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Proposition of Economic Valuation Index for Sustainable Ecosystem Management: An Island Case Study in Vietnam

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Abstract: Economic valuation indices of ecosystems in Con Co Island, Vietnam were developed for translating scientific results into management and user friendly systems. Main methods employed for the study are indicator and index development published worldwide. With data set collected for years in the study area, indices were proposed and calculated using three sub-indices, including direct use value index (*Idev*) of factor 0.40, indirect use value index (*Iidev*) of 0.55 and non-use value index (*Inuv*) of 1 (one). A total economic valuation index (*Ieev*) of the coastal island ecosystem that composed of coral reefs, seagrasses and rocky reefs was calculated for 2015 based on the combination of *Idev*, *Iidev* and *Inuv*. At the scale of 100 points with *Ieev* between 50 and 100 points indicating the ecosystem in sustainable use and *Ieev* from 0 to 49 points presenting the ecosystem in sustainable use, *Ieev* for the coastal ecosystem of Con Co Island in 2015 was a factor of 65.1, indicating that the ecosystem was in sustainability. Developing these indices can well be applied for coastal ecosystems as beaches, mangroves, corals in Vietnam, particularly in regions of international importance like Ha Long Bay Heritage, Cat Ba Biosphere Reserve and etc.

Key words: sustainability, indices, coastal ecosystems, values

1. Introduction

The sustainability assessment of coastal and marine ecosystems is much helpful to support making policies, plans and actions for rational utilization and conservation of ecosystems toward coastal and marine sustainable management [1]. For recent decades, tools for assessment of sustainable use of ecosystems have been more and more developed, including the application of indicators and indices [2-4]. Ecosystem sustainability indices have often been developed based on the application of the DPSIR (Driver – Pressure – State – Impact – Response) framework and by combining sets of indicators of marine ecosystem characteristics like spatial distribution area, coral and seagrass living covers, qualities of water and sediment, values of ecosystem services, natural and human impacting factors on ecosystems, efforts of human being to conserve the nature, and etc. [3]. Recently, some more quantitative tools of developing sustainable use indicators and indices for sustainable management have been studied over the world. Based on the characteristics of socio-economic development, coastal ecosystems and environments, Lan (2009) proposed a set of 31 sustainable use indicators for marine and coastal ecosystems in Hai Phong–Ha Long area and adjacent region of Vietnam [5]. The set of the indicators showed the applicable potentials for the ecosystems in other coastal and marine areas. For marine spatial planning and ecosystem-based management, appropriate indicators of ecosystem services were selected and applied and showed how the ecosystem service concept being used in the planning and management [6]. Assessing ecosystem

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services to support the EU Biodiversity Strategy to 2020, a framework of indicators were proposed to potentially employed although data gaps remaining to be filled [7]. Stefanie et al. (2017) considered how to use the indicators of good environmental status for assessment biodiversity and ecosystem services at the same time in the European Union (EU) Region and concluded that, 247 of 296 biodiversity related indicators was as potentially useful ecosystem service indicators [8]. However, an ecosystem valuation index developed for assessment of ecosystem sustainable management is almost absent so far while it is a factor that may be important and easy understanding to managers and the public.

To quickly translate scientific information concerning current status of ecosystem economic values of Con Co Island to an easy understanding way to the public, managers, planners and policy makers, indices of ecosystem values were studied and developed. Therefore, in 2013-2015, with the study on economic valuation of coastal ecosystem (project KC09.08/11-15, 2014), the economic valuation index was developed in order for rapid estimation of coastal ecosystem sustainability of the Island. The indices calculated for Con Co ecosystem include: direct use value index (*Idev*), indirect use value index (*Iidev*) and non-use value index (*Inuv*) as well as index of the total ecosystem economic value (*Ieev*) which was used to estimate generally the real situation of ecosystem economic values of this Island.

2. Materials and Methods

Con Co Island is in the entrance of the Tonkin Gulf and makes part of North Central Vietnam. The Island extends over 220 ha of land above the highest sea level and 440ha including the intertidal zone. It hosts and has a population of 500 people (project KC09.08/11-15, 2014) excluding a number of people commuting daily to the Island for their business for sea products (no tourists and floating population allowed in the study area). Coastal ecosystems of the Island are sandy and rocky ones on the intertidal zone and rocky, coral ones in the submerged area to 30m deep. The study were carried out on the Island, covering marine areas to 30 m deep seaward. The intertidal zones (between the low water line and the highest tide level) are equally part of the study areas (Fig. 1). All ecosystems contributing to the economic valuation were selected.

Data used were mainly from the Vietnam national project, entitled “Economic valuation of marine and islandish typical ecosystems for sustainable development of some frontier islands in Vietnam coastal waters” (coded KC09.08/11-15) implemented during 2013-2015. The following datasets were used for developing valuation indices:

- Data on main characteristics of marine ecosystems and the biodiversity were from surveys during the period 2013-2015 with six transects (Fig. 1) for two seasons of Northeast wind and Southwest wind, covering the various coastal ecosystems of the Island. Ecosystem surveys were following the survey methods described by English et al. (1997). The spatial distribution of the ecosystems (in hectare) around the Islands was defined by a combination of remote sensing data and underwater surveys with SCUBA devices [9]. Data on species diversity were obtained from surveys for about past ten years and completed by underwater surveys in 2014-2015 [9].
- Data on monetary economic values of the ecosystems were from the project coded KC09.08/11-15 calculated following methods for environmental economic valuation of ecosystem services [10] for the services of Con Co coastal ecosystems in Table 1 [11].

The core method employed is the developing indicators and indices for ecosystem sustainable use [3]. To develop indicators and indices, model of total economic valuation is taken as a conceptual framework (Fig. 2). The indices are developed based on ecosystem indicators through mathematical functions or

expressions. The ecosystem indicators are chosen from the characteristics of an ecosystem [3, 12]. The method for calculating ecosystem economic indices of coastal waters in Con Co Island is summarized in Fig. 2.

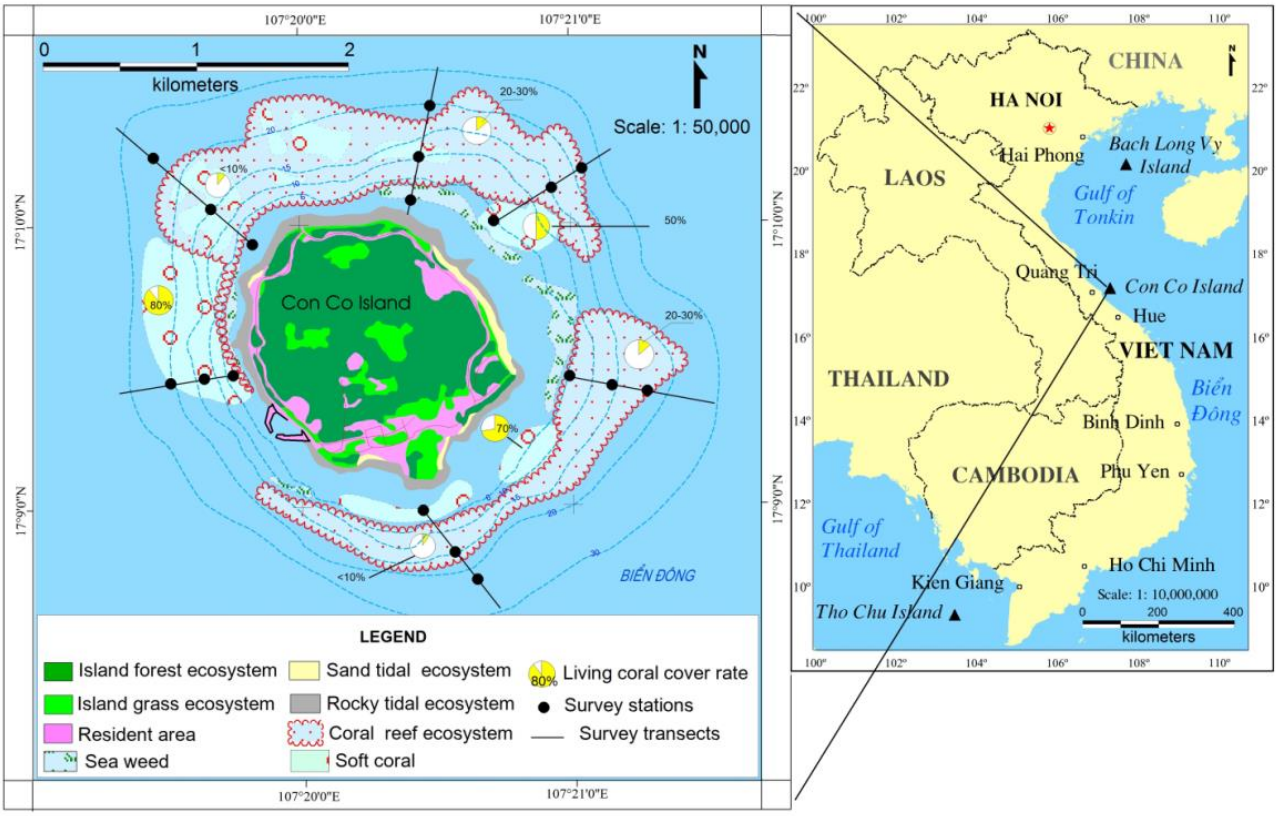

Fig. 1 Study area and survey stations (sources: KC09.08/11-15).

Table 1 Economic values of the coastal ecosystems surrounding Con Co Island for the period 2014-2015 [11].

Use value groups of ecosystem	Basic ecosystems	Use values	Value in VND (million/year)	Value in US Dollars (USD) (1 USD = 22,503.68 VND - rate May 1st 2015)
Direct use value	Tidal ecosystem	Sea food	6,398	284,309.06
	Coral and soft bottom ecosystems	Sea food	144,994	6,443,123.97
		Tourism	14,980	665,668.90
	Total		166,372	7,393,101.93
Indirect use value	Coral and soft bottom ecosystems	Coastal protection	23,012	1,022,588.31
		CO_2 absorption,	12	533.25
		Nutrient filter	45,418	2,018,247.68
		Biodiversity, nursery grounds, habitat	30,279	1,345,513.27
	Total		98,721	4,386,882.50
Non-use value	Coral and soft bottom ecosystems	Bequest, conservation, option	2,425	107,760.15

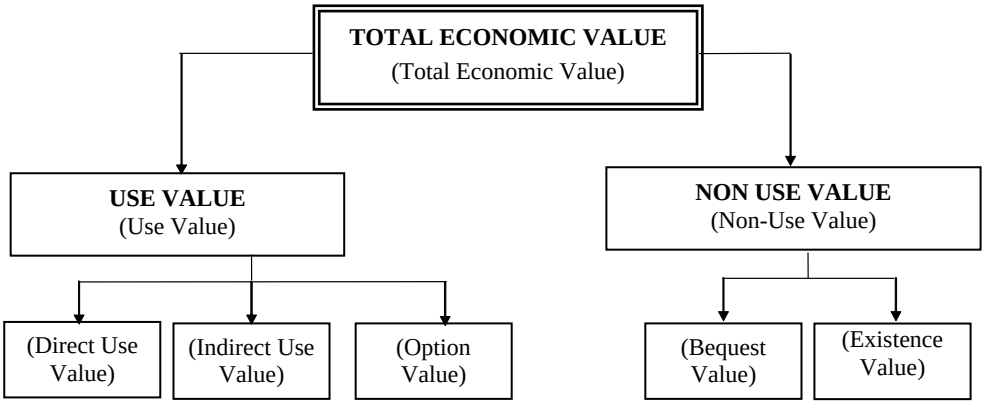

Fig. 2 The model of Total economic value of marine ecosystems in Con Co island [13, 14].

2.1 Direct Use Value Index (Idev)

Idev = (Ifood – Ifoodmin)/(Ifoodmax – Ifoodmin)*C1+ (Itour-Itourmin)/(Itourmax-Itourmin)*C2

Where:

C1, C2: the weight of indicators; *Ifood*: the value of food and non food (VND-Vietnamese currency); *Itour*: the value of tourism services (VND); *Ifoodmax*: the expected value of *Ifood* (VND); *Itourmax*: the expected value of *Itour* (VND); *Ifoodmin*: the minimum value of *Ifood* (VND); *Itourmin*: the minimum value of *Itour* (VND)

Itourmax and *Itourmin* were calculated by indicators when the values of ecosystems get maximum or minimum. The weight of indicators C_i is often estimated by 2 methods: assessing expert and mathematical expression. For this study area, however, on the assuming that the roles of ecosystems were equal for simplification, that means C_i = 1. Therefore, above formula will be:

Idev = (Ifood – Ifoodmin)/(Ifoodmax – Ifoodmin) +(Itour - Itourmin)/(Itourmax - Itourmin)

2.2 Indirect Use Value Index (Iidev)

Indirect use value index was also calculated in the same way as calculating direct use value index.

Iidev = (Icoast – Icoastmin)/(Icoastmax – Icoastmin)+ (Icarbon- carbonmax)/(Icarbonmax-Icarbonmin)+ (Ienvi-Ienvimin)/(Ienvimax-Ienvimin)+ (Inurs-Inursmin)/(Inursmax-Inursmin)

Where: *Icoast*: the value of coastal protection (VND); *Icarbon*: the value of accumulation of carbon (VND); *Ienvi*: the value of decreasing environmental pollution (VND); *Inurs*: the value of food, habitat for aquatic organisms (VND); *Icoastmax*, *Icarbonmax*, *Ienvimax* and *Inursmax*: the expected values of *Icoast*, *Icarbon*, *Ienvi* and *Inurs; Icoastmin*, *Icarbonmin*, *Ienvimin* and *Inursmin*: the minimum values of *Icoast*, *Icarbon*, *Ienvi* and *Inurs*. These values were also estimated by calculating directly each parameter.

2.3 Non-Use Value Index (Inuv)

Similar to the calculated methods of the two above indices, non-use value index of Con Co Island was also calculated with the formula below:

Inuv = (Ioev – Ioevmin)/(Ioevmax – Ioevmin)

Where: *Ioev*: the value of option, bequest and exist (VND); *Ioevmax*: the expected value of *Ioev* (VND); *Ioevmin*: the minimum value of Ioev (VND); *Ioevmax* and *Ioevmin* were estimated by calculating directly each parameter;

d. Index of the total ecosystem economic value

Ieev = 100*(Idev+Iidev+Inuv)/3

Where: *Ieev*: the index of the total ecosystem economic value.

3. Results

3.1 Overview of Coastal Ecosystem of Con Co Island

Coastal ecosystem of Con Co with total area of 870 ha composes of intertidal ecosystem (rocks and

beaches) and marine ecosystem (corals and underwater soft bottom) down to 30m deep. Intertidal ecosystem of poor biodiversity hosted few main organism groups of seaweeds (40 species) and invertebrates (53 species of polychaeta, mollusks, crustacea and echinodermata). Marine ecosystem with high biodiversity consisted of coral reefs (181 species) of 330 ha and maximum coral cover reaching 70-80 percent, and underwater soft bottom with muddy beds and seaweed (71 species), invertebrates (173 species). Environment qualities of water and sediment within the ecosystem were good with all environmental parameters meeting Vietnamese regulations (KC09.08/11-15).

The coastal ecosystem in Con Co Island is also affected by human activities for social economic development on the Island. Overfishing with about 150 fishing boats in waters around the island threatened coral reef damages (net fishing, anchoring) and depleted marine living resources. Pressure from tourism to be planned in 2020 to contribute 80% income to the district of Con Co and about 5,000 visitors in the Island is increasing on the ecosystem. Besides, the development of a harbor, resident areas and planned fishery service center on the Island will create more pressures on the ecosystems.

3.2 Identifying the Indices of Ecosystem Economic Values in Coastal Waters of Con Co Island

Ecosystem research results of coastal waters in Con Co have represented most value groups. However, option value has not been defined clearly (Table 2).

Indicators were defined based on the parameters that were established from the components contributing to ecosystem values, and indices were also developed from the values of the ecosystems of Con Co Island following the methods of developing indicator and index [3, 14].

Table 2 Summarizing ecosystem values of coastal water in Con Co Island [12].

Ecosystem values to be built as indices	Basic values to be built as indicators	The components contributing to value to be as parameters
Direct Use Value to be built as index of direct ecosystem values (Idev)	Fisheries, food and non-food to be built as *Ifood*	Living resources of tidal flat and wetland, including zoobenthos, marine fish, seaweed, seagrass and sea mammal
	Tourism to be built as *Itour*	Coral reefs-rocky ecosystem, beach sand, geological structure, island position
Indirect Use Value to be built as index of indirect ecosystem values (Iidev)	Coastal Protection to be built as *Icoast*	Coral reefs–rocky ecosystem
	Enhancing productivity of waters, carbon absorption to be built as *Icarbon*	Microorganism and seaweed in coastal waters (mainly seaweed)
	Decreasing environmental pollution of coral reefs to be built as *Ienvi*	Microorganism and seaweed in ecosystem and absorption of organics as well as nutrients
	Food, habitats for aquatic organisms to be built as *Inurs*	Waters around the island, coral reefs-rocky ecosystem
Non-Use Value to be built as index of non-use ecosystem values (Inuv)	Bequest, existence, option and quasi-option values to be built as *Ioev*	High valuable species, rare species, endangered species, coral reefs, rock, tidal area as habitats for many marine organisms.

3.3 Calculating Indicators and Indices of Ecosystem Economic Values in Coastal Waters of Con Co Island

3.3.1 Direct Use Value Index (Idev)

To get *Idev* value, *Ifood* and *Itour* need to calculate. In case of Con Co Island, *Ifood* was calculated from the economic values resulted from marine fish such as: anchovy, scads, codfish, cuttlefish, shrimp, crap,… and other species like: shellfish, arca on coral reefs — rocky ecosystem. Calculated *Ifood* of 0.85 seems to be an index representing fishery value. *Itour* was calculated from tourists who visited Con Co Island for a year and socio-economic characteristics as well as information on the study area. Calculated *Itour* of 0.08 shows tourism value that equals to 14,980 million VND per year in the period 2013-2015.

To calculate maximum and minimum values of the ecosystems in waters surrounding the Island, living

coral cover as a key parameter reached the highest of 47.3% (1996) and was only 25% in 2014. Also, some studies on living coral cover showed that the minimum cover of 10% would be maintained all functions of coral ecosystem [15, 16]. Then, the min and max values of indicators are defined (Table 3).

Table 3 The values of sub-indicators (million VND).

Ifoodmax	*Ifoodmin*	*Itourmax*	*Itourmin*
286.436	60.557	28.342	5.992

From the values of the above sub-indicators, *Idev* was calculated as a factor of 0.4 (scale from 0 to 1) or 40 at scale of 100 points.

3.3.2 Indirect Use Value Index

Iidev was estimated through four sub-indicators, including: *Icoast, Icarbon, Ienvi* and *Inurs*. In Con Co island, *Icoast* was calculated by replacement costs of constructing a sea dyke that protects island coast. Calculated *Icoast* was a factor of 0.13 representing coastal protection value of the ecosystems. *Icarbon* was calculated based on total value of carbon and CO_2 absorption by marine ecosystems. For Con Co Island, calculated *Icarbon* was a factor of 0.0001. *Ienvi* was defined based on substances such as nitrogen, carbon, NO_2, NO_3 absorbed by micro-organism and seaweed, and the characteristics related to their absorbability. Calculated *Ienvi* was a factor of 0.82 representing the value of decreasing environmental pollution, economically 144,842 million VND per year in the period 2013-2015 [9]. *Inurs* of Con Co coastal ecosystem was resulted from the inshore and offshore fishing production and market prices of sea products. Calculated *Inurs* was a factor of 0.17**,** seeming to be an index ò biodiversity value**.**

Normally, *Ienvi* and *Icarbon* depend on the components constituting of the value of ecosystems (parameters) as well as the ecosystem health when they are well developed and vice versa. Thereby, the expected and minimum values of *Ienvi* and *Icarbon* were also estimated similarly to the ones of *Ifood* and *Itour*.

For the values of biodiversity and habitats, Lan et al. (2016) calculated that, the economic value of this group achieved 20% of the fishery value. Hence, the expected value of *Inurs* was of 20% of the expected value of *Ifood* [9].

The value of *Icoastmax* depends on the coast length that coral reefs and rocky ecosystems around the Island take their protection function. During the period 1993-2015, there was no change of these ecosystems with their protection function [9]. For this reason, *Icoastmax* takes the current calculated value (as of Icoast). The minimum value of *Icoast* (*Icoastmin*), however, will get the lowest value (as of zero (0)) if this ecosystem does not exist to protect the Island.

Thus, the expected and minimum values of the indicators are as follows (Table 4).

Table 4 The values of sub-indicators (million VND).

Icoastmax	*Icoastmin*	*Icarbonmax*	*Icarbonmin*	*Ienvimax*	*Ienvimin*	*Inursmax*	*Inursmin*
23.012	0	81	17	274.041	57.937	57.287	12.111

With the sub-indicators, *Iidev* was calculated as of 0.55 (scale from 0 to 1) or 55 at scale of 100 points. This index is corresponded with 198.133 million VND per year in the period 2013-2015 [9].

3.3.3 Non-Use Value Index

In case of Con Co Island, the non use value (*Inuv*) has been estimated through *Ioev, Ioevmin* and *Ioevmax* that depend much on the public awareness. Data from questionnaires and interviews show that all responded people had their willingness to pay for keeping healthy marine ecosystems in Con Co Island. This means that the expected value of *Ioev* (*Ioevmax*) was *Ioev* itself during studying, and this value would be minimum (equal to 0) if the value of marine ecosystems were not in people's mind. Hence, *Ioevmax* equaled to 100.

Inuv was then calculated as of 1 (scale from 0 to 1) or 100 at scale of 100 points, representing the non use value.

3.3.4 Index of the Total Ecosystem Economic Value

The index of the total ecosystem economic value (*Ieev*) was equal to 65.1, calculated based on three sub indices: *Idev, Idiev* and *Inuv* (2015). At assessment scale of 100 points with one forth interval: less than 25 (the low values — unsustainable use of ecosystems), from 25 to 50 (the medium values — not very sustainable use of ecosystems), from 50 to 75 (the high values — sustainable use of ecosystems) and higher than 75 (the very high values — very sustainable use of ecosystems), *Ieev* of coastal waters in Con Co Island got high value (65.1). It is said that coastal ecosystems in Con Co Island of Vietnam was in sustainable use.

4. Discussion

Although the indices have been increasingly widely used in most fields, the indices of ecosystem economic values have not been well developed for sustainable management of coastal and marine ecosystems. Most studies concerning ecosystem economic values have been on total ecosystem values, ecosystem service values, some component values of an ecosystem. Egoh et al. (2012) defined some indicators of ecosystem services, including secondary indicators such as deposition velocity, pollutant concentration, tree cover… and primary indicators like air quality regulation, erosion prevention, food provision [17]. Besides, Spencer and Boyd (2005) calculated an ecosystem services index (ESI) through the values of ecosystem services. This index not only shows the relationship between ecological conditions and economic benefits but also measures the service values [18]. Furthermore, these authors also estimated indices of willingness to pay of ecosystem service goods [18]. Those monetary values express the specific values of an ecosystem (total or component) at any time, but show difficult level of evaluation (high, low, sustainable or not) or comparison among ecosystems in different geographic areas. Building and calculating the indices of ecosystem economic values reflect not only the ecosystem changing over time and space, but also the ecosystem health [12, 19].

The index of total economic value of the ecosystem in Con Co generally indicated the sustainable use of the ecosystems (as of 65.1) in 2015. Calculated values of sub-indices including *Idev, Iidev* and *Inuv* of coastal ecosystem surrounding Con Co Island show, however, some matters of ecosystem sustainability. *Idev* of 40 presents that, the ecosystems of the Island were in unsustainable direct use. *Iidev* of 55 means that the ecosystems were in sustainable indirect use but close to unsustainable management. *Inuv* of 100 shows that local people supported solutions for marine conservation and also indicates the lack of data for calculation of the index. Though several limits of index calculation are not solved due to lack of relevant data, the developing and calculating the indices of ecosystem economic values of coastal waters in Con Co Island seem to be a model that contributes to the development and improvement in the sustainability ecosystem management in a qualification way. Thus, in Vietnam recently, economic valuation studies for coastal and marine ecosystem have been paid more attention and got fine outcomes. These outcomes were dealt with coastal ecosystems as mangroves in Hai Phong [20], Thai Binh (North Vietnam), Ho Chi Minh City (South Vietnam), coastal lagoons (central Vietnam) [21], coral reefs, coastal ecosystems surrounding some offshore islands [11] and islands of Cat Ba – Ha Long area of Vietnam [21]. The results of the studies are good for developing and assessing indices to contribute to coastal and marine sustainable management, especially for the coastal ecosystems of mangroves, coral reefs, sandy beaches in Ha Long Bay Heritage (Quang Ninh) and Cat Ba Biosphere Reserve (Hai Phong) that have been much impacted by human activities. When the indices of economic valuation are developed and calculated, managers and the public can understand clearly totally sustainable ecosystem use and also each way of uses that needs proper

management measures to meet sustainable management goals.

5. Conclusion

The index of the total ecosystem economic value for the coastal ecosystem of Con Co Island was calculated in 2015 as a factor of 65.1 at assessment scale of 100 points, indicating that the coastal ecosystem of Con Co Island was in sustainability. The index development and calculation show one of the potential tools for sustainable management of coastal and marine ecosystems, particularly the ecosystems of mangroves, coral reefs, sandy beaches in Ha Long Bay Heritage and Cat Ba Biosphere Reserve, although some limitations related to the estimating ecosystem service values are still needed to tackle.

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