mangrove forest in Thai Thuy district would be VND1,008 billion or US$0.452 mil. if the probability of strong typhoon is 10% per years. In case, the probability of strong typhoon is 20%/years, this annual value of aquaculture protection would be VND 2,016 billion or US$0.904 mil.

c. Provision of Typhoon Shelters for Fishing Boats

Mangrove forests in the Thai Thuy district could provide safe typhoon shelters for fishing boats of the local fishermen. Usually, before the typhoons came, the fishermen directed their boats to go inside the mangrove forests or behind the mangrove belts to avoid the strong waves and winds that could overturn or break their fishing boats. By this way, the fishing boats in Thai Thuy district were safe during the typhoons, even huge typhoons in the past.

Recently, the typhoon anchorage site (namely Diem Ho) was constructed in the Thai Thuy district (Thai Thuong commune) to provide safe shelters for the fishing boats and vessels during typhoons. The area of the site was around 22 ha and total investments for the Diem Ho anchorage site were around VND106 billion (Vietnam Communist Party Newspaper, 2015), and the life cycle of the Diem Ho typhoon anchorage site was estimated at 25 years. The site was designed to provide safe shelters for 104 boats and vessels (up to 300 CV/vessel) and was completed in 2014. The construction cost of an anchorage site for one fishing boat was therefore around VND1.02 billion on average.

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However, according to the fishermen in Thai Thuy, the site was not really safe because there were no trees to prevent the winds during the typhoon. Therefore, almost all fishing boats did not go to the site during the typhoons (Vietnam Newspaper, 2015). The fishermen still used the traditional sites in mangrove forests or behind the mangrove belts to shelter their fishing boats for safety. This indicates that the mangrove forest could provide the typhoon shelters with the safety at least equivalent to the Diem Ho typhoon anchorage site.

According to Thai Thuy DARD (2017), there were a totally 540 fishing boats in Thai Thuy. All of them shelter inside or behind mangrove belts during the typhoon for safety. The value of mangroves in providing the typhoon shelters for a fishing boat in the Thai Thuy district was estimated at VND22.03 billion per year or US$0.986 mil. per year.

4.3. Valuation of Carbon Storage of Thai Thuy wetland

The importance of mangroves in providing ecological services has been highlighted in discussions on global climate change, in particular concerning Reduced Emissions from Forest Degradation and Deforestation Plus (REDD+). Mangroves have a relatively high Greenhouse Gas (GHG) removal capacity and thus higher potential to earn carbon revenues.

Mangroves absorb a significant amount of carbon into the plant biomass through net primary production. Importantly, they also sequester some of this carbon in the soil for long periods. In the context of CO2 sequestration, the relevant carbon sinks to consider are: Carbon buried in sediments - locally or in adjacent systems - generated by the annual turnover of small litter such as flowers, fruits, leaves, twigs, and small branches; Net growth of forest biomass, both above and below-ground, during development, e.g. after (re)planting. A recent assessment of carbon stored in various forest domains found that in comparison with boreal, temperate and tropical upland forests, mangroves throughout the Indo-Pacific are among the most carbon-rich forests in the tropics containing, on average, 1,023 MgC per ha, most of which is stored in soils >30 cm deep (Donato *et al.*, 2011).

Nguyen Thi Kim Cuc (2007) also conducted a study on *Stand structure and carbon accumulation process in mangrove forests in Thai Binh River Mouth, Northern Viet Nam* for her PhD Dissertation (in Ehime University, Japan). According to her study, carbon accumulation in the mangroves in Dai Hop commune (Kien Thuy district, Hai Phong province) could be estimated using the formula: $y = 29.766e^{0.17x}$ where *y* is the cumulative amount of carbon (carbon tons/ha) and *x* is the stand age of planted mangrove trees (Nguyen Thi Kim Cuc, 2015). Dai Hop commune was very close to Thai Thuy district and the natural condition of Dai Hop commune and Thai Thuy district was nearly the same. Mangroves in the Thai Thuy district were mainly planted in the periods 1990-1996 while mangroves in Dai Hop commune were mainly planted in periods 1993-2000. The only significant difference was the stand age of mangroves between Thai Thuy district and Dai Hop commune (Kien Thuy district). With the assumption of the mangroves in Thai Thuy were mainly planted in 1995 or 21 years old up to 2016, the storage carbon of mangroves forest in the Thai Thuy district was estimated at 1,056 MgC per ha using the formula from Nguyen Thi Kim Cuc. This number was only a little bit higher than the average amount of carbon storage estimated by Donato *et al.* (2011) for mangroves in the Indo-Pacific. We, therefore, used the amount estimated by Donato *et al.* (2011) to calculate the carbon storage for Thai Thuy mangroves.

In addition, according to Merriman and Murata (2016) (that is summed up from IPCC 2013 Supplement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC in Good Practice Guidance for

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Land use, Land-use Change, and Forestry (Penman *et al.*, 2003)), the carbon storage in intertidal and aquaculture was around 88MgC/ha on average. Using the average rate of carbon storage in the mangrove forest in the Indo-pacific region and in intertidal and aquaculture areas, the total carbon storage in Thai Thuy wetland could be estimated as in the Table 3.

Table 3. Total Carbon Storage in Thai Thuy Wetland

Habitat type in Thai Thuy wetland	Area (ha)	Carbon Storage (MgC/ha)	Total Carbon storage in Thai Thuy wetland (MgC)	Estimate of Carbon storage value -using Plan vivo price (US$mil)
1. Mangrove forest	1,759	1023*	1,799,457	57.02
2. Intertidal mudflat	4,700	88**	413,600	13.11
3. Aquaculture (outside dikes)	1,039	88**	91,432	2.90
Total	7,498	-	2,304,489	73.03

(*) From Donato *et al.* (2011)
(**) From Merriman and Murata (2016)

There is no fixed price for carbon and the market price is highly variable. In this study, the price of Plan Vivo certification (US$31.69 MgC in 2016) was used for the calculation. This is the price that a buyer would pay for carbon credits from the Plan Vivo certification scheme if there were to be a carbon trade project established at Thai Thuy. The price of US$31.69 MgC in 2016 was adjusted from the 2014 price based on the IMF inflation rate and was also used by Merriman and Murata (2016) for valuation. The estimated value was US$73.03 mil. This is a one-off stored value or not an annual value. With the discount rate for the long-term of 3% per year, the value of carbon storage in the Thai Thuy wetland is then equivalent to US$2.19 mil. per year.

4.4. Valuation of water purification of Thai Thuy wetland

Several studies have been conducted to investigate water quality treated by mangrove forests. The study by Jitthaisong *et al.* (2012) conducted at the mangrove forest site of Ban Laem District, Phetchaburi Province, Thailand showed that water quality from mangrove forest met the effluent standards for coastal aquaculture. Mangrove forests can be able to improve water quality by increasing DO (dissolved oxygen) by 32.39%, while reducing phosphate, ammonia, and nitrate by 88.23%, 73.77%, and 64.28% respectively. It can be used as an additional natural system to increase the efficiency of the man-made wastewater treatment system. Wong *et al.* (1997) investigated the feasibility of using mangrove wetlands as a sewage treatment facility in the field of 300-hectare natural mangrove intertidal wetlands in Shenzhen, a newly developed city in southern China and the study results showed that those mangrove intertidal wetlands were of great potential for natural wastewater treatment. Shimoda *et al.* (2009) also assessed the water purification ability of Mangrove (*Sonneratia caseolaris*) in Mesocosm Tanks. Both nitrogen and phosphorus showed high removal rates in the mangrove mesocosm tanks.

Despite the significant function of water purification and waste assimilation, yet very few studies have valued this important function. Schuyt & Brander (2004) based on a sample of 89 case studies of wetlands all around the world showed that the medium value of water filtering of wetlands was US$288 per year per ha. According to Constanza *et al* (1997), the waste treatment value of mangroves was US$6,696 per year per ha. Cabrera *et al.* (1998) estimated the water purification of mangrove forests using the alternative cost method. The

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annual value of this ecological service for one ha of mangrove was obtained by dividing the total annual cost by the mangrove area receiving residual wastewaters. The economic value of the water filtering mangrove service was about US$1,193/year/ha.

Similarly, mangroves in the Thai Thuy district also provide the important service of water purification. In the context of serious environmental pollution in Thai Thuy wetland caused by intensive aquaculture activities and by water discharge from Thai Binh, Tra Ly, and Diem Ho rivers (with pollutants from agricultural activities), the water purification by mangroves plays a more and more important role. Using the benefit transfer from the study of Cabrera *et al.* (1998), the value of water purification of Thai Thuy mangroves was estimated at US$1,193 year/ha. With the total areas of mangroves of 1,759 ha, the total value of water purification service in the Thai Thuy wetland was equivalent to US$2.10 mil. per year.

4.5. Sensitivity Analysis of regulating service value of Thai Thuy Wetland

With the assumption that the probability of big typhoon occurrence is 10%/year (base case), the economic value of regulating services of the Thai Thuy wetland is estimated at US$6.077 mil. per year (Table 4). However, due to the impacts of climate change, strong typhoons seem to happen more often in recent years. In the scenario that if the probability of strong typhoon occurrence increases up to 20%/years, the contribution of mangroves to dike protection and aqua-pond protection in the Thai Thuy district would be two folds. The economic value of regulating services of Thai Thuy wetland then would reach up to US$6.874 mil. per year.

Table 4. Sensitivity Analysis of Economic Value of Regulating Services (USD mil.)

	Base case (Prob. of big typhoon occurrence to be 10% per year)	Scenario (Prob. of big typhoon occurrence to be 20% per year)
a. Disaster risk reduction	1.787	2.584
- Value of sea dike protection	0.345	0.690
- Value of aqua-pond protection	0.452	0.904
-Provision of typhoon shelters	0.990	0.990
b. Carbon storage	2.190	2.190
c. Water purification	2.100	2.100
Total	6.077	6.874

(Source: calculated by authors)

5. Conclusion

The ecosystems in the Thai Thuy wetland play a significant role in providing goods and regulating services such as disaster risk reduction, carbon storage, and water purification. Using the valuation methods of benefit transfer, and replacement cost, the economic value of regulating services in the Thai Thuy wetland is estimated at US$6.1 mil per year, including US$1.787 mil. from disaster risk reduction, US$2.19 mil. from carbon storage and US$2.1 mil. from water purification. In case, the occurrence of big typhoons increases up to 20% per year, the value of regulating services would reach up to US$6.874 mil. The results from the valuation study in Thai Thuy wetlands demonstrate the significant economic value of coastal wetlands in Viet Nam and several recommendations were identified such as (1) the importance of the benefits from wetlands should be reflected in the regulations and policies addressing wetland management and conservation; (2) better dissemination of information on wetland economic values should be implemented for raising the awareness of

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local people, community members and authorities; and (3) more considerations should be given for wetland conservation and management and the value of regulating service should be incorporated into decision making processes for better sustainability.

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