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RESEARCH PAPER

Economic valuation of wetland ecosystem services in northeastern part of Vietnam

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Abstract – Coastal wetlands have been heavily exploited in the world. Valuation of ecosystem services help to provide the necessary improvements in coastal policy and management to monitor the driving forces of ecological changes in wetland ecosystems. In this study, the monetary values of wetland ecosystem services (WES) in the northeastern part of Vietnam were evaluated based on the integration of different quantitative methods, including interview, remote sensing, ecological modeling, statistic, and cost-benefit analyses. Particularly, seven wetland ecosystems and eleven services obtained from them were identified. As a result, the annual net WES value is evaluated at more than 390 million USD. The intensive and industrial aquaculture ecosystems in the northeastern part represent the highest economic value with more than 2100 USD/ha/year. A "planning" scenario was formulated to predict WES for the next ten years based on policy changes published by local managers. The framework developed here can serve as a decision support tool for environmental and economic managers in wetlands planning.

Keywords: Ecosystem service value / cost benefit analysis / wetland ecosystem

1 Introduction

The economic value of wetland ecosystem services (WES) per hectare has been ranked first among all kinds of natural ecosystems (CBD, 2015; Meng and Dong, 2019). The value of WES is expected to be 47 percent of the total value of the global ecosystem (Xu *et al.*, 2020). However, according to the Ramsar Convention Secretariat, the area of global wetlands has reduced by about 35% between 1970 and 2015 due to sea level rise, extreme storms, and human activities, including 35% of mangroves, 29% of seagrass beds, and 30% of coral reefs (Barbier *et al.*, 2008; Waycott *et al.*, 2009). This led to a significant reduction in the overall value of WES. For example, the decrease marsh WES value by 9.9 trillion dollars per year from 1997 to 2011 according to recent research is equivalent to 1.4 times of China's Gross Domestic Product in 2011 (Costanza *et al.*, 2014; Kubiszewski *et al.*, 2016). Therefore, it is undeniable that the destruction of wetlands will result in massive economic losses. However, current knowledge of the trends and processes underlying human impacts on coastal WES values is poor, especially in emerging regions where wetland changes are escalating due to rapid urbanization and industrialization (Gao *et al.*, 2014; He and Sikor, 2015).

Wetlands play an important role in regulating the global environment, preserving the global hydrological cycle, sustaining habitat diversity, and ensuring human well-being (Chen *et al.*, 2009a; Liquete *et al.*, 2016; Sun *et al.*, 2018; Xu *et al.*, 2020). Wetland ecosystems can provide humans with not only direct economic resources such as seafood, recreation and tourism, but also indirect values such as climate and natural hazard regulation (Burkhard *et al.*, 2014; Dang *et al.*, 2019). Since the majority of the values rendered by wetland environments are not exchanged in the economic market, the importance of wetland habitats is still overlooked or ignored by owners, government, and the general public (Friess, 2016; Vieira da Silva *et al.*, 2014). Therefore, the valuation of WES is useful for coastal managers to track the driving forces of ecological change, and then to choose appropriate coastal policy and management for local wetland ecosystems.

The northeastern coast of Vietnam has become a dynamic and sustainable economic zone during the last decade (Thi Kim Chi *et al.*, 2017; Tue *et al.*, 2018). The gross regional domestic product (GRDP) rate increased 10.05% from 2019 to 2020

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although the national economy was strongly affected by the COVID-19 crisis according to Vietnamese General Statistics Office[1]. To do so, local managers have encouraged green economy to obtain sustainable benefits[1] from coastal ecosystems. Particularly, local fishing production has increased from 86,000 tons to more than 130,000 tons since 2019 (Thi Kim Chi *et al.*, 2017). More than 4,000 tons of rubbish collected on the sea since 2015 have made the local coastal environment cleaner (Naganuma, 2014). The area of mangrove forests has strongly fluctuated from 17,000 ha to 23,000 ha during the period 2000–2020 (Thao *et al.*, 2013), and famous landscapes in the world, such as Ha Long Bay or Bai Tu Long Bay, attracted 14 million tourists in the year 2019 (Mai and Smith, 2018; Tseng *et al.*, 2011, 2018). The rapid economic growth and land use/cover changes require a clear valuation of the use and non-use values of wetland ecosystem services to avoid negative impacts on environment (Tajima *et al.*, 2019; Thai *et al.*, 2017). The valuation of WES is an important step to balance the benefits obtained from wetland ecosystems and to propose suitable Wetlands of International Importance (RAMSAR) and world natural heritage sites.

The main aim of this study is to estimate the Ecosystem Service Value (ESV) of wetlands in the northeastern coast of Vietnam, particularly from the Mong Cai city (Quang Ninh province) to the Van Uc estuary (Hai Phong province). Instead of using an economic approach, only focusing on the interests from ecosystem stocks, the ecosystem service approach was proposed to analyze in deep the spatial and temporal relations between the multi-services provided by wetlands (Moore and Hunt, 2012; Zorrilla-Miras *et al.*, 2014; Baveye *et al.*, 2016; Merriman *et al.*, 2016). The ecosystem service approach to estimate WES values is a potentially interesting option for environment valuation.

The primary goal of this study is to explore three research questions:

- Is it feasible to estimate the value that wetland ecosystems provide to human in the northeastern part of Vietnam?
- What is the worth (value) of wetland ecosystems in the northeastern part of Vietnam?
- How the economic values of wetland ecosystem services in the northeastern part of Vietnam have changed over the past 20 years and how they may change in the future?

2 Material and methods

Various methods were used in this study including interview, remote sensing, statistic and cost benefit analysis for valuating WES. In addition to the use of the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model as a powerful tool for ecological analysis (Redhead *et al.*, 2016), a machine-learning model for land-cover classification was developed to assess change of wetland area in the research area (*i.e.* the ResU-Net; Dang *et al.*, 2020).

2.1 Case study

The spatial scope of the study area includes the coastal wetlands of Hai Phong and Quang Ninh (Fig. 1). Based on the boundary defined by administrative management unit (Naganuma, 2014), we separated the research area into seven wetland regions from north to south: Mong Cai-Dam Ha region, Tien Yen estuary, Van Don district, Cua Luc bay, Cam Pha district, Quang Yen district, and Van Uc estuary (Dang *et al.*, 2020; Thao *et al.*, 2013).

The wetland strip in the northeastern Vietnam is an ecosystem with a high diversity of landscapes and flora and fauna, with *e.g.* 400 species of fishes, 160 species of coral, and 140 species of sea algae (Thi Kim Chi *et al.*, 2017). Quang Ninh province has more than 40,000 ha of tidal flats, 20,000 ha of bays and more than 100,000 ha of shallow coastal lagoons in Ha Long Bay and Bai Tu Long Bay (Lan, 2009; Thuy *et al.*, 2019). The area enjoys a very favorable environment for developing shrimp, fish and seafood farming for export. The application of advanced technologies in aquaculture, marine and coastal aquaculture has turned fisheries into a strong economic sector.

According to photo-interpretation provided by the Vietnam Academy of Science and Technology, the entire studied area covers nearly 378,000 hectares, agricultural land area representing 54,000 ha (14.3%) (Fig. 1). The area of wet rice cultivation covers more than 33,000 ha, making up 61.4% of the agricultural land. Wet rice land is mainly concentrated in the districts of Quang Yen, Mong Cai, Tien Yen, Uong Bi and Ha Long city (Tong *et al.*, 2020). Mangroves are mainly concentrated in the Quang Ninh province with 14,400 ha covered, the Hai Phong province owning only 3500 ha near the mouth of the Van Uc River and Cat Ba Island (Bui *et al.*, 2014).

According to provinces statistics (Naganuma, 2014), the area of abandoned shrimp ponds in the studied region is about 15,000 ha, of which, 9,100 ha belong to Quang Ninh and 5900 ha belong to Hai Phong. Meanwhile, the lagoon area being used for aquaculture/seafood is nearly 21,000 hectares, accounting for 38.6% of the agricultural land. The services provided by wetlands are also reflected in the potential for aquaculture, with 13,000 ha of ponds, lakes, and low-lying fields that can be developed for intensive farming. Areas with great potential for aquaculture are Quang Yen town (7500 ha), Mong Cai-Dam Ha coastal strip (5500 ha), Van Don district (3300 ha), Van Ucestuary (2000 ha), and Tien Yen district (1400 ha) (Dang *et al.*, 2020).

The sea dyke system in the northeastern coast of Vietnam has a length of 22.85 km, with 9.7 km (42.35%) of sea dyke with mangrove protected forests and 13.15 km of sea dyke (57, 55%) without mangroves protection (Le, 2015). The planting of mangrove forests to protect the sea dykes in the study area is currently being implemented by many national and international organizations. Mangrove systems not only minimize marine disasters but also play an important role in accumulating soil carbon and creating annual coastal livelihoods.

2.2 Identification of wetland ecosystems

As mentioned in the Government's Decree No. 66/2019/ND-CP in 2019, Decision No. 1093/QD-TCMT of the Vietnam Environment Administration, and the Ramsar Convention, wetlands are defined as “peatlands, permanent or temporary inundated areas, including coastal areas and islands, with a depth of no more than 6 meters at the lowest tide” (Ramsar

[1] https://www.gso.gov.vn

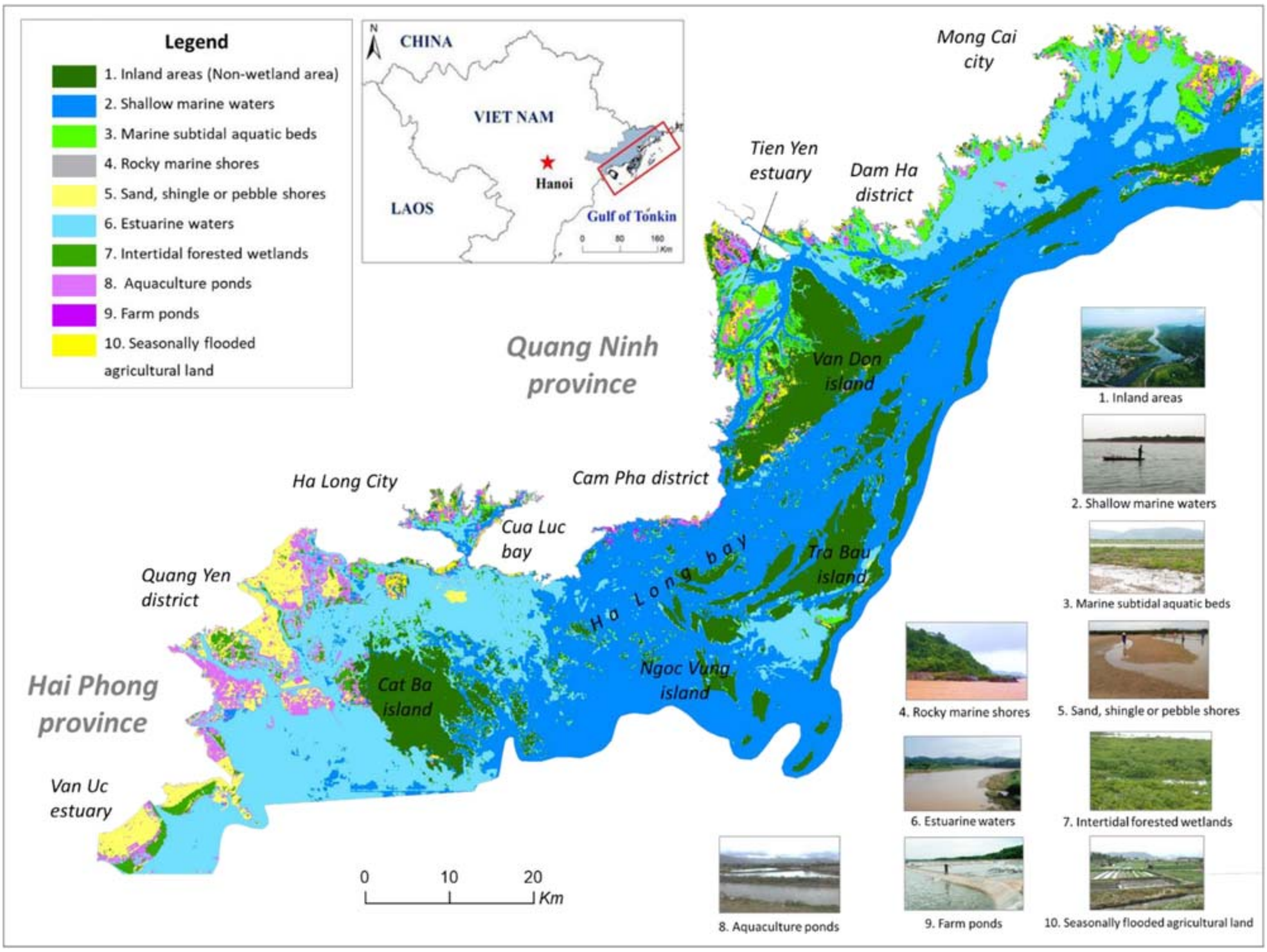

Fig. 1. Wetland ecosystems in the northeastern part of Vietnam (adapted from (Dang *et al.*, 2020)).

Convention Secretariat, 2016). According to the above definition, wetlands are defined as the ecological transition zone between the terrestrial environment and the submerged environment where the typical flora and fauna can develop (Maynard *et al.*, 2015; RAMSAR, 2010).

Based on the MONRE classification system and the RAMSAR convention (Tab. 1), the coastal wetland ecosystems are classified into 19 types, including 12 types of natural wetlands and seven types of human activities. Irrigated land and seasonally inundated agricultural land were grouped into one category (Hoang and Le, 2006). In this study, we only focused on 10/19 types of natural wetlands as the remaining nine types are mainly found in the southern regions and island systems. In addition, objects with narrow width, difficult to identify on remote sensing images, such as canals, drainage canals, small ditches were also discarded.

The daily tidal water level in the study area ranges from three to four meters, and the shoreline in the topographic map of Vietnam is determined at the mean tidal range. Therefore, the contour line of the highest boundary wetland areas will be two meters long. In topographic maps, the lowest value of the inland contour before reaching the coastline is 2.5 m. The distance from these contour lines to the coastline is less than 10 m. Therefore, we chose the isometric line 2.5 m deep as the deepest boundary of the wetlands. In addition, the offshore boundary is limited to "6" meters below sea level according to the wetland classification system of RAMSAR and MONRE.

We developed a deep learning tool named the ResU-Net model for wetland classification in the research area. The model was built based on the integration of two deep learning networks called Restnet and U-Net (Dang *et al.,* 2020). The ResU-Net model uses Sentinel-2, ALOS-DEM and NOAA-DEM remote sensing images as input data to identify the location of nine coastal wetland ecosystems in 19 types of the RAMSAR and MONRE classification systems. After training and testing processes, the accuracy of the outcomes reaches more than 90% (Dang *et al.,* 2020), especially for forested intertidal wetlands, aquaculture ponds and farms. Once optimized, the ResU-Net model was also used to accurately map coastal wetlands in the Northeast of Vietnam. Results are presented in Figure 1.

2.3 Monetary valuation of wetland ecosystem services

In addition to the use of the ResU-Net model for wetland ecosystems classification, different methods were applied to monetarize WES, including: interview, remote sensing, ecological modeling (InVEST), and cost benefit analyses. According to Champ *et al.* (2003), Turpie *et al.* (2010) and Vo *et al.* (2012),

Table 1. Wetlands classification system for the Northeastern part of Vietnam , based on RAMSAR, MONRE, modified from (Dang *et al.*, 2020; Guo *et al.*, 2017; Hoang and Le, 2006).

No.	Eco.	Coastal Wetland types	Classification systems		
			Northeastern part in Vietnam	MONRE	RAMSAR
1	Natural Wetland	Permanent shallow marine waters	x	x	x
2		Marine subtidal aquatic beds	x	x	x
3		Coral reefs		x	x
4		Rocky marine shores	x	x	x
5		Sand, shingle or pebble shores	x	x	x
6		Estuarine waters	x	x	x
7		Intertidal mud, sand or salt flats		x	x
8		Intertidal marshes		x	x
9		Intertidal forested wetlands	x	x	x
10		Coastal brackish/saline lagoons		x	x
11		Coastal freshwater lagoons		x	x
12		Karst and other subterranean hydrological systems			x
13	Man-made wetland	Aquaculture ponds	x	x	x
14		Farm ponds	x	x	x
15		Irrigated land	x	x	x
16		Seasonally flooded agricultural land		x	
17		Salt exploitation sites		x	x
18		Canals and drainage channels, ditches		x	x
19		Karst and other subterranean hydrological systems			x

the WES valuation was processed in three steps which include identifying economic value types (Step 1), valuating each WES (Step 2) and valuating total WES (Step 3) in the research area.

2.3.1 Identification of economic value types of ecosystem services

The process of identifying the different types of economic values obtained from the ecosystems (*e.g.* Almeida *et al.*, 2018; Haines-Young, 2011; Pennington *et al.*, 2017; Zhou *et al.*, 2020) is developed in Figure 2. We also took into account consultation of experts, local officials and people. These consulted persons included 23 ecologists and scientists in geography and environmental economics, and 16 local officials directly interviewed from the Agriculture, Urban Planning and Cadastral Departments of the District People's Committees. The scientists and local officials played an important role in assessing and validating all questions, criteria and procedures established before initiating the interview process. The interview process was done in a face-to-face form with 15 main questions related to different kinds of local livelihoods in wetland ecosystems (Tab. 2). Each question includes a few sub-questions related to income and expense of local people from direct and indirect benefits obtained from the wetland ecosystems. Lastly, four important groups of economic values were classified in the study area (Fig. 2). These groups correspond to direct and indirect use values, option values and non-use values. Indirect use value and existence values were directly collected from regulators; while most of the direct, option and bequest values were collected from local people.

The surveys and interviews in this study were conducted after the second outbreak of Covid-19 in Vietnam, so the research team encountered some difficulties related to people's reluctance to interact with strangers. In addition, the people in some places such as Tien Yen and Dam Ha are not well educated, so that many of them did not fully understand the content of the questions. In order to minimize falsity in collecting information, the interviewers were accompanied by local officials during the interviews for help in explaining the questions asked to people.

The interview process was conducted in seven regions of the northeastern part of Vietnam. 672 households with wetland and tourism-based livelihoods were interviewed directly. In addition to the detailed information on economic values mentioned above, the households were also asked to confirm or supplement other benefits obtained from the local wetland ecosystems. To cover all local likelihood features in the wetland, the interview process received helps from local officials to select typical households. Accordingly, all interviewees provided all information about their income and expense from their production. This information was pre-processed and used to calculate all WES values. The values of each WES were chosen based on median values of interviewed data after transforming all data to normal distribution.

2.3.2 Direct Use Values (DUV)

In this study, the use value is the value that individuals receive from natural resources of wetland ecosystems, directly or indirectly. Use values included: direct, indirect and option values (Chen *et al.*, 2009a; Sannigrahi *et al.*, 2019). Accordingly, the direct use values from wetland ecosystems were obtained from six main sources including (1) wild fishing captures, (2) aquaculture production, (3) aquatic bird production, (4) wet rice production, (5) beekeeping (or apiculture), and (6) tourism and recreation. Different equations to evaluate six WES types are presented in detail below based on guidelines from Defra (2007), Newton *et al.* (2012), and

Table 2. The list of 15 main questions related to different kinds of local livelihoods in wetland ecosystems.

No.	Question
1	What manufacturing sector are you currently working in?
2	Where is your working area?
3	What are the economic values you get from fishing?
4	What are the costs you have to pay for fishing activity?
5	What are the economic values you get from aquaculture?
6	What are the costs and benefits from selling your aquaculture breeds?
7	What are the costs and benefits from selling your aquatic birds?
8	What are the costs and benefits from selling your aquatic bird breeds?
9	What are the costs and benefits from your rice farming activities?
10	Can you list the costs of planting mangroves in the locality?
11	What is the frequency and volume of firewood extraction in the mangrove area?
12	What are the costs and benefits of beekeeping around your mangrove area?
13	What is the frequency and volume of collection of medicinal herbs in wetlands?
14	How much money would you like to contribute to conserve, restore and develop the resources of the current wetland landscape?
15	How much money would you like to contribute to conserve, restore and develop the resources of the wetland landscape for future generations?

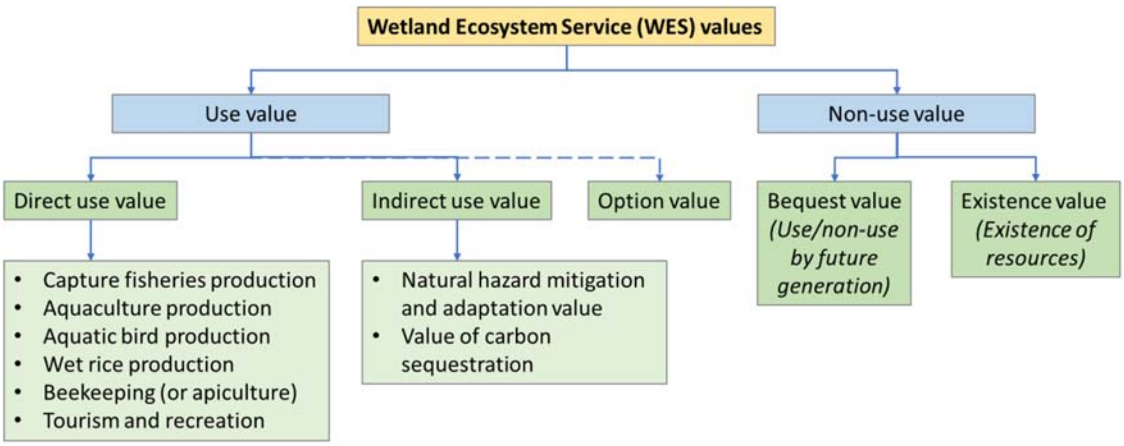

Fig. 2. Groups of economic values for wetland ecosystems in the northeastern coastal area of Vietnam.

Pascual *et al.* (2010). The process of data collection and calculation of economic values from these types of services are discussed in this section.

2.3.2.1 DUV_1 – wild fishing value

Fishing is mainly done in estuarine, intertidal and mangrove areas. The aquatic species there include: (1) Molluscs such as scallops, cockles, snails, mussels and cephalopods; (2) Crustaceans such as shrimps and crabs; (3) fishes such as gobies; and (4) other types of seafood such as earthworms (Yee *et al.*, 2014). To calculate the ability of wetland ecosystems to provide natural seafood resources throughout the area, the following formula was applied:

$$DUV_1 = \sum_{i=1} \left(H.n_i.([q_i.m_i + p_i.k_i] - C_i) \right) \qquad (1)$$

where i is the ordinal number of the caught species; H is the total number of fishermen; n_i is the percentage of the exploiters of the species i (%); q_i is the catch volume of species i per person in the season (kg/person/year); p_i is the catch volume of species i per off-season person (kg/person/year); m_i is the cost of 1 kg of species in the season (million VND); k_i is the cost of 1 kg of species in the off-season (million VND); C_i is the cost of fishing gear in 1 year (million VND).

2.3.2.2 DUV_2 – aquaculture value

Regarding aquaculture, local people focus on farming in ponds, tidal flats, estuaries and mangroves. Currently, there are two popular farming methods: extensive farming and industrial farming, in which shrimps, sea crabs, fishes and mollusks are commonly farmed (Bayne, 2017; Froehlich *et al.*, 2017; van Oudenhoven *et al.*, 2015). To calculate the ability of wetland ecosystems to provide marine resources through farming, the following formula was applied:

$$DUV_2 = \sum_{i=1} \left(S.n_i.[NS_i.p_i - C_i] \right) \qquad (2)$$

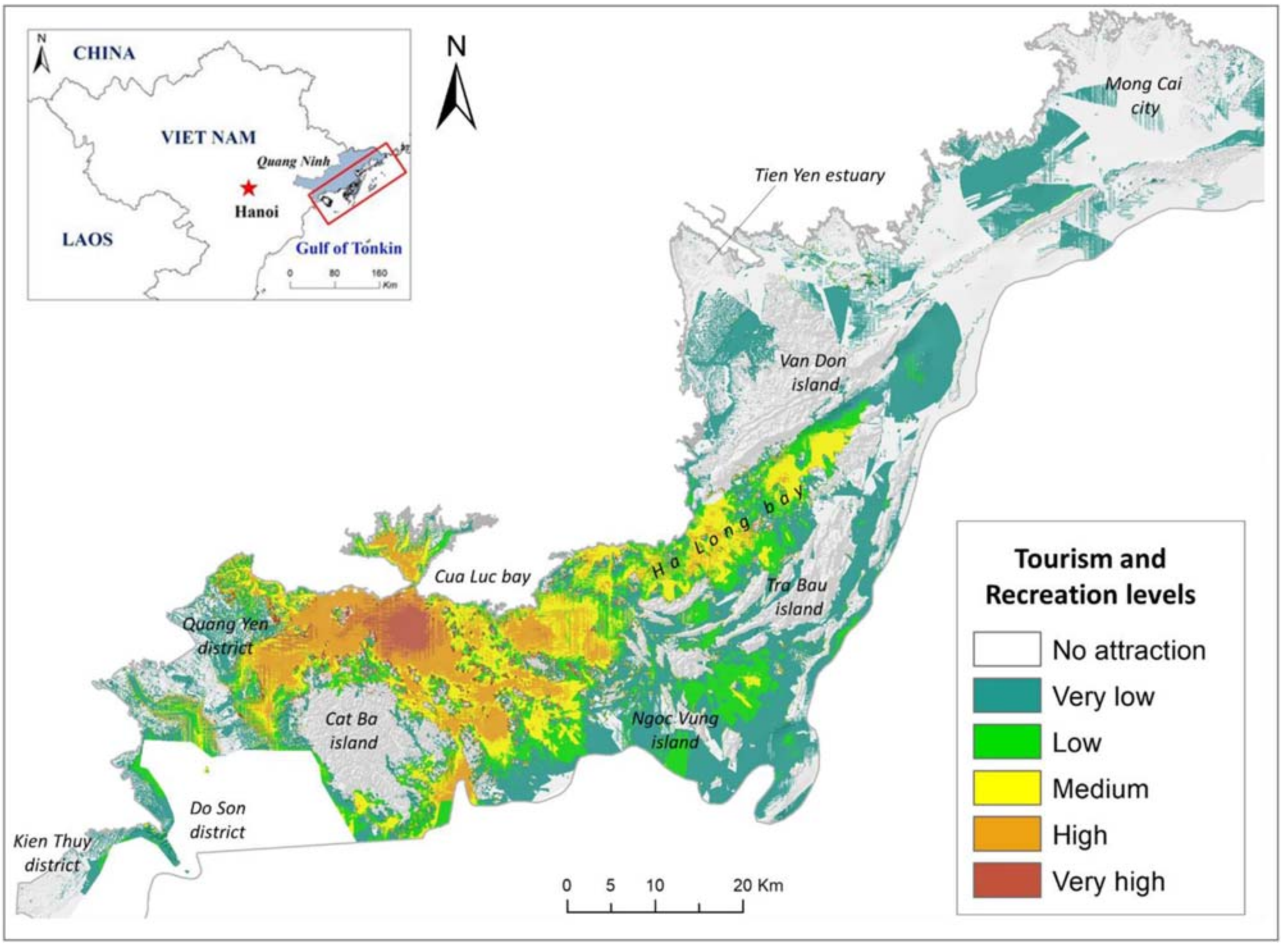

Fig. 3. Tourism and recreation values from wetland ecosystems in the northeastern part of Vietnam.

where i is the ordinal number of farmed species; S is the aquaculture area (ha); n_i is the percentage area used for species i (%); NS_i is the yield of species i in 1 ha/year (kg/ha); P_i is the market price of 1 kg of species i (million VND); C_i is the aquaculture investment cost of species i in 1 year (million VND).

2.3.2.3 DUV_3 – aquatic poultry value

People in the northeastern coast of Vietnam take advantage of mollusks, plankton, shrimps, juveniles of fishes living in mangrove ecosystems, tidal flats and estuaries for waterfowl farming. The estimation of the economic value was calculated by the following formula:

$$DUV_3 = \sum_{i=1} (T.n_i.[W_i.p_i - C_i]) \quad (3)$$

where i is the ordinal number of farmed aquatic birds; T is the total number of aquatic birds in the whole area; n_i is percentage of i aquatic bird type (%); W_i is the meat weight of i aquatic-bird type (kg); P_i is the market price of 1 kg of i aquatic-bird meat (million VND); C_i is investment cost of i aquatic bird farming in one year (million VND).

2.3.2.4 DUV_4 – value of agricultural cultivation in wetlands

The northeast coastal region enjoys great values from wet rice cultivation (Naganuma, 2014). The following formula was used to calculate the value of agricultural production in wetlands:

$$DUV_4 = S.(NS.P - C) \quad (4)$$

where S is the total area of wet rice cultivation in 1 year (ha); NS is the yield of rice obtained per 1 ha in 1 year (quintal); P is the market price of 1 quintal of rice (million VND); C is the investment cost of rice cultivation of 1 ha per year (million VND).

2.3.2.5 DUV_5 – beekeeping value

The expansion and protection of the mangrove system not only helps in regulating the air quality and storing carbon, but also helps people taking advantage of the flowering season to develop beekeeping and collecting honey (Davis *et al.*, 2017; Hardman *et al.*, 2016). When mangrove apples and large-leafed orange mangrove bloom in the summer, bees can enjoy a favorable condition to grow. On average, each year, a flock of bees can bring households 15–20 liters of natural honey. With an average price of 4.5 USD/liter, the income from selling honey is about 4500–7000 USD/year. In addition, households receive income from selling bees for about 45 USD/flock. Taking the advantage of the available coastal mangroves, beekeepers do not have to incur the expense of planting flowering trees to feed the bees. The value of beekeeping in mangrove forest is calculated by the following formula:

$$DUV_5 = T.(SL.P - C) \tag{5}$$

where T is the total number of swarms of bees in the whole area in a year; SL is the honey production of a swarm of bees per year (liter); P is the market price of 1 liter of honey (million VND); C is the investment cost of beekeeping for a flock per year (million VND).

2.3.2.6 DUV_6 – tourism and recreation values

In cultural ecosystem services, tourism and recreation values have become the largest sector in the world (Kubalíková, 2020; Nahuelhual *et al.*, 2013). For example, tourism and recreation have provided more than 280 million jobs and produced nearly 10% of the global gross domestic product in 2015 (Pröbstl-Haider, 2015).

In the study area, the calculation of cultural services and natural entertainment values was based on visiting fees and the revenue of the local ecotourism industry. Potential costs of tourists, citizens and other stakeholders in this sector include: ticket fee for tourist attractions, environmental protection fee, fee for marine waste collection, and other service fees. Total tourism value was collected from the economic departments of coastal communes and districts in 2019; the aim was to avoid irrelevant information from the COVID-19 crisis in 2020 during the assessment process.

The InVEST tool is an application to quantify the value of ecosystem services including sub-models (Posner *et al.*, 2016). In order to quantify the tourism and recreation values in particular sub-regions, the authors integrated the "recreation and tourism" and "Scenic quality" models in the InVEST tool (Ma *et al.*, 2016; Posner *et al.*, 2016). The "Recreation and tourism" model provides the level of entertainment and tourism of indigenous peoples and tourists, based on how often photos taken in the research area are uploaded from the internet and on their accessibility to tourist destinations. It is assumed that higher numbers of uploaded photos can traduce attention of visitors. Besides, the "scenic quality" model provides the locations where visitors can observe the landscape. The output of the "recreation and tourism" model is based on the "scenic quality" model. The selected maximum radius from the place where the photos were taken is 8km. The final output from these two models is the attractiveness of wetland ecosystems to visitors as shown in Figure 3.

Tourism and recreation value of each ecosystem (T) are calculated as follows:

$$T = \frac{DUV_6}{\sum_{i-1}^{n} (L_i.A_i)}. \tag{6}$$

In which, DUV_6 is the total tourism and recreation value collected from the interview and statistics, L_i and A_i are the wetland ecosystems attractiveness values (Fig. 3) and their respective surface area.

2.3.3 Indirect use value

2.3.3.1 IUV1 – disaster protection value

Coastal protection systems such as dykes and embankments are often constructed to separate agricultural and rural settlements from mangrove and shallow water ecosystems (Cooper *et al.*, 2016). In the study area, the sea dykes are entirely within the mangrove area. The coastal protection value also comes from the mangrove ecosystems located outside the dykes. Sea dykes protect inland ecosystems from storm surges and rising water. All resources inside the dyke are protected, and people's lives are guaranteed (Naganuma, 2014).

The construction cost of the coastal protection works was obtained locally from investment capital sources: district, provincial and central budgets. The project's objectives were to invest and develop sustainable coastal protective mangroves, improve forest coverage, use mangrove land effectively, create protective mangrove forests along the sea dyke's corridor to ensure national security, protect the ecological environment, and create jobs and improve living standards for local people living in coastal areas of Quang Ninh and Hai Phong provinces. These investment-related databases were collected from the People's Committees of districts and provinces. From 2015 to 2019, the whole region had 22 projects to build anti-erosion embankments, river dikes, and to repair irrigation reservoirs for disaster prevention. The total investment value was around 87 million USD. In addition, other 13 projects with an investment value of 54 millions USD were done effectively for environmental protection and mangrove ecosystem restoration (Trung Thanh *et al.*, 2021). All of these projects are documented in writing as well as officially announced in decisions at national and province levels. Accordingly, the total disaster protection value in the research area during five years is 141 million USD. However, all embankments, dams, dykes, culverts, canals, ditches, ports are considered as level 2 constructions (according to Circular 162/2014/TT-BTC (MOF, 2014) of the Ministry of Finance dated November 6, 2014). They have a service life of 20 years with a wear rate of 5% in 1 year. Therefore, the total cost for coastal protection was divided by 20 to calculate this value for 1 year.

2.3.3.2 IUV_2 – carbon sequestration value

Carbon storage and sequestration have been considered as an indicator of global climate regulating services in various studies (Ghaley and Porter, 2014; van Oudenhoven *et al.*, 2015). The carbon sequestration is an important ecological function of wetland forests. The Kyoto Protocol limits the amount of carbon emissions, creating a carbon market through the Clean Development Mechanism (Corbera and Brown, 2008). Various studies have been made to value wetland ecosystems contribution to carbon sequestration. Therefore, we collected the carbon sequestration values in wetland ecosystems from former studies. Particularly, Murray and Pendleton (2011) published a useful review about the carbon sequestration of different wetland ecosystems in different countries.

According to the Forest Carbon Partnership Facility (FCPF), the payment for carbon sequestration of the forest ecosystems is 11 USD/ton CO_2 (Angelsen *et al.*, 2013; Hilton, 2018). Based on the willingness to pay of related factories for the carbon sequestration, the cost that these factories have to

Table 3. Value of carbon sequestration of each wetland ecosystem in the northeastern part of Vietnam. The average price of carbon sequestration is 11 USD/ton CO_2.

Wetland ecosystems	CO_2 sequestration (ton/ha/yr)	Total price (USD/ha/yr)	References
Permanent shallow marine waters	4.4	48.4	(Sondak and Chung, 2015)
Marine subtidal aquatic beds	5.54	60.94	(Murray and Pendleton, 2011)
Rocky marine shores	0	0	
Sand, shingle or pebble shores	7.97	87.67	
Estuarine waters	2.64	29.06	(Dean and Gorham, 1998)
Intertidal forested wetlands	6.33	69.63	(Murray and Pendleton, 2011)
Aquaculture ponds	5.5	60.5	
Farm ponds	5.5	60.5	
Seasonally flooded agricultural lands	1.2	13.2	(Arunrat and Pumijumnong, 2017)

pay for 1 ton of CO_2 in the forestry sector is 258,650 VND, equivalent to about 11 USD/t CO_2. USD/VND (with exchange rate: 1 USD = 23,250 VND in February, 2020) (Decision No.99/2010/ND-CP, 2010). This value is multiplied with the amount of carbon sequestrated from wetland ecosystems to achieve the total price per hectare in a year (Table 3). This information was used as the input data to evaluate the carbon sequestration in the northeastern part of Vietnam.

2.3.3.3 *IUV_3 – optional values*

The optional value is the value measuring the willingness to pay (WTP – Willingness To Pay) for an individual wishing to conserve, restore and develop resources of the wetland ecosystem (Doherty *et al.*, 2014). The optional value is difficult to be evaluated in terms of money because it depends heavily on the subjective opinions of each individual and the economic situation of the household. However, we calculated this option value, based on our interview results that allowed to obtain the level of people's regular payments for environmental issues. The optional value was calculated using the following formula:

$$IUV_3 = \sum\nolimits_{i=1}^{8} (M_i \cdot P_i \cdot H) \tag{7}$$

where i is the payment level (million VND); Mi is the average payment value made by a contributor at level i (million VND); The contribution levels of this fund are divided into 8 levels including: (1) no payment; (2) less than 1 USD / year; (3) 2 USD / year; (4) 3 USD / year; (5) 4 USD/year; (6) 5 USD/year; (7) from 6 to 40 USD/year; (8) over 40 USD/year. P_i is the percentage of the population who pay at level i. H is the total population of a district/region.

2.3.4 Non-use values (NUV)

The level of biodiversity and the social and cultural significance of ecosystems are often reflected in non-use values (Wam *et al.*, 2016), and were integrated into two main value groups: bequest value and existence value which are discussed in below.

2.3.4.1 *NUV1 – bequest value*

The bequest value was proposed to determine the capacity to preserve, restore and develop wetland resources for future generations (Diafas *et al.*, 2017). This is also a value that needs to be assessed through the people's willingness to pay for future generations. The method to get and process information is similar to that of the optional value mentioned above. The formula for calculating the bequest value of the district/region was calculated as in equation (7).

NUV2 – existence value

Existence value is the value that lies in the perception, feeling and satisfaction of an individual when knowing the properties of existing wetlands in a certain state and is often measured by the willingness of each individual to pay to achieve that state (de Groot *et al.*, 2018). This value is measured based on a combination of grants from national and international nature conservation organizations during the year (Newcome *et al.*, 2005; Wolff *et al.*, 2015). In this study, data on investment projects aimed at conserving natural resources were collected from the People's Committees of districts and provinces in the last 5 years. The aid and investment capital sources are from the district, provincial and central budgets, and domestic and foreign units and organizations such as World Bank and Official Development Assistance (ODA) in the Climate Change Response Programs and Forest Protection and Development Program 2011-2020 (57/QD-TTg, 2010). All these funds were divided by the number of years to calculate the value for each year.

2.3.5 Total Ecosystem Service Value (ESV)

The assessment of the entire wetland ecosystem includes direct, indirect, optional and non-use values. Accordingly, the total value of ecosystem services was calculated by the following formula:

$$ESV = \sum_{n=1}^{6} DUV_i + \sum_{m=1}^{3} IUV_i + \sum_{i=1}^{2} NUV_i. \tag{8}$$

ESV values were calculated for the seven economic regions of the northeast Vietnam region, as well as for the entire region. Based on the total value and area of each ecosystem, we calculated the ESV value for each ecosystem per hectare. After combining ecosystem distribution maps for years 2000, 2005, 2010, 2015 and 2019 and the statistics of the

Table 4. Ecosystem service values of each wetland types in the northeastern part of Vietnam in 2019 (Unit: Thousand USD per year).

Ecosystem service value	Total value	Ecosystems						
		Shallow marine waters	Marine subtidal aquatic beds; and Sand or shingle shores	Estuarine waters	Intertidal forested wetlands	Seasonal flooded agriculture lands	Aquaculture and farm ponds	Rocky marine shores
A - Direct use value (DUV)	*352.465,67*	*65,596.33*	*115,146.34*	*67,502.18*	*5,659.91*	*56,057.06*	*42,503.85*	-
Value of capture fisheries production	71,026.22	2,697.20	32,366.38	30,568.25	5,394.40	-	-	-
Value of aquaculture production	72,325.10	-	19,880.83	5,484.37	-	4,456.05	42,503.85	-
Value of aquatic bird production	3,237.21	-	-	-	-	3,237.21	-	-
Value of wet rice production	48,363.80	-	-	-	-	48,363.80	-	-
Beekeeping (or apiculture)	265.52	-	-	-	265.52	-	-	-
Tourism and recreation	157,247.83	62,899.13	62,899.13	31,449.57	-	-	-	-
B - Indirect use value (IUV)	*23,962.49*	*9,360.52*	*8,205.88*	*3,269.53*	*1,250.13*	*614.06*	*1,262.38*	-
Natural hazard mitigation and adaptation value	4,397.58	-	2,110.84	2,110.84	-	175.90	-	-
Value of carbon sequestration	19,564.92	9,360.52	6,095.04	1,158.69	1,250.13	438.16	1,262.38	-
C - Option value	*4,024.80*	-	*804.96*	-	*2,414.88*	*402.48*	*402.48*	-
Option value	4,024.80	-	804.96	-	2,414.88	402.48	402.48	-
D - Non-use value (NUV)	*12,354.74*	-	*763.35*	-	*9,883.79*	*1,707.60*	-	-
Bequest value	3,816.76	-	763.35	-	3,053.41	-	-	-
Existence Value	8,537.98	-	-	-	6,830.39	1,707.60	-	-
Total WES value	*392,807.71*	*74,956.85*	*124,920.53*	*70,771.70*	*19,208.71*	*58,781.20*	*44,168.71*	-
Area of wetland ecosystem (ha)	377,792.82	193,399.20	69,522.55	39,872.25	17,953.83	33,193.90	20,865.80	2,985.29
WES value per 1ha	1.04	0.39	1.80	1.77	1.07	1.77	2.12	-

Table 5. Ecosystem service values in seven regions of the Northeastern part of Vietnam in 2019 (Unit: Thousand USD per year).

Natural hazard mitigation and adaptation value	4,397.58	1,925.42	326.09	130.98	580.24	95.08	1,324.22	15.55
Value of carbon sequestration	19,564.92	4,504.26	1,153.04	2,532.43	4,670.11	1,318.16	1,473.79	3,913.12
C - Option value	*4,024.80*	*604.86*	*738.01*	*1,051.49*	*132.64*	*144.03*	*1,111.80*	*241.97*
Option value	4,024.80	604.86	738.01	1,051.49	132.64	144.03	1,111.80	241.97
D - Non-use value (NUV)	*12,354.74*	*1,029.57*	*626.32*	*1,022.80*	*7,175.56*	*248.26*	*1,143.09*	*1,109.16*
Bequest value	3,816.76	677.39	626.32	892.36	148.55	161.30	1,097.33	213.50
Existence Value	8,537.98	352.17	-	130.43	7,027.01	86.96	45.75	895.65
Total WES value	*392,807.70*	*71,376.81*	*36,838.67*	*70,403.64*	*83,399.82*	*19,546.13*	*57,833.86*	*53,408.78*
Area of administration regions (ha)	377,792.82	99,172.90	25,636.65	48,672.90	92,653.95	23,318.45	30,748.48	57,589.49
Total WES per 1ha in administration regions	*1.04*	*0.72*	*1.44*	*1.45*	*0.90*	*0.84*	*1.88*	*0.93*

province, the change of the total value of WES over the past 20 years was assessed by multiplying the ESV value of each ecosystem by their area each year.

The “Planning scenario” was proposed based on the decision 1588/QĐ-UBND (1588/QĐ-UBND, 2014) of the Quang Ninh and Hai Phong provinces. According to this decision, the agricultural lands can be narrowed to 29,000 ha, whereas the mangrove area and aquaculture lands can be increased respectively to 34,000 ha and 33,700 ha by 2030 to meet economic needs and protect the environment. Based on the areal changes, the economic value of ESV was calculated to estimate a development trend of the research area in the next ten years.

3 Results

3.1 ESV of each wetland ecosystem

The ESV of each wetland types per hectare in the research area in 2019 is shown in Table 4. The average WES value in one hectare reaches 1040 USD per year. Seven wetland ecosystems can be separated into three groups based on their economic benefits to humans. Particularly, the aquaculture and farm ponds in the first group provide the highest economic value (2120 USD/ha/year) according to high-technological aquaculture production, carbon sequestration and option values. The second group which includes (1) marine subtidal aquatic bed and sand/shingle shores, (2) estuarine waters, and (3) agricultural lands provide more than 1770 USD/ha/year. Based on high benefits from capture fisheries, intensive aquaculture production, tourism and recreation, the marine subtidal aquatic bed and sand/shingle shores provide about 1800 USD/ha/year. In the third group, although intertidal forested wetland ecosystems contain high potential benefits related to the IUV and NUV values, their areas are narrowed, leading to their WEV reaches 1,070 USD/ha/year. The shallow marine waters have the lowest WES value with 390 USD/ha/year with the benefits mainly from the tourism and recreation.

3.2 ESV in the northeastern part of Vietnam

The total WES value of all regions in the Northeastern part of Vietnam reaches more than 392 million USD/year (Tab. 5). This value mainly comes from the DUV value with 89% in total. The wetland ecosystems in Quang Yen district provide more than 1880 USD/ha/year, followed by those in Cam Pha district and Cua Luc bay with more than 1440 USD/ha/year. The other regions provide from 700 to 900 USD/ha/year. The wetland ecosystems from Mong Cai city to Van Don district, mainly represented by rocky marine shores and narrow estuaries provided the lowest WES value. In contrast, the local people in Quang Yen and Cam Pha districts receive large incomes from fisheries and aquaculture production, tourism and recreation, leading to the highest WES value.

3.3 Changes of WES during twenty years

Based on the land use/cover maps from the years 2000 to 2019 and the average use value from each wetland ecosystem, the fluctuation of use value over 20 years is depicted in Figure 4. The degradation of the use value is a result of the conversion from traditional agricultural and aquaculture production to intensive ones. In general, the total use value in the northeastern part of Vietnam has decreased since 2005, although the economic values of intensive aquaculture farming activities have significantly increased. In particular, the incomes of aquaculture farmers increased from 9000 USD/year in 2005 to more than 45,000 USD/year in 2019. The total ESV obtained from the agricultural lands were increased from 25 million USD in 2000 to more than 40 million USD in 2019. In contrast, the area of agricultural ecosystems significantly decreased, leading to a concomitant decrease in their economic benefits from 73 to 59 million USD. The area of intertidal forested wetlands has decreased slightly from years 2000 to 2010, but has recovered since 2019. Therefore, intertidal forested wetlands values remained overall stable at around 19 million USD. In contrast to the reduction of use values in marine subtidal aquatic beds, sand/pebbles shores, and estuarine waters, the use value of aquaculture ecosystems increased more than twice from years 2000 to 2019. Based on the province’s planning, the expanding of the aquaculture lands and narrowing of agricultural lands although can increase the incomes of local people, the total ESV of whole region can be decreased about three percent, from 390 to 380 million USD.

4 Discussion

This study is the first to synthesize 11 types of wetland ecosystem services values for seven regions in the northeastern coastal strip of Vietnam. The evaluation of some direct values such as aquaculture, marine resources, medicinal plants and tourism was more complementary and up-to-date than that of other previous researches carried out in Tien Yen, Van Uc estuary

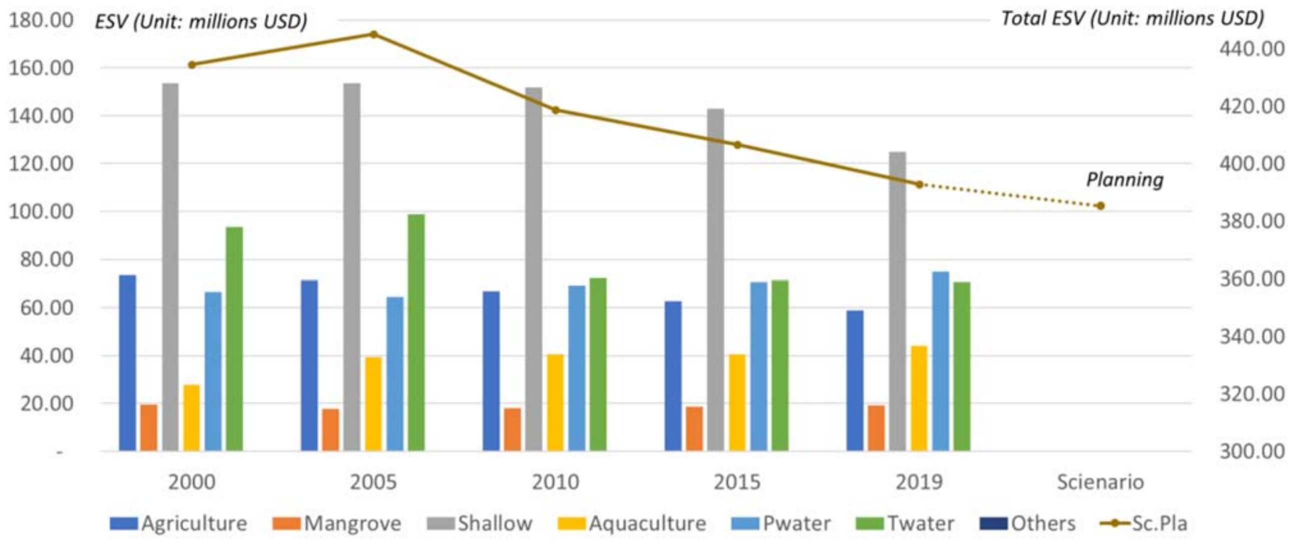

Fig. 4. Changes of use values obtained from wetland ecosystems over 20 years and prediction in province's planning till 2030 in the Northeastern part of Vietnam.

and some inland wetland ecosystems (McDonough *et al.*, 2014; Talberth, 2015). Specifically, the total economic cost of wetlands in Van Uc estuary estimated in this study is 0.93 thousand USD/ha/year, higher than the result of Mai *et al.* (2003) with the value of is 0.71 thousand USD/ha/year. The wetland area in the Dong Rui island in Tien Yen district brought 0.84 thousand USD/ha/year in this study, a value higher than the value of 0.75 thousand USD/ha/year calculated by Mai *et al.* (2003). The evaluations made in previous studies often lacked synchronization, especially with option, existence and circulated values, which decreased the ESV value of each ecosystem.

The results show that 100% of the interviewees are aware of the benefits and value of wetlands for their livelihoods. In the coastal wetlands from Quang Ninh to Hai Phong, the provided values included fisheries, tourism development, agriculture, livestock raising and beekeeping. In the Northern part of Vietnam, wetlands represent one of the four major fishing grounds of Vietnam, because hosting high species diversity and biomass. Fisheries are mainly concentrated in estuaries, canals, tidal flats, mangroves and ponds in the Quang Ninh – Hai Phong provinces. These fisheries include shrimps, crabs, fishes, squid, and other mollusks such as clams and mussels. Especially, the Van Don district has a favorable environment for mollusk species and has been planned to become the largest mollusk farming place in the Quang Ninh province. According to the interviews, current fishing activities have caused serious water pollution, especially in ports. The local people are aware of the limited coastal resources. However, it is necessary to have more studies to analyze the tourism and fishing capacities in this wetland area to minimize the effects of aquaculture and other economic development in the future.

Beekeeping in mangroves, together with fishing, is a new livelihood that helps local people earn high economic income. People in the northeastern coastal provinces of Vietnam not only develop and protect the mangrove forest system, but also take advantage of the flower season to exploit honey and create favorable conditions for the development of beekeeping in the mangroves. On average, each year, a colony of bees can bring each household 15–20 liters of natural honey. With an average price of 5 USD/liter, income from selling honey is about 5000–7000 USD/year, without considering the income from selling bees for 50 USD/swarm. Beekeepers are very conscious of the interest to protect mangroves to bring long-term and sustainable economic benefits. Therefore, taking care of bees has the same meaning as taking care of mangroves. In other words, the beekeepers play the same role as rangers.

In Quang Ninh province, agriculture is not the main economic sector (accounting for only 5% of the province's economic structure), but this sector has a decisive role in the life and socio-economy of local people. 70% of the interviewed households mentioned needing rice land to support daily activities. However, agricultural activities in rice cultivation tend to decrease due to low economic efficiency. Instead, people are gradually changing their crops structure from rice land to fruit trees and organic vegetables growing. In addition, the raising of aquatic birds in several districts is also getting more attention, especially commercial sea ducks raising as providing a great source of income for local people.

In terms of ability to regulate natural hazards, 65% of the respondents highly appreciated the role of wetlands in limiting flooding and soil erosion. However, due to the short and steep estuary system in Quang Ninh, the flow rate is high and often causes soil erosion, increasing the amount of silt and rock, especially during big floods. Such silt and rock in many places fill up rivers and streams very quickly, especially in areas with coal mining activities such as in the Mong Duong River, the Cam Pha city and Quang Ninh province. Consequently, investment projects for environmental protection and disaster prevention are planned during the next 5 years with huge capital sources ranging from several billions to trillions of VND. The use value of these future infrastructures is classified as 2nd level architecture, so that they will be used for 10–20 years with a depreciation value of 5–10% according to Circular No. 45/2018/TT-BTC dated May 7, 2018

(MOF, 2018) and Circular No. 162/2014/TT-BTC of the Ministry of Finance dated November 6, 2014 (MOF, 2014). It is important information to calculate correctly the ESV value for all constructions in one year.

Concerning transmission and option values, they are measured based on the "subjective" answers from local people. Therefore, it is difficult to evaluate their monetary values. In this study, the level of households' willingness to pay for current and future goals was used to evaluate these values. Results partly reflect people's perception of the role of wetland ecosystems in local life and environmental protection. 48% of interviewees whose livelihoods depend directly on wetlands agree to make financial contributions to conservation, restoration and development of local resources activities. Meanwhile, 52% of interviewees have doubts about the province managers' performance, therefore disagreeing to contribute to sustainability development activities in the wetland areas.

5 Conclusions

Based on the integration of different quantitative methods, the economic benefits obtained from seven wetland ecosystems in the northeastern part of Vietnam were clearly valuated. 11 service types could be identified in the wetland ecosystems. The local people in the research area received the largest economic benefits from the marine subtidal aquatic and sand/shingle ecosystems. On a per-hectare basis, the aquaculture ecosystems provide the highest value, whereas the shallow marine waters provide the lowest value. In 2019, the wetland ecosystems in the northeastern part of Vietnam are worth the equivalent of over 390 million USD per year. This value was reduced by nearly 15% since the year 2000, and can decrease three percent more by 2030 if the planning of the local managers is completed. To avoid this degradation of ESV in the future, the economic development in the research area requires an improvement of the indirect use values, especially in the marine subtidal aquatic bed, estuarine, and intertidal forested wetland ecosystems, toward a balance between environmental conservation and economic development. The methods and outcomes of this study can be applied for other wetland areas in Vietnam, as well as in other countries in the future.

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