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Creating Added Value for Korea's tidal flats: Using Blue Carbon as an Incentive for Coastal Conservation.

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# Creating added value for Korea's tidal flats: Using blue carbon as an incentive for coastal conservation

Jeongim Mok

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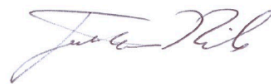
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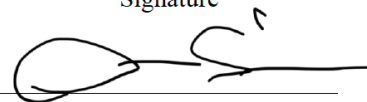
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## Executive Summary

Korean tidal flats are one of the most productive ecosystems on the planet, but their value has not been properly recognized. Thus, since the late 1970s, about 40% of Korea's tidal flats have been converted through land reclamation. Some converted tidal flats have led to negative consequences, such as deteriorating water quality, diminished livelihoods of fishing communities, and inefficient use of national budgets. These are types of market failure. Knowing the potential market value of ecosystem services may correct these market failures. Recently, as the importance of blue carbon has increased, it is expected that coastal ecosystems that store carbon can better receive their full social value, including possible access to carbon markets. This report presents a methodology for estimating the economic value of tidal flats as a coastal carbon repository and its application to tidal flat conservation policies. Korea's tidal flats store carbon that accounts for 8% of Korea's annual greenhouse gas emissions in 2016. To estimate the net benefit of tidal flat conservation, a cost-benefit analysis that included carbon dioxide reduction values was conducted for Ganghwa tidal flat. With a 25-year time horizon, the break-even point between benefit and cost occurs when the carbon price is \$ 4 – 6/tCO<sub>2</sub>e. Given the average carbon market price in 2018 in Korea is \$ 20.62/tCO<sub>2</sub>e, the 'blue carbon' valuation is high enough to incentivize coastal wetlands conservation, and climate change mitigation and adaptation policies. Based on this blue carbon 'viability,' this paper examines some related issues and legislative improvements, as well as future considerations to increase participation by the private sector.

Key words: blue carbon, tidal flat, reclamation, CO<sub>2</sub> emission, cost-benefit analysis, coastal wetland restoration, carbon offset

## I. Introduction

### 1. Background of blue carbon introduction

Global coastal habitats have decreased and still are under a growing threat of destruction through various human activities, such as farming, aquaculture, harbor construction, and real estate development. Since the 1800s, approximately 25% of salt marshes have disappeared internationally due to these developments, and are still decreasing 1-2% every year (McLeod, 2011). The tidal-flats in the Republic of Korea (Korea) have also turned into land for the development of airports, harbors, industrial complexes, and farms. Most of the reclamation was done between the late 1970s until the mid 1990s, and around 656 square miles (1,700 km<sup>2</sup>) of tidal flats have disappeared (Koh et al., 2014).

The loss of tidal flats carries with it the loss of critical goods and services these ecosystems provide: fishing, habitat provision, recreational and tourism benefits, ecosystem regulation (water purification, climate regulation, erosion control), and cultural benefits (Barbier, 2007).

These losses are vast from an ecological perspective, but they are economically significant as well (Barbier, 2007). Knowing the monetary value of these goods and services is important in the development decision-making process. While the economic value of ‘fishing’, which is traded as goods in the market, is relatively easy to identify, the value of other ecosystem services is more difficult to capture. Thus, decision-makers have often ignored these non-market values when they have to make choices between conservation and development. This market failure leads to excessive tidal flat loss (Murray et al., 2011).

In an effort to correct this market failure, another service that could be measured by market transactions is the “carbon market.” Recent global attention is focusing on the role of coastal habitats as the reservoir of “blue carbon.”

## 2. Blue carbon definition and international discussion

According to the International Union for Conservation of Nature (IUCN), estuaries and tidal flats are classified as wetland habitats. Estuaries and tidal flats are defined as “where rivers meet the sea and salinity is intermediate between salt and freshwater. Habitat types include deltas, mudflats and salt marshes. These areas support a food web that permits the rapid growth of young fish in estuarine nursery areas” (Shine et al., 1999). These habitats are also being focused on as “blue carbon” repositories. “Blue carbon” is the term internationally used when carbon is stored and sequestered in coastal habitats such as salt marshes, mangrove forests, and seagrass beds. The UNEP “Blue Carbon” report stated that 55% of biological carbon is captured by marine organisms, hence it is called ‘blue carbon’, and more than 50%, perhaps as much as 71% of blue carbon sinks in coastal areas (Nellemann, 2009).

As the function of the coast for a carbon repository began to be emphasized, the United Nations Framework Convention on Climate Change (UNFCCC) has included coastal and marine ecosystems for the sinks and reservoirs of greenhouse gases:

“Article 4 (Commitments) 1. All parties ... shall: (d) promote sustainable management, and promote and cooperate in the conservation and enhancement ... of sinks and reservoirs of all greenhouse gases ... including ... oceans as well as ... coastal and marine ecosystems.”

Although blue carbon has not yet been actively used as part of climate change mitigation policy, many efforts are underway to include a number of possible mechanisms that currently support emission reductions and removals from natural systems under the UNFCCC: Reducing Emissions from Deforestation and Forest Degradation (REDD+), Nationally Appropriate Mitigation Actions (NAMAs), and Land-Use and some Land-Use Change and Forestry (LULUCF) including those implemented under Clean Development Mechanism (CDM) (Alongi, 2018).

### 3. Background of this research

Korean tidal flats are highly productivity due to the important food source, which is a combination of mineral-rich sediments and microalgal organisms, also known as microphytobenthos (Koh et al., 2006). Recent studies show daily productivity of the tidal flats in Gyeonggi Bay reached  $\sim 1,000 \text{ mg C m}^{-2} \text{ d}^{-1}$  (Kwon et al., 2014). Thanks to this high productivity, Korean tidal flats produce annually about 50,000-90,000 tons of clams, over 1,000 tons of mud octopuses, and 500 tons of polychaetes (Je et.al., undated).

Given that tidal flats are important in Korea economically and culturally, knowing the economic value of the tidal flats is essential for establishing conservation policies. It is especially important to know the monetary value of the items that can be traded in the market and receive market values. Since the economic value of tidal-flat fishery can be relatively easily identified, this paper will focus on identifying the value of the carbon stored in these tidal flats. Although there are a number of studies on the monetary value of blue carbon, little research has been done about the carbon value of Korean tidal flats.

The assessment of the value of carbon stored in the tidal flats can be used as incentives for coastal conservation, such as MPA designation and management, coastal wetlands restoration, and sustainable fisheries. The awareness of blue carbon value also helps prevent development done without consideration of the coastal ecosystem service values, which form the opportunity cost. In addition, this value recognition can function as a stimulus for the restoration of coastal wetlands through voluntary carbon offset markets or related carbon valuations in Korea. Payments for ecosystem services, whether or not part of offset markets, also require a calculation of any blue carbon's economic value to set the appropriate valuation or payment (such as the minimum willingness to accept). Therefore, this report examines the amount and value of carbon stored in the tidal-flats in Korea and finds some ways in which to use the carbon storage value for tidal-flat conservation policies.

### 4. Objectives of this research

This report produces an assessment of the amount and monetary value of carbon stored in vegetated and non-vegetated tidal flats in Korea and suggests some measures on how to utilize it for tidal-flat conservation policies. I pursued this task by asking and answering several questions:

- What ecosystem services are provided by tidal flats and what is their economic value?
- How much of Korean tidal flats are currently turned into lands and what are the existing problems for their management?
- How much blue carbon is captured and sequestered in Korean tidal flats? Are there any differences in the amount of carbon stocks between (1) vegetated and non-vegetated tidal

flats, (2) the area where there is active fishing activity (e.g. shellfish harvest) and the area where it is not, (3) protected and unprotected coastal wetlands?

- What is the net present value (NPV) of tidal flats?
- What are the direct costs associated with measures needed to avoid tidal flat conversions (e.g. MPA designation and management), and to restore coastal wetlands?
- What are the coastal conservation policies in which blue carbon can serve as an incentive, how can it be used? (e.g. MPA designation, wetland restoration, Environmental Impact Assessment (EIA), fishery management, coastal management)?
- What are the legislative improvements that can be implemented to prevent the reduction of tidal flats and increase blue carbon stocks (e.g. Conservation and Management of Marine Ecosystems Act, Coast Management Act)?
- What are expected barriers and what recommendations can be suggested to resolve these barriers?

## 5. Usage of this paper

The research on blue carbon in Korea is just beginning, and its value is little known to the public. This report presents a methodology for estimating the economic value of tidal flats as a coastal carbon repository and its application to tidal flat conservation policies. Therefore, this report can be used as a reference for those who establish and implement tidal flat conservation and restoration policies.

## II. Ecosystem services of tidal flats

### 1. Ecosystem service provided by tidal flat

‘Ecosystem services’ are the benefits that people obtain from ecosystems. There are strong linkages between ecosystems and human well-being. Ecosystem services include (UNEP, 2006):

*“provisioning services* such as food, water, timber, and fibre;  
*regulating services* such as the regulation of climate, floods, disease, wastes and water quality;  
*cultural services* such as recreational, aesthetic, and spiritual benefits; and  
*supporting services* such as soil formation, photosynthesis, and nutrient cycling.”

Coastal and marine ecosystems are some of the most productive, yet threatened, ecosystems on earth. They provide a range of social and economic benefit to humans<sup>1</sup> (UNEP, 2006). Among coastal and marine ecosystems, an intertidal flat, also called a ‘coastal wetland’, is the area between the high tide and low tide. This area is commonly classified as a salt marsh or mud flat. Salt marsh is a vegetated area where it is above mean sea level in the intertidal zone that taller plants (cordgrass, pickleweed) grow (Figure 1). While a mud flat is vegetated by algae or an unvegetated area between the low tide and mean tide (Figure 2) (Teal, 2010; Philip Williams & Associates Ltd., 2009).

*Figure 1. Salt marsh (Suncheonman wetland)*



Source: Ramsar

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<sup>1</sup> “More than one third of the world’s population live in coastal areas and small islands that make up just over 4% of Earth’s total land area. Fisheries and fish products provide direct employment to 38 million people. Coastal tourism is one of the fastest growing sectors of global tourism and provides employment for many people and generates local incomes. For example, reef-based tourism generates over \$1.2 billion annually in the Florida Keys (of the United States) alone” (UNEP, 2006).



Figure 2. Mud flat (Muan tidal flat)



Source: Ministry of the Interior and Safety

Healthy intertidal habitats provide a wide range of ecosystem services: (1) habitat and food chain support for many species of commercial fish, (2) recreational and tourism benefits, (3) water purification, (4) climate regulation (e.g. carbon sequestration), (4) disaster prevention (e.g. shoreline stabilization, flood attenuation), and (5) cultural benefits (e.g. heritage values) (Barbier, 2007; UNEP & CIFOR, 2014). These services play a crucial role in maintaining the livelihood of coastal communities that rely on these services.

Besides these services, Korean intertidal habitats are internationally recognized for their importance as resting and feeding places for long-range migrant shorebirds of the East Asian-Australasian Flyway, supporting an official estimate of 12.7% of the Flyway's shorebirds on northward migration and 8.7% on southward migration (Moore, 2006).

## 2. Value of tidal flats

These various ecosystem services are what drives much of the coastal wetland's monetary value, estimated at US\$ 193,843 ha<sup>-1</sup> yr<sup>-1</sup>, which is more than 35 times the value of cropland (US\$ 5,567 ha<sup>-1</sup>yr<sup>-1</sup>) (Costanza et al., 2014). In another literature, the ecosystem service values of intertidal flats in Xinghua Bay, Fujian, China, were estimated at \$ 38,235 ha<sup>-1</sup>yr<sup>-1</sup> with an estimated loss of value of \$ 8,250 ha<sup>-1</sup>yr<sup>-1</sup> if the land were reclaimed for agriculture or ponds (Yu et al., 2008). For the Korean tidal habitats, the Ministry of Oceans and Fisheries (MOF) of Korea assessed the annual value of tidal flats as KRW 63.1 million ha<sup>-1</sup> yr<sup>-1</sup> (US\$ ~56,850 ha<sup>-1</sup> yr<sup>-1</sup>), which includes fisheries products (KRW 17.5 million), water purification (KRW 6.6 million), recreation and tourism benefits (KRW 2.5 million), habitat provision (KRW 13.6 million), disaster prevention (KRW 2.6 million), and conservation value (KRW 20.3 million) (MOF, 2013).

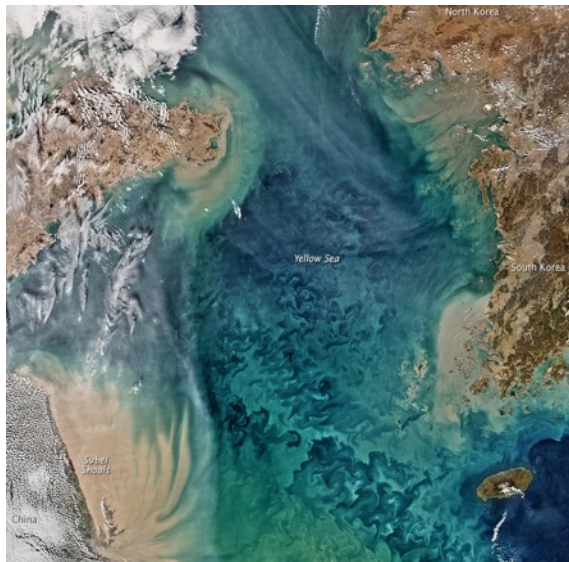
### III. The Status of tidal flats in Korea

#### 1. Distribution and loss

The Yellow Sea has some of the most turbid and dynamic waters in the world (NASA, 2015). Soils that come from large rivers in China and Korea are deposited on the Yellow Sea coast, forming a wide-scale of tidal flats (Figure 3). The area of Korean tidal flat is around 2,500 square kilometers as of 2013, and 84% of the area is situated on the west (Yellow Sea) coast (Table 1&2, Figure 4) (MOF, 2013).

The tidal flat has decreased about 40%, through land conversion (often called “land reclamation”), from 4,200 square kilometers of the area in the late 1970s. According to the Worldatlas (2019), Korea ranked third after China and the Netherlands with the most land reclaimed from seas and wetlands. Most reclamation was completed between the late 1970s until the mid 1990s, and around 1,700 km<sup>2</sup> of coastal area have turned into land (Table 3) (Koh et al., 2014). Tidal flats had very high development pressures during this period. They were reclaimed by large industrial complexes because the cost of development was lower than inland real estate, and the use of a nearby port also made converting tidal flats even more convenient. The reclamation enthusiasm began to decline rapidly from the mid 2000s due to a change in citizens’ consciousness who learned from the catastrophic environmental changes brought by large scale reclamations.

Figure 3. Swirls and color in the Yellow Sea



(source: NASA, data date: February 24, 2015)

Table 1. Area of Tidal Flats in Korea as of 2013

Region	Area (km <sup>2</sup> )	Ratio (%)	Remarks
<b>Total</b>	<b>2,487.2</b>	<b>100.0</b>	
Incheon	709.6	28.5	West coast: 2,084.5 km <sup>2</sup>
Gyeonggi	165.9	6.7	
Chungnam	357.0	14.3	South coast: 402.7 km <sup>2</sup>
Jeonbuk	118.2	4.8	
Jeonnam	1,044.4	42.0	
Gyeongnam	68.8	2.8	
Busan	23.3	0.9	

Table 2. Changes in Tidal Flat Area by Year

Year	1987	2003	2013
Area (km <sup>2</sup> )	3,203.5	2,550.2	<b>2,487.2</b>

Figure 4. Tidal flats distribution in Korea (MOF, 2016).

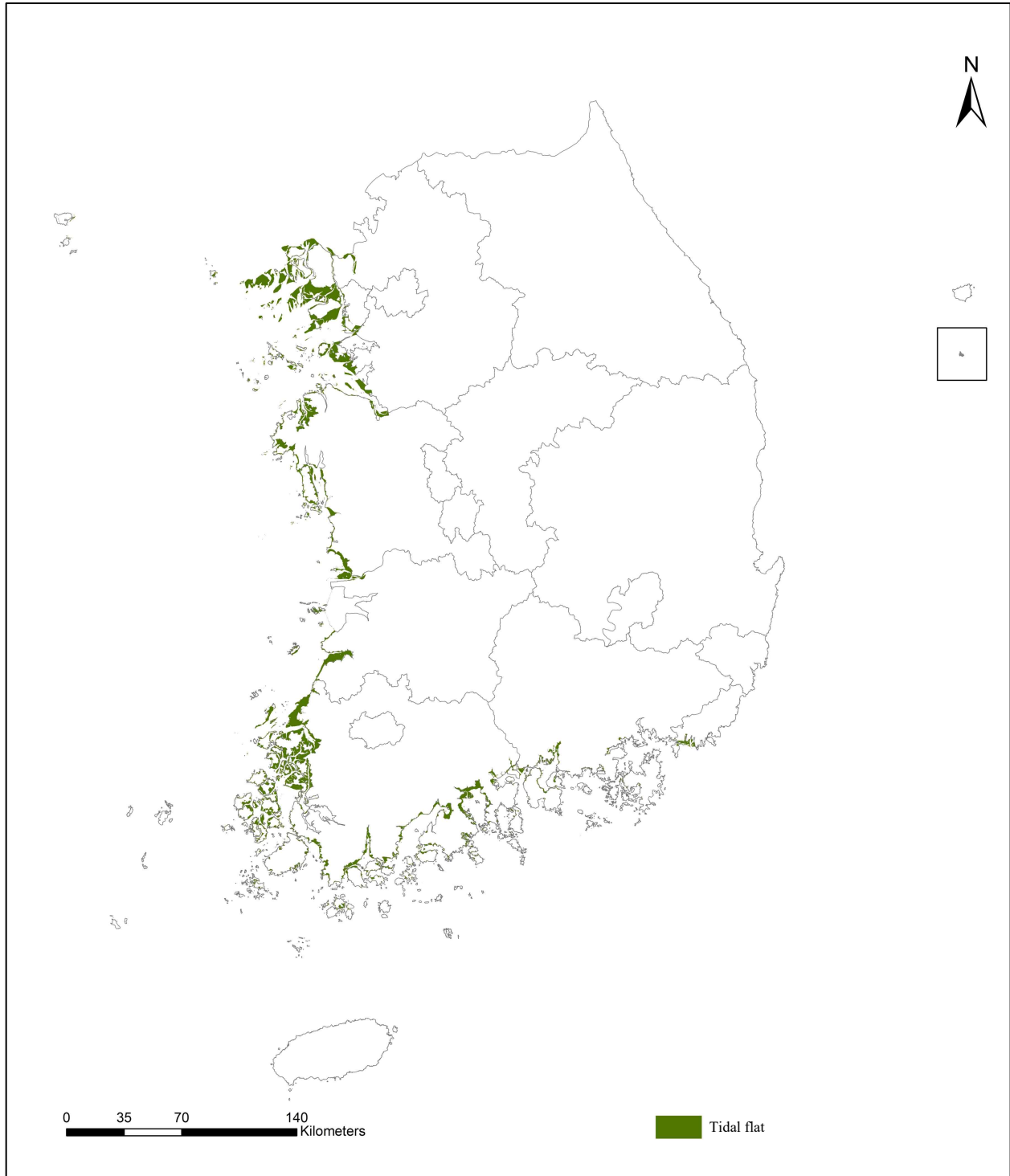


Table 3. Major reclamation projects of the Korean tidal flats since the late 1970s (Koh et al., 2014)

Reclamation Project	Claimed area (km <sup>2</sup> )	Freshwater lake area (km <sup>2</sup> )	Dike length (km)	Began-completed
Saemangeum	401	118	33.9	1991 - 2005
Sihwa	173	61	12.7	1987 - 1996
Seosan	156	40	7.7	1980 - 1995
Gunjang	150			
Yeongsan R. II	108	35	8.6	1978 - 1982
Yeongsan R. III-1	128	43	2.2	1988 - 1993
Yeongsan R. III-2	74	23	2.1	1989 - 2005
Yeongjong	46			1992 - 1995
Gimpo	38			1980 - 1989
20 other projects	400			
<b>Total</b>	<b>1,700</b>			

## 2. Use of tidal flats

The coastal wetland ecosystem lies at the boundary between the sea and land. In this transition zone, species are diverse due to the overlap of two different ecosystems. The inputs of abundant nutrients from the land help the vegetation grow, allowing these areas to serve as spawning and nursing grounds. Korean tidal flats accommodate many forms of wildlife, including gobies, manila clams, razor clams, worms, large log worms, and octopuses which are the most popular wetland species in Korea (Park et al., 2013). According to the 2013 ‘National Coastal Wetland Ecosystem Survey’ conducted by Korea Marine Environment Management Corporation (KOEM), Korean tidal flats provide habitats to more than 1,100 species of marine organisms, including 160 species of fish, 240 species of Crustaceans, 185 species of mollusks, 213 species of polychaetas, 117 species of diatoms, 78 species of shorebirds, and 55 species of halophyte (MOF, 2013).

Because of this high productivity, fisheries are prevalent in tidal flats. Fishermen who hold fishing rights harvest clams and octopuses at low tide. Fishing rights are categorized into licensed, permit-required, and reported fishery based on the Fisheries Act. The harvest of clams and octopuses with bare-hand fall within the reported fisheries. The shellfish and algae farming, which is classified as licensed fisheries, also take place on tidal flats. A rent for farming is granted with validation of 10 years and this ‘use right’ can be traded (Koh et al. 2014).

Figure 5. Organisms living in tidal flats.



Source: KOEM (<http://www.ecosea.go.kr>)

### 3. Conservation status

As people became more aware of the environmental side effects of large-scale reclamation (e.g. deterioration of water quality, the loss of livelihood of fishing communities) and the demand for tidal flat conservation grew, the Korean government started to designate ‘Coastal Wetland Protected Areas (CWPAs)’ based on the Wetlands Conservation Act (WCA) of 1999. Starting from the Muan tidal flat in 2001, a total of 13 areas have been designated as CWPAs by 2018, with a total area of about 1,430 km<sup>2</sup> (Figure 6, Table 4). These areas account for 80% of the total Marine Protected Areas including CWPAs and 57% of a total area of tidal flats in Korea. Eight of 13 CWPAs are Ramsar sites, which are wetland sites designated to be of international importance under the Ramsar Convention.

In the CWPAs, all forms of disturbance activities are strictly restricted by law, except in fishing cases where the local residents have continuously cultivated, captured, or harvested for the purpose of livelihood or recreation. Activities that are restricted by WCA are as follows:

- (1) Construction or expansion of a building or other artificial structure, and the change of the shape and characteristic of the land,
- (2) Activities that increase or decrease the water level or quantity of wetland,
- (3) Collecting soil, sand, gravel or stones,
- (4) Mining minerals,
- (5) Importing, cultivating, capturing, or harvesting animals and plants.

Massive tidal flat losses from reclamation and negative environmental and ecological changes in the development process led to criticism of the abuse of public resources against the government, thereby bringing about a change in the government’s policy on tidal flats turning from development to conservation. As part of this conservation policy, the Korean government began restoring tidal flats in 2013. Restoration has mainly been aimed at salt ponds and fish farms that are no longer in use, or dikes and levees that had disrupted natural tidal flows.

Figure 6. MPAs in Korea (KOEM, 2018).



Table 4. Area of MPAs (KOEM, 2018)

Site	Designation year	Area (km <sup>2</sup> )	Remarks
<b>MPAs</b>	<b>(28 sites)</b>	<b>1,782.9</b>	
<b>CWPAs</b>	<b>(13sites)</b>	<b>1,427.1</b>	
<i>Muan</i>	<i>2001</i>	<i>42.0</i>	<i>Ramsar site</i>
<i>Jindo</i>	<i>2002</i>	<i>1.4</i>	
<i>Suncheonman</i>	<i>2003</i>	<i>28.0</i>	<i>Ramsar site</i>
<i>Jangbongdo</i>	<i>2003</i>	<i>68.4</i>	
<i>Buanjulpoman</i>	<i>2006</i>	<i>4.9</i>	<i>Ramsar site</i>
<i>Songdo</i>	<i>2009</i>	<i>6.1</i>	<i>Ramsar site</i>
<i>Masan bongam</i>	<i>2011</i>	<i>0.1</i>	
<i>Siheung</i>	<i>2012</i>	<i>0.7</i>	
<i>Daebudo</i>	<i>2017</i>	<i>4.5</i>	<i>Ramsar site</i>
<i>Bosungbulkyo</i>	<i>2003</i>	<i>31.9</i>	
<i>Gochang</i>	<i>2007</i>	<i>64.7</i>	<i>Ramsar site</i>
<i>Seocheon</i>	<i>2008</i>	<i>68.1</i>	<i>Ramsar site</i>
<i>Shinan</i>	<i>2018</i>	<i>1,100.9</i>	<i>Ramsar site</i>
<b>Other MPAs</b>	<b>(15 sites)</b>	<b>355.8</b>	

\* CWPA: designated under the Wetlands Conservation Act of 1999

Other MPAs: designated under the Conservation and Management of Marine Ecosystems Act of 2006

#### 4. Issues and limitations of tidal flat management

Reclamation of tidal flats leads to loss of flood-storage areas, so the storm surge gets higher and spreads faster and further inland through delta or estuarine channels (Temmerman et al., 2013). Korea has lost large areas of tidal flats due to pro-reclamation and development policies. Consequently, Korea is considered one of the top 20 countries in the world with the highest risk of sea level rise that affects to either inundation or flooding from storm surges (Gordon, 2017).

Recently, there have been calls for ecosystem-based coastal management, but changes in policy and management have been slow to proceed (Table 5). Most tidal flats in Korea are excessively dependent on fisheries and are not expanding into other industries such as tourism and leisure. The failure to diversify into other industries creates difficulties for revitalizing fishing communities that are rapidly aging and declining in population.

Table 5. Issues and limitations of Korean tidal flat management.

Issues and limitations	Reasons
170,000 ha of tidal flats have been reclaimed since the late 1970s.	Many companies and institutions think tidal flats are the most suitable for development because they have low development costs.
Conservative policies can easily be abandoned when there is political pressure.	<p>There is no clear and objective economic justification to support conservation.</p> <p>Although the Korean government assessed the annual value of tidal flats as KRW 63.1 million ha<sup>-1</sup> yr<sup>-1</sup> (US\$ ~56,850 ha<sup>-1</sup> yr<sup>-1</sup>) based on their ecosystems service, this value is considered ambiguous and abstract as it does not provide specific estimation methods that can be applied according to the characteristics of each tidal flat.</p>
Some tidal flats are heavily affected by erosion due to changes in tidal currents caused by coastal engineering built to combat flood risk.	Current coastal management and maintenance plans do not actively pursue helping climate change mitigation and adaption.
Currently, tidal flat restoration projects are aimed at increasing the tourism and production of fishery, and other ecosystem services are not seen as important.	From an economic point of view, only ecosystem service functions that can be monetized are considered to be significant for the purpose of tidal flat restoration, and functions that are difficult to monetize are not getting much attention.
There is some difficulty to restrict fishing activities to conserve the ecosystem of tidal flats.	Tidal flats are closely connected to the livelihoods of nearby fishing villages. The economy of fishing villages is heavily dependent on fishing in the tidal flats and a large number of fishing households are involved in artisanal fisheries.
Tidal flats are less likely to be utilized in conjunction with other industries other than fishing.	Although some tidal flats, mostly coastal wetlands with vegetation, contribute greatly to revitalizing local tourism, most tidal flats have fewer factors that can be made into tourism resources.



## IV. The amount of carbon stock in tidal flats

### 1. Tidal flats for carbon repository

Carbon sequestered in vegetated coastal ecosystems, specifically mangrove forests, seagrass beds, and salt marshes, has been termed “blue carbon” (McLeod et al., 2011). McLeod et al. (2011) explain that this is because vegetated coastal areas can sequester more carbon from both internal and external sources than unvegetated coastal areas. However, some studies show that even unvegetated tidal flats can also sequester large amounts of carbon in areas with high levels of mud (Sanders et al., 2010; Chmura et al., 2003). It is not surprising that mudflats have a rapid and high carbon sequestration capacity. This is because mudflats have a lower permeability so they bind depositional organic matter for a long time, and also have a high primary yield due to a large number of microorganisms such as cyanobacteria.

Recently, at the 13<sup>th</sup> Meeting of the Conference of the Contracting Parties to the Ramsar Convention on Wetlands, Parties adopted the “Resolution XIII.14: Promoting conservation, restoration and sustainable management of coastal blue-carbon ecosystems.” In this Resolution, blue carbon is defined as “The carbon captured by living organisms in coastal (e.g. mangroves, saltmarshes and seagrasses) and marine ecosystems and stored in biomass and sediments” with the following contents:

“4. NOTING that the United Nations General Assembly (UNGA), in Resolution A/RES/71/257 on *Oceans and the law of the sea*, notes the vital role that coastal blue-carbon ecosystems, including mangroves, tidal marshes, and seagrasses<sup>3</sup>, play in climate adaptation and mitigation through carbon sequestration, [...]”

“<sup>3</sup> **Unvegetated mudflats** and intertidal marshes are also important blue-carbon ecosystems. [...]”

It is worth noting that, according to the Resolution, unvegetated mudflats are now being recognized as an important blue carbon repository.

### 2. Carbon storage per area in tidal flats

Korea’s blue carbon research is in its early stages, and the national-level survey was launched in 2018. The survey, conducted by Seoul National University (SNU), is funded by the Ministry of Oceans and Fisheries (MOF) and Korea Marine Environment Management Corporation (KOEM). This blue carbon assessment aims to identify the total amount of organic carbon present in the form of organic matter in the tidal flat. The accumulation of organic carbon in the tidal flats varies depending on the vegetation and soil characteristics of the survey area (Table 6). The mean organic carbon of total surveyed areas is 57.58 t C ha<sup>-1</sup>. When comparing soil characteristics, tidal mudflats have an average of 2.3 times more carbon than tidal sandflats. Figure 7 shows the amount of carbon by survey areas.

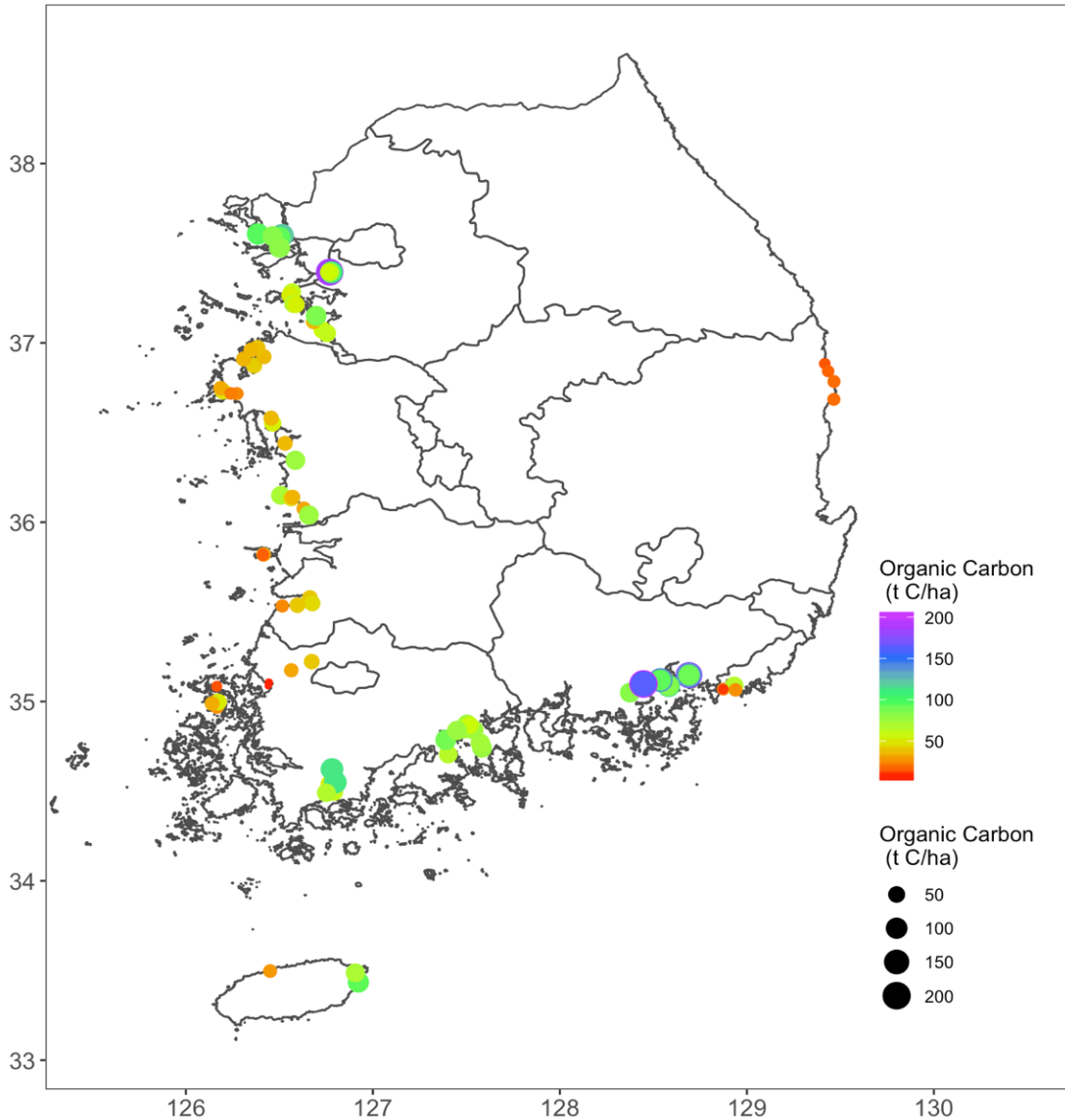
Coastal blue carbon is known to be heavily stored in peat beds, areas less directly influenced by tide. As the first-year of 2018 blue carbon survey was conducted to include almost all types

of tidal flats (e.g. vegetated, unvegetated, sandy, muddy, disturbed, and undisturbed), the mean value of carbon stocks was relatively low. Further surveys will be needed to better understand characteristics of the best blue carbon repositories to achieve more reliable results.

Table 6. The amount of organic carbon in Korean tidal flats (t C/ha) (raw data: SNU, 2018).

	Total			muddy			sand-muddy			sandy		
	mean	median	sd	mean	median	sd	mean	median	sd	mean	median	sd
Total	57.58	50.46	39.50	64.66	60.89	34.55	55.77	36.18	53.92	27.91	18.88	22.69
- vegetated	56.27	50.46	39.64	64.87	65.98	26.31	55.98	35.90	59.04	19.61	18.78	2.23
- unvegetated	58.60	49.06	39.70	64.53	53.91	39.10	55.36	50.61	47.30	33.45	21.05	28.50

Figure 7. The amount of organic carbon stored in tidal flats (raw data: SNU, 2018).



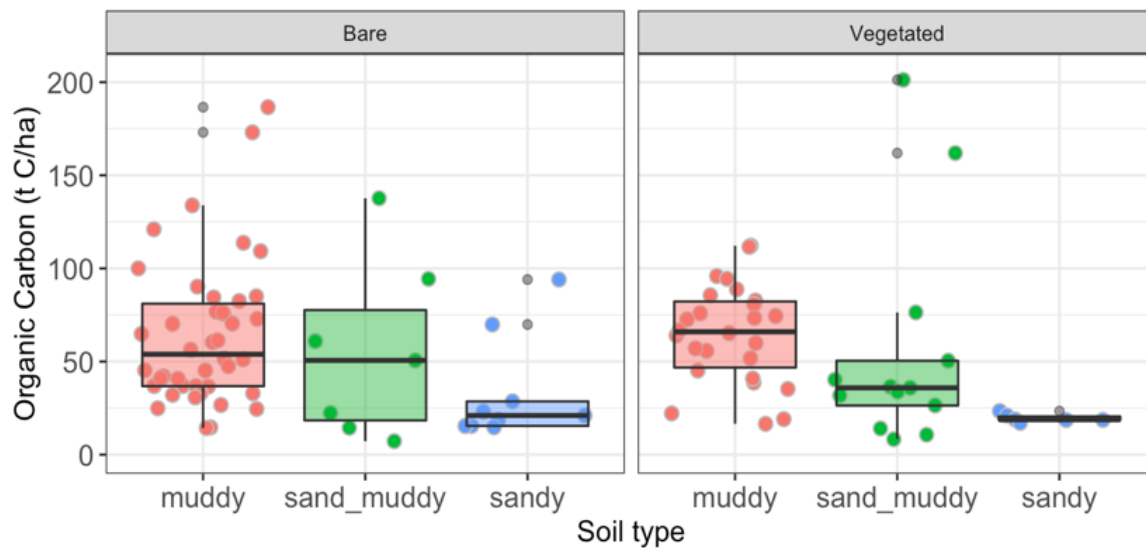
### 3. Carbon stock difference between vegetated and unvegetated areas

Some research shows that total organic carbon (TOC) burial rates of the intertidal mudflats are almost four times greater fluxes than within mangrove forests, areas amongst the largest biological carbon pools (Sanders et al., 2010). The composition of the sediment influences the rate at which buried organic material breaks down. The reason for the high sediment deposition rate of intertidal mudflats is that organic material is retained in mudflats because muddy sediments have a lower permeability than sandy sediment, preventing organic material from being flushed out (Philip Williams & Associates et al., 2009).

The carbon flux within the tidal flats may have many different origins, some of it derived from rivers, and some of it from marsh vegetated and eroding soils. Knowing the origin of organic carbon (OC) stored in tidal flats might be important to understand the linkages between OC dynamics and carbon sequestration rates by sources. However, for evaluating the monetary value of carbon, Philip Williams & Associates et al. (2009) recommended disregarding the origin of carbon sources and focusing on quantifying the carbon sequestered within the soil.

According to the 2018 SNU's blue carbon survey, the median organic carbon stock sequestered in the Korean tidal flats is 65.98 t C ha<sup>-1</sup> in muddy vegetated areas, and 53.91 t C ha<sup>-1</sup> in muddy unvegetated areas (Table 6, Figure 8). This suggests that vegetated tidal mudflats principally sequester 122% more carbon stocks than bare tidal mudflats.

Figure 8. The amount of organic carbon stored in tidal flats (raw data: SNU, 2018).



### 4. Carbon stock difference between protected and unprotected areas

A recent study conducted to identify differences in carbon stocks between protected and unprotected areas has shown that protected areas accumulate around 1.5-2 times more organic carbon in its soil. Here, “protected areas” refer to wetlands or mud flats that have been preserved in pristine conditions without human intervention, whereas “unprotected areas” refer

to areas with human interference. The mean carbon storage per unit area was 145 t C ha<sup>-1</sup> in the unprotected salt marsh, 198 t C ha<sup>-1</sup> in the protected salt marsh, 286 t C ha<sup>-1</sup> in the protected mud flat, and 139–182 t C ha<sup>-1</sup> in the unprotected mud flats (Table 7) (Byun et al., 2019).

Table 7. The difference in carbon stocks between protected and unprotected areas (Byun et al., 2019).

Type		Carbon storage per unit area (t C ha <sup>-1</sup> )	Remarks
Salt marshes	Unprotected (Impacted)	145	- Eulsukdo - Carbon storage: 98.2% in soil, 1.2% in vegetation
	Protected (Pristine)	198	- Seomjin River estuary (protected wetland) - Carbon storage: 98.5% in soil, 1.5% in vegetation
Mud flats	Unprotected (Impacted)	Range: 73–349 Mean: 182	- Ganghwa
		Range: 48–272 Mean: 139	- Garolimman
	Protected (Pristine)	Range: 78–479 Mean: 286	- Suncheonman (protected wetland)

## 5. Impact of shellfish harvest in the tidal flat

Shellfish respiration and calcification improve CO<sub>2</sub> production, while shellfish harvest ultimately results in the reduction of carbon since harvest is the act of removing fixed carbon from the natural carbon recycling system. There is a debate on whether shellfish farming is positive or negative for coastal carbon storage and flux. To summarize the results of research up to now, it seems that the flux of carbon by shellfish has many variables so that it is difficult to conclude with only one factor. Shellfish are a food resource for humans and provide various ecosystem benefits: improving water quality that allows to control eutrophication, increasing oxygen in the coastal environment, aiding in the growth of seagrasses, and helping prevent harmful algal blooms (Baker et al., 2015). As the shellfish culture varies greatly depending on the aquaculture type, method, and environment, it is important to understand the changes in CO<sub>2</sub> according to these variables.

The 2018 blue carbon assessment was conducted to compare the carbon stock variance according to soil and vegetation types, without taking into account the existence of fishing activities. It is therefore difficult to examine the difference in carbon stocks between areas with active fishing activity (e.g. shellfish harvest) and areas without. Future blue carbon studies should consider reflecting this factor to understand the impact of shellfish culture and harvest on the flux of carbon in tidal flats.

## 6. Total amount of carbon stored in Korean tidal flats

The area of tidal flats in Korea is 250,000 ha as of 2013. To estimate the total amount of carbon stored in the tidal flats, this area was multiplied by the mean value of the 2018 survey, 57.58 t C ha<sup>-1</sup>, that resulted in 14.4 × 10<sup>6</sup> t C. Assuming that all carbon stored in the tidal flats is released into the atmosphere, the potential CO<sub>2</sub> emissions from the tidal flats is 52.85 × 10<sup>6</sup> t CO<sub>2</sub> e (carbon dioxide equivalent) that is calculated by multiplying C stocks by 3.67, the molecular weight ratio of CO<sub>2</sub> to C (Table 8). Given Korea's total amount of greenhouse gas (GHG) emission in 2016 is reported as 694.1 × 10<sup>6</sup> t CO<sub>2</sub> e (MOE, 2018), the potential tidal flats emission corresponds to around 8% of total GHG emissions.

Table 8. Estimated total amount of carbon stored in Korean tidal flats.

Total area of tidal flats (ha)	Mean value of organic carbon in tidal flats (t C ha <sup>-1</sup> )	Estimated amount of carbon stored (t C)	Molecular weight ratio of CO <sub>2</sub> to C	CO <sub>2</sub> equivalent (t CO <sub>2</sub> e)
250,000	57.58	14.4 × 10 <sup>6</sup>	3.67	52.85 × 10 <sup>6</sup>

## 7. Carbon stock changes by reclamation

The direct effect of reclamation is that organic matter in the soil is oxidized and carbon dioxide is released into the atmosphere as the tidal flat turns into lands. Thus, previous tidal flats, where reclamation has been completed, are losing their historically stored carbon (Philip Williams & Associates, 2009). According to the recent study of Kwon et al. (2018), carbon stocks in reclaimed areas have dramatically reduced, and now average 0.27 t C ha<sup>-1</sup>. Considering the mean carbon stock in the Korean tidal flats is 57.58 t C ha<sup>-1</sup>, the net decrease by reclamation is calculated to be 57.31 t C ha<sup>-1</sup>. Given Korea reclaimed around 170,000 ha since the late 1970s (Koh et al., 2014), the amount of sequestered blue carbon has decreased around 9.74 × 10<sup>6</sup> t C. The CO<sub>2</sub> emissions from previous reclamation is calculated to be 35.8 × 10<sup>6</sup> t CO<sub>2</sub> e.

Figure 9. Dead shellfishes after dike construction for reclamation (left: Saemangeum, right: Sihwa)



Source: © Yongki Ju via <https://www.sisain.co.kr>



Source: © Jongin Choi via <http://ecoview.or.kr>

## V. Monetary value of carbon stored in tidal flats

Coastal habitats help maintain healthy marine ecosystems and provide substantial economic values for people living near them. However, many of the world’s essential habitats are being destroyed by human intervention. The value of the various ecosystem services provided by coastal habitats is generally not taken into account during the development process. Consequently, many habitats are disappearing due to development, even though they provide essential ecosystem services that are ecologically and economically beneficial (Barbier, 2007). This market failure can often lead to habitat destruction at a dangerous rate.

To evaluate how blue carbon can serve as an economic incentive to protect essential coastal habitats from developments, this report aims to calculate the monetary value of blue carbon. For more specific data, three tidal flats (Ganghwa, Suncheonman, and Daebudo) were selected considering their location, use and conservation state. Most of these areas consist of muddy soil, and table 9 shows their mean organic carbon stock ( $t\ C\ ha^{-1}$ ) and the carbon dioxide equivalent ( $t\ CO_2\ e\ ha^{-1}$ ) that may potentially be emitted in the form of carbon dioxide.

Table 9. Mean organic carbon in Ganghwa, Suncheonman, and Daebudo tidal flats.

Location	Mean organic carbon <sup>a</sup> ( $t\ C\ ha^{-1}$ )	CO <sub>2</sub> equivalent ( $t\ CO_2\ e\ ha^{-1}$ )	Remarks
Ganghwa	95.15	349.20	Incheon Metropolitan City, The mouth of Han River, Presence of high development pressure
Suncheonman	65.33	239.76	Jeollanam-do Province (southwest coast), CWPA (Coastal Wetland Protected Area)
Daebudo	56.85	208.64	Gyeonggi-do Province (west coast) CWPA

Source: (a) The 2018 blue carbon survey conducted by the Seoul National University.

Figure 10. The locations of Ganghwa, Suncheonman, and Daebudo tidal flats.



Source: coast portal (<http://www.coast.kr>)

To evaluate the net present value of carbon stocks as a public good, it is important to use the appropriate discount rate and time periods since these factors yield very different outcomes. The discount rate refers to the interest rate used in discounted cash flow analysis to determine the present value of future cash flows (Defined by Investopedia). The Korean government recently reduced the social discount rate from 5.5% to 4.5% by revising the ‘Guideline for Conducting Preliminary Feasibility Studies’ in 2017. This social discount rate is being used in analyzing the economic feasibility of public investment projects (NLIC, 2019). Accordingly, it is reasonable to apply a 4.5% discount rate since this guideline is ‘administrative rule.’ However, considering the sensitivity of the discount rate, this paper also examines the case of applying a lower rate (2%) and a higher rate (7%).

Lopez (2008) noted that the appropriate discount rate should depend on the horizon of the project; he suggested applying 25-year horizons for a 4.4% discount rate in his study. In other study for blue carbon payment, Murray et al. (2011) used a 25-year time horizon based on a decay function of biomass and organic matters in soil. This is because most organic carbon in biomass and soil is emitted to the atmosphere in 25 years after conversion and disturbance. Considering this carbon longevity in soil and the Korean government’s official discount rate of 4.5%, it is compelling to set it to the 25-year time horizon.

Using the estimation of sequestration rates and carbon stocks in the tidal flats, this paper evaluates the monetary value of blue carbon benefits. The top meter of soil pool only is used for the estimation of carbon storage and monetary value, because most of the vulnerable organic carbon is stored within a meter of the soil’s surface. Since the annual carbon burial rate of Korea’s tidal flats has not been investigated yet, the global mean value (Murray et al., 2011) is used for the calculation.

*Table 10. Annual carbon sequestration rates and stored carbon stocks in the Ganghwa, Suncheonman, and Daebudo tidal flats.*

Location	Area (ha)	Annual carbon burial rate (t CO <sub>2</sub> e ha <sup>-1</sup> yr <sup>-1</sup> ) <sup>(a)</sup>	Soil organic carbon (t CO <sub>2</sub> e ha <sup>-1</sup> ) <sup>(b)</sup>
Ganghwa tidal flat	35,300	8.0±8.5	349.20
Suncheonman tidal flat	2,800	8.0±8.5	239.76
Daebudo tidal flat	453	8.0±8.5	208.64

Source: (a) Global average and standard deviation of carbon sequestration rate for salt marshes (Murray et al., 2011)

(b) The 2018 blue carbon survey conducted by the Seoul National University.

The potential monetary value of blue carbon is the ‘CO<sub>2</sub> reduction (emission avoidance + annual new sequestration)’ multiplied by the price received per unit of reductions. The ‘CO<sub>2</sub> reduction’ is the quantity of CO<sub>2</sub>e whose release will be averted by avoiding conversion of tidal flats and whose influx will be stored in the soil by burial process (Murray et al., 2011). Some studies show that methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions can be neglected in areas affected by tides (Chmura et al., 2003). Therefore, CO<sub>2</sub>e caused by CH<sub>4</sub> and N<sub>2</sub>O were

excluded from the calculation. Using the following equation, the ‘CO<sub>2</sub> reduction’ is monetized by multiplying the annual CO<sub>2</sub>e reduction by a stream of expected carbon prices over time horizon of t. All calculated values are real values without inflation.

### Net Present Value of Blue Carbon

$$= \sum_{t=0}^n \frac{\text{annual CO}_2 \text{ reduction (t CO}_2 \text{ e)} \times \text{CO}_2 \text{ price (\$/t CO}_2 \text{ e)}}{(1 + r)^t}$$

where, r: social discount rate (2%, 4.5%, 7%)  
t: time horizon (25 years)

According to Zhang et al. (2015), the soil respiration is three-folds higher in reclaimed lands than in salt marshes. After reclamation, therefore, previously sequestered soil organic carbon pool may decline to 50% in approximately 10 years (Zhang et al., 2015). The release is based on the assumption that only the top meter of soil is disturbed and reflects an exponential decay function whereby soil organic carbon has a half-life of 10 years. Decay of the remaining biomass carbon is much slower, and 8% of it remains at the end of the 25-year period (Murray et al., 2011). Based on the 10-year of half-life and the 25-year of 8% residual (orange line in Figure 11), an exponential emission curve from disturbed or converted the Ganghwa tidal flat was drawn (blue line in Figure 11), and the annual amount of release of carbon was estimated from this curve (Table 11).

Figure 11. Release of carbon (t CO<sub>2</sub> e/ha) to atmosphere from converted the Ganghwa tidal flat.

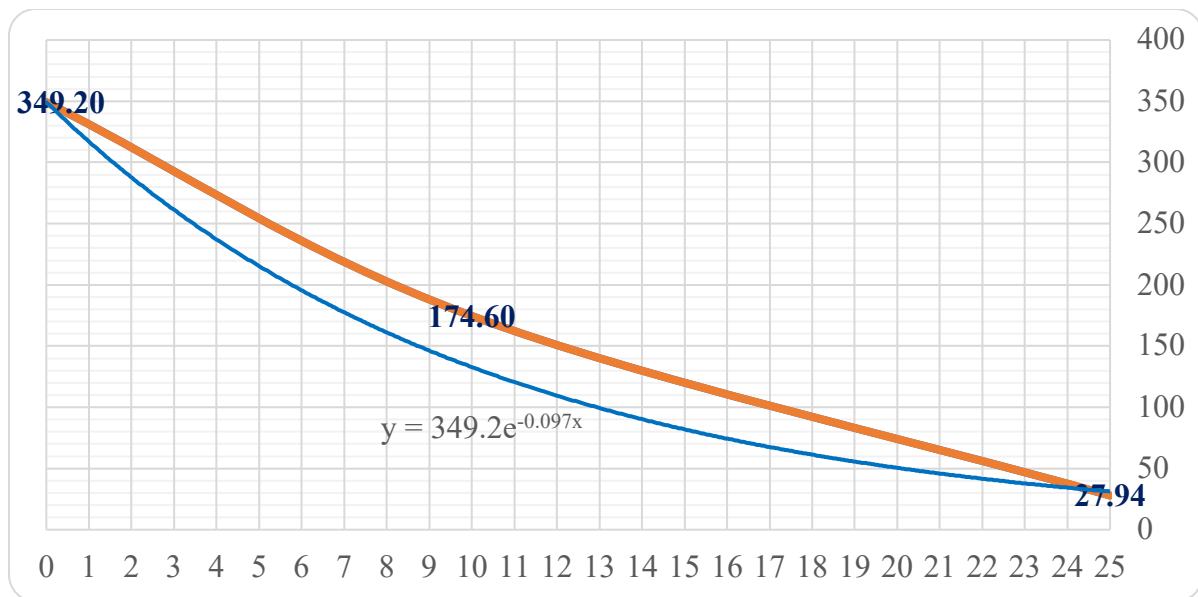




Table 11. Release of carbon (t CO<sub>2</sub> e/ha) to atmosphere from converted the Ganghwa tidal flat.

	1	2	3	4	5	6	7	8	9
t CO <sub>2</sub> e/ha	32.28	61.58	88.17	112.30	134.20	154.07	172.11	188.48	203.34
	10	11	12	13	14	15	16	17	18
t CO <sub>2</sub> e/ha	216.82	229.06	240.17	250.25	259.39	267.70	275.23	282.07	288.27
	19	20	21	22	23	24	25 yrs	-	-
t CO <sub>2</sub> e/ha	293.91	299.02	303.66	307.87	311.69	315.16	318.30		

Note: annually accumulated amounts

Table 12. Annual amount of carbon prevented emission and newly sequestered in the Ganghwa tidal flat.

		1	2	3	4	5	6	7	8	9
t CO <sub>2</sub> e/ha/yr	avoided emissions	32.28	29.30	26.59	24.13	21.90	19.88	18.04	16.37	14.86
	annual new sequestration	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		10	11	12	13	14	15	16	17	18
t CO <sub>2</sub> e/ha/yr	avoided emissions	13.48	12.24	11.11	10.08	9.15	8.30	7.53	6.84	6.21
	annual new sequestration	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
		19	20	21	22	23	24	25 yrs	-	-
t CO <sub>2</sub> e/ha/yr	avoided emissions	5.63	5.11	4.64	4.21	3.82	3.47	3.15		
	annual new sequestration	8.00	8.00	8.00	8.00	8.00	8.00	8.00		

To estimate a monetary value of blue carbon, the amount of avoided carbon emissions and newly sequestered carbon in the Ganghwa tidal flat are calculated first (Table 12), and then discounted back to the present with a 4.5% discount rate. The carbon price range used is \$ 5-30/ t CO<sub>2</sub> e, taking into account current carbon prices in compliance and voluntary markets across the world (Table 13).

Table 13. Carbon prices in the markets.

Markets		Price / tCO <sub>2</sub> e		Source	Date for price
EU ETS	EUA (EU Emission Allowances)	€21.40	US\$24.02	EEX ( <a href="https://www.eex.com">https://www.eex.com</a> )	04/02/19
CA-ETS	California Carbon Allowance		US\$15.10	California Carbon Dashboard ( <a href="http://calcarbodash.org">http://calcarbodash.org</a> )	03/29/19
ACCU	Australia Offset Prices	A\$15.72	US\$11.19	Carbon Pulse ( <a href="https://carbon-pulse.com">https://carbon-pulse.com</a> )	02/04/19
NZU	New Zealand Prices	NZ\$25.70	US\$17.52	Carbon Pulse	02/04/19
KAU	Korean Allowance Unit	₩26,650	US\$23.52	Carbon Pulse	02/04/19
KOC	Korean Offset Credit	₩26,500	US\$23.39	Carbon Pulse	02/04/19
Voluntary market	Forestry and land use		US\$5.1	Forest Trends <sup>(a)</sup> ( <a href="https://www.forest-trends.org">https://www.forest-trends.org</a> )	Average price in 2016

Source: (a) Hamrick et al., 2017

The net present value (NPV) of ‘CO<sub>2</sub> reduction’ in the Ganghwa tidal flat is 61–367 million dollars with a discount rate of 4.5%, when carbon price is \$ 5–30/t CO<sub>2</sub> e (Table 14).

Table 14. The NPV of blue carbon in the Ganghwa tidal flat (discount rate= 4.5%).

Total area of the Ganghwa tidal flat: 35,300 ha								
	Carbon price	Units	t= 1	2	3	...	25	
Total ‘CO <sub>2</sub> reduction’		t CO <sub>2</sub> e/ha/yr	40.28	37.30	34.59	...	11.15	
		10 <sup>6</sup> × t CO <sub>2</sub> e/yr	1.422	1.317	1.221	...	0.393	
- avoided emissions		t CO <sub>2</sub> e/ha	32.28	61.58	88.17	...	318.30	
		t CO <sub>2</sub> e/ha/yr	32.28	29.30	26.59	...	3.15	
- annual new sequestration		t CO <sub>2</sub> e/ha/yr	8.00	8.00	8.00	...	8.00	
Undiscounted carbon value	\$5/t CO <sub>2</sub> e	10 <sup>6</sup> USD	7.110	6.583	6.105	...	1.967	
	\$10/t CO <sub>2</sub> e		14.219	13.166	12.210	...	3.935	
	\$20/t CO <sub>2</sub> e		28.439	26.332	24.420	...	7.870	
	\$30/t CO <sub>2</sub> e		42.658	39.498	36.630	...	11.805	
Discount factor (discount rate= 4.5%)			0.957	0.916	0.876	...	0.333	
Discounted carbon value	\$5/t CO <sub>2</sub> e	10 <sup>6</sup> USD	6.804	6.028	5.350	...	0.655	
	\$10/t CO <sub>2</sub> e		13.607	12.056	10.699	...	1.309	
	\$20/t CO <sub>2</sub> e		27.214	24.113	21.399	...	2.619	
	\$30/t CO <sub>2</sub> e		40.821	36.169	32.098	...	3.928	
NPV	\$5/t CO <sub>2</sub> e	10 <sup>6</sup> USD	61.172					
	\$10/t CO <sub>2</sub> e		122.343					
	\$20/t CO <sub>2</sub> e		244.686					
	\$30/t CO <sub>2</sub> e		367.029					

The NPV of blue carbon in Suncheonman and Daebudo tidal flats, which are estimated using the same method of the Ganghwa tidal flat, is \$15.4 and \$ 2.3 million respectively. These values are calculated with the discount rate of 4.5% and the carbon price of \$ 20/ t CO<sub>2</sub> e that is similar to the carbon market price in Korea as of April 2, 2019 (\$ 23.52). Under the same circumstances, the total monetary value of coastal carbon stored in Korea’s tidal flat is estimated at \$ 1.276 billion (~ 1.5 trillion won) (Table 15).

Table 15. Net present value of blue carbon in tidal flats.

Location	Area (ha)	Discount rate (%)	NPV (10 <sup>6</sup> USD)			
			\$5/t CO <sub>2</sub> e	\$10/t CO <sub>2</sub> e	\$20/t CO <sub>2</sub> e	\$30/t CO <sub>2</sub> e
Ganghwa	35,300	2.0	75.5	151.0	302.0	453.0
		4.5	61.2	122.3	244.7	367.0
		7.0	51.0	101.9	203.8	305.8
Suncheonman	2,800	2.0	4.8	9.6	19.2	28.8
		4.5	3.9	7.7	15.4	23.1
		7.0	3.2	6.4	12.7	19.1
Daebudo	453	2.0	0.7	1.4	2.9	4.3
		4.5	0.6	1.2	2.3	3.5
		7.0	0.5	1.0	1.9	2.9
Total area of Korean tidal flat	248,720	2.0	398.6	797.3	1,594.6	2,391.8
		4.5	319.1	638.2	1,276.3	1,914.5
		7.0	263.1	526.1	1,052.2	1,578.3

Previously, the amount of stored carbon decreased due to reclamation since 1978 has been calculated to 35.8 ×10<sup>6</sup> t CO<sub>2</sub> e. If this amount is simply multiplied by the carbon market price in Korea as of April 2, 2019 (\$ 23.52/ t CO<sub>2</sub> e) without consideration of the discount rate, the value is calculated as 841 million dollars (Table 16). When 40-year of the time period (1978-2018) is applied without consideration of the interest rate, it is roughly estimated to be 21 million dollars annually, which is not a small sum.

Table 16. Value of carbon has decreased through reclamation since the late 1970s.

Reclamation Project	Claimed area (km <sup>2</sup> )	Amount of carbon decreased		Carbon market price (\$/ t CO <sub>2</sub> e)	Value of carbon (\$)
		(t C /ha)	(t CO <sub>2</sub> e)		
Saemangeum	401	57.31 <sup>(a)</sup>	8,434,141	23.52 <sup>(b)</sup>	198,370,991
Sihwa	173		3,638,669		85,581,500
Seosan	156		3,281,112		77,171,757
Gunjang	150		3,154,916		74,203,613
Yeongsan R. II	108		2,271,539		53,426,601
Yeongsan R. III-1	128		2,692,195		63,320,416
Yeongsan R. III-2	74		1,556,425		36,607,116
Yeongjong	46		967,507		22,755,775
Gimpo	38		799,245		18,798,249
20 other projects	400		8,413,108		197,876,300
Total	1,700		35,755,709		840,974,276

Note: (a) average amount of carbon decreased after reclamation

(b) carbon market price in Korea as of April 3, 2019

## VI. Cost-benefit for tidal flat conservation

To assess the costs associated with conservation measures for tidal flats, two strategies are considered: Protection from conversion, and restoration of coastal wetland. Restoration here refers to the introduction of vegetation in unvegetated areas to increase carbon stocks. Tidal flats can be avoided from conversion to other uses through the designation and management of CWPA (Coastal Wetland Protected Area). The restoration of coastal wetland is implemented by the WCA (Wetlands Conservation Act). For the benefit, the net present value (emissions avoidance + new yearly quarantine) estimated in the previous chapter is considered as the benefit of the protected area designation, and the value of the additional carbon stored by the coastal wetland restoration is calculated as the benefit of restoration.

### 1. Cost-benefit for CWPA establishment and management

Costs associated with establishing and managing CWPA are divided into direct and indirect costs. Direct costs are incurred for the designation and management of protected areas. On the other hand, indirect costs may include the foregone benefit from the establishment of a no-take zone, which prohibits any activity such as fishing and mining, and the opportunity costs for development lost due to the establishment of CWPA.

However, this report only evaluates direct costs for the following reasons. As can be seen in 'III. 3 Conservation status', Korea's CWPA allows fishing cases where the local fishing communities have continuously cultivated, captured, or harvested for the purpose of livelihood or recreation. Therefore, the creation of a no-take zone is not always accompanied by the establishment of CWPA. In addition, the purpose of this paper is not to analyze the cost-benefits on a specific development, but to assess the benefits of carbon stored in tidal flats and to estimate the costs of preserving these values. Given this conservation specificity of CWPA and the purpose of this paper, the foregone benefit from the creation of a no-take zone and an opportunity cost for a certain type of development are excluded from the estimation of costs.

To estimate the appropriate value of the direct costs of CWPA establishment and management, the Ministry of Oceans and Fisheries' internal 2008-2012 budget data (Son, 2013) is used. In this budget data, the cost for CWPA establishment was \$ 263,469 yr<sup>-1</sup> (price levels adjusted to reflect 2019 money value), which was mostly administrative expenses for hearing from stakeholders and local governments, consultation of experts and scientists, and evaluation process. Given, on average, one CWPA is designated per year in Korea and the CWPA establishment cost does not vary greatly depending on the area, this cost (\$ 263,469) can be used for CWPA establishment cost. Note that the establishment cost occurs once the CWPA is designated.

According to the same budget data, the CWPA annual management cost was \$ 2,160,448 yr<sup>-1</sup> (price levels adjusted to reflect 2019 money value), which is mostly composed of monitoring, outreach and education expenses. Using this data, the cost per unit area is calculated as \$ 99 ha<sup>-1</sup> yr<sup>-1</sup> (price levels adjusted to reflect 2019 money value), and \$1,469 ha<sup>-1</sup> for 25 years with a 4.5% discount rate (Table 17). The conversion of value from 2010 to 2019 is based on the inflation rate of 1.96% over the past decade in Korea (K indicator, 2019). If Ganghwa tidal flat

is designated as a CWPA, the total cost for CWPA establishment and management is estimated to \$ 52 million with a 4.5% discount rate.

Table 17. Cost for CWPA establishment and management of the Ganghwa tidal flat.

		Discount rate (%)	Costs
CWPA establishment cost (\$, one-time)		-	263,469
CWPA management cost	undiscounted cost (\$/ha/yr)	-	99
	discounted cost (\$/ha/25yrs)	2	1934
		4.5	1,469
		7	1154
	discounted cost (\$/25yrs)	2	68,270,200
		4.5	51,855,700
		7	40,736,200
Total		2	68,533,669
		4.5	52,119,169
		7	40,999,669

For the benefit of CWPA establishment and management, the net present value of ‘CO<sub>2</sub> reduction’ (emission avoidance + annual new sequestration) estimated in the previous chapter is used. The benefit of ‘CO<sub>2</sub> reduction’ for the Ganghwa tidal flat is \$ 61–367 million with a discount rate of 4.5%, when carbon price is \$ 5–30/t CO<sub>2</sub> e (Table 18). The Ganghwa tidal flat is a place where development pressure is high. If Ganghwa tidal flat is developed, this benefit will be converted into opportunity cost.

Table 18. Benefit for CWPA establishment and management

Location	Area (ha)	Discount rate (%)	NPV (10 <sup>6</sup> USD)			
			\$5/t CO <sub>2</sub> e	\$10/t CO <sub>2</sub> e	\$20/t CO <sub>2</sub> e	\$30/t CO <sub>2</sub> e
Ganghwa tidal flat	35,300	2.0	75.5	151.0	302.0	453.0
		4.5	61.2	122.3	244.7	367.0
		7.0	51.0	101.9	203.8	305.8

## 2. Cost-benefit for wetland restoration

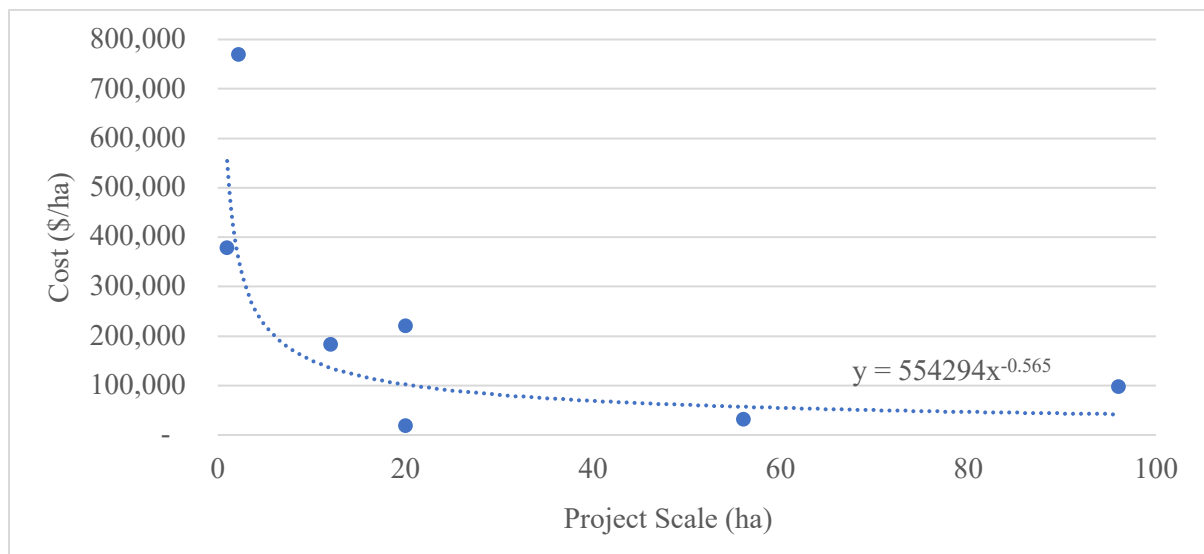
If a tidal-flat that stores large amounts of carbon is designated as a CWPA, coastal wetland restoration—introduction of vegetation in unvegetated tidal flats—may be considered to enhance carbon sequestration service.

Table 19 shows tidal-flat restoration projects in Korea since 2010. The cost of restoration of coastal wetlands is highly variable. The economies of scale are evident (Figure 12) and the costs vary depending on site conditions and restoration methods. The average cost for coastal wetland restoration is estimated \$ 97,663 ha<sup>-1</sup>. This includes planning cost and construction cost. Planning cost includes cost to process various administrative procedures with environmental impact assessment (EIS) and feasibility study. Construction cost may include cost for land acquisition or compensation for fishery use right if needed.

Table 19. Wetland restoration projects since 2010 (MOF, 2016).

	Location	Contents	Project term	Project scale (km <sup>2</sup> )	Budget (\$)	Cost (\$/ha)
1	Ganghwa	dike → bridge (to allow the flow of seawater)	2014-2016	0.2	4,408,000	220,400
2	Gochang	fish farm → coastal wetland	2010-2013	0.96	9,434,000	98,271
3	Muan	restoration of brackish water zone	2013-2014	0.01 (0.2km × 50m)	379,000	379,000
4	Sinan	remodeling the embankment to allow the flow of seawater	2012-2014	1.2km × 3.5m	1,675,000	769,938
5	Sinan			1.05km × 3.5m		
6	Sinan			0.97km × 4m		
7	Sinan			0.97km × 4m		
8	Goheung	fish farm → coastal wetland	2014-2015	0.2	370,300	18,515
9	Suncheon	salt ponds → coastal wetland	2010-2012	0.12	2,204,000	183,667
10	Sacheon	dike → bridge (to allow the flow of seawater)	2010-2012	0.56	1,763,000	31,482
average				0.30	2,890,471	97,663

Figure 12. Coastal wetland restoration costs by project scale.



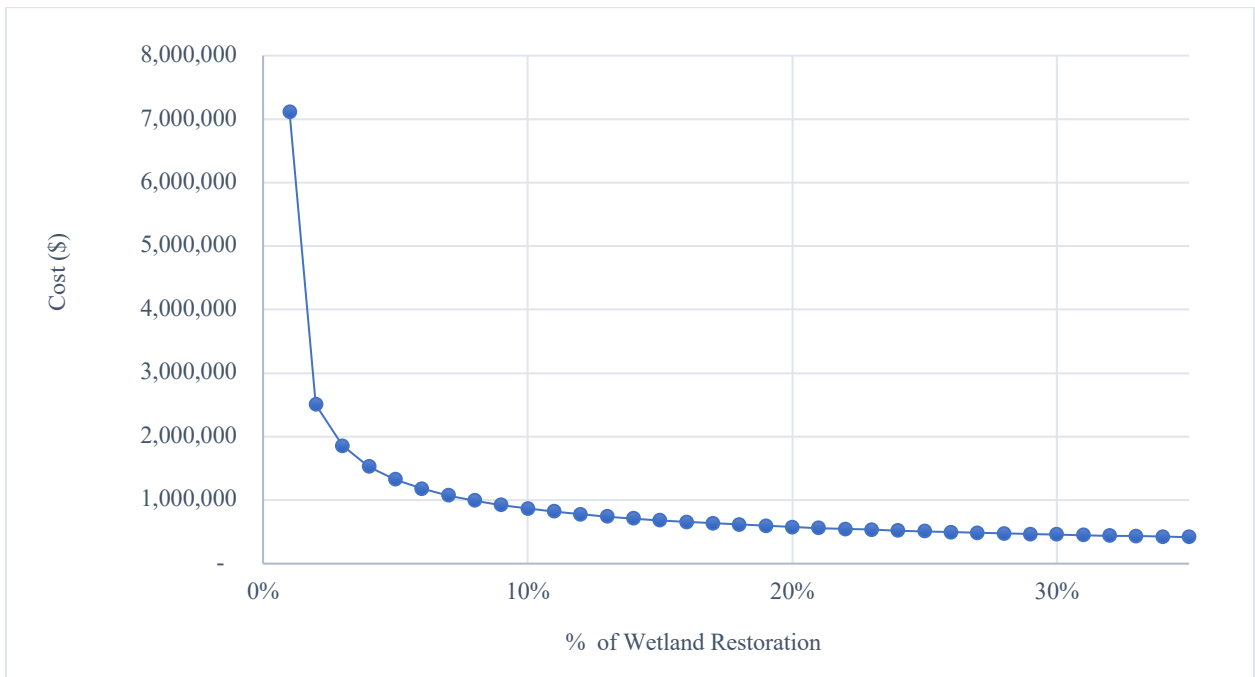
Given that planning costs generally account for about 10% of total restoration costs, the cost is divided between \$ 9,770 ha<sup>-1</sup> for planning and \$ 87,890 ha<sup>-1</sup> for construction. As stated previously, in accordance with ‘economy of scale’ expressed in equation (a), the larger the restoration area, the smaller the restoration cost per unit area (Figure 12). The coastal wetland restoration cost is estimated using this equation.

$$y = 554294x^{-0.565} \quad (a)$$

where, y: coastal wetland restoration cost (\$/ha)  
 x: project scale (ha)

To determine the scale of wetland restoration to apply to the calculation, the unit cost per unit of restoration scale (marginal cost) is calculated (Figure 13). The marginal cost decreases remarkably until the restoration scale of 5% and it can be seen that there is no big difference after that. However, restoration scale cannot be greatly increased. The widespread distribution of fishing rights in Korea’s tidal flats is a major factor limiting the scale of coastal wetland restoration. Therefore, it is assumed that only the upper 10% of the intertidal zone is restored in consideration of the fact that the fishing in the tidal flats is mainly performed in the middle and lower parts of the tidal flat.

Figure 13. Marginal cost for the wetland restoration of the Ganghwa tidal flat.





Considering ‘global average and standard deviation of carbon sequestration rate for salt marshes’ is  $8.0 \pm 8.5 \text{ t CO}_2 \text{ e ha}^{-1} \text{ yr}^{-1}$  (Murray et al., 2011), the sequestration rate of carbon additionally stored through wetland restoration is assumed to be  $8 \text{ t CO}_2 \text{ e ha}^{-1} \text{ yr}^{-1}$ . This means that carbon is now being stored at the rate of  $8 \text{ tCO}_2\text{e ha}^{-1} \text{ yr}^{-1}$ , and  $8 \text{ tCO}_2\text{e ha}^{-1} \text{ yr}^{-1}$  carbon additionally will be stored through wetland restoration. The reason for adopting a higher value of the standard deviation, it is assumed that the restoration and thorough management can maximize the carbon storage capacity. For the calculation, a 4.5% discount rate, 25-year time horizon, and \$20/t CO<sub>2</sub> e of a carbon price is used.

When the 10% of the Ganghwa tidal flat is restored, the cost is calculated \$19 million (Table 20), and the benefit from additionally stored carbon through wetland restoration is estimated \$ 2–13 million with a discount rate of 4.5% and a carbon price of \$ 5–30/t CO<sub>2</sub> e (Table 21). In this calculation, the cost is higher than the profit due to the initial high construction cost. It should be noted the net benefit of restoration does not occur within a short period of time but rather over a long period of time of more than 25 years. However, to attract investment from private sectors, efforts are needed to lower high construction costs (\$ 19 million).

Table 20. Cost for the wetland restoration of the Ganghwa tidal flat

Location	Area restored (ha)	Cost	
		(\$/ha, one-time)	(\$, one-time)
Ganghwa tidal flat	3,530	5,486	19,365,580

Table 21. Benefit for the wetland restoration of the Ganghwa tidal flat

Location	Area restored (ha)	Discount rate (%)	NPV (10 <sup>6</sup> USD)			
			\$5/t CO <sub>2</sub> e	\$10/t CO <sub>2</sub> e	\$20/t CO <sub>2</sub> e	\$30/t CO <sub>2</sub> e
Ganghwa tidal flat	3,530	2.0	2,756,712	5,513,424	11,026,848	16,540,272
		4.5	2,093,743	4,187,486	8,374,972	12,562,459
		7.0	1,645,486	3,290,972	6,581,944	9,872,916

### 3. Net benefit for tidal flat conservation

The net benefit is estimated assuming that the Ganghwa tidal flat was designated as CWPA and the wetland restoration project was implemented in 10% of the total area to increase carbon stocks. The net benefit is estimated to be \$ 182 million with 4.5% discount rate and \$ 20/ t CO<sub>2</sub> e of carbon market price (Table 22).

Table 22. The net benefit for the Ganghwa tidal flat conservation

	Discount rate (%)	Cost (10 <sup>6</sup> USD)	Benefit (10 <sup>6</sup> USD)	Net benefit (10 <sup>6</sup> USD)	Remarks
- Total area of the Ganghwa tidal flat: 35,300 ha - Area restored: 3,530 ha (10% of the Ganghwa tidal flat)					- time period: 25 years - carbon price: \$ 20/ t CO <sub>2</sub> e
CWPA establishment & management	2	68.5	302.0	233.5	- annual monitoring cost included
	4.5	52.1	244.7	192.6	
	7	41.0	203.8	162.8	
Coastal wetland restoration	2		11.0	-8.4	- annual monitoring cost excluded
	4.5	19.4	8.4	-11.0	
	7		6.6	-12.8	
Total	2	87.9	313.0	225.1	
	4.5	71.5	253.1	181.6	
	7	60.4	210.4	150.0	

The net benefit is highly variable depending on the carbon market price, discount rate (Figure 14). If the carbon price is \$ 5 and 10% of the Ganghwa tidal flat was restored, the net benefit is -8.2 million dollars. However, as carbon prices rise, wetland restoration projects become more economically feasible. At a discount rate of 4.5%, the break-even point between benefit and cost occurs when the price of carbon is \$ 4-6/tCO<sub>2</sub>e (Figure 15). Given the average carbon market price in 2018 in Korea is \$ 20.62/tCO<sub>2</sub>e, the concept of blue carbon is economically viable (Figure 16).

Figure 14. The net benefit of the Ganghwa tidal flat conservation.

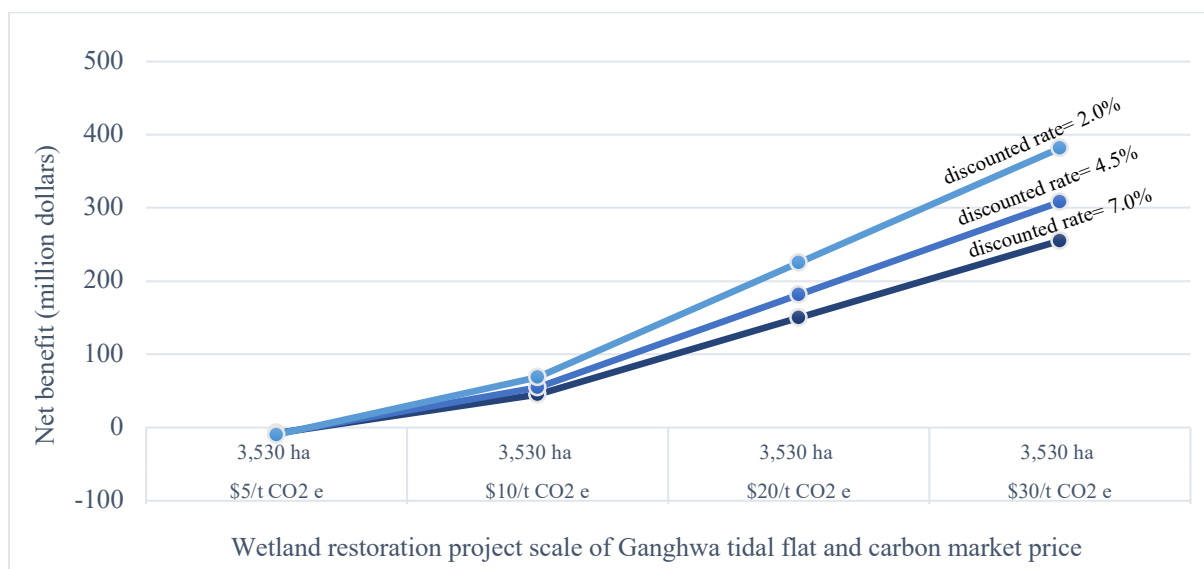
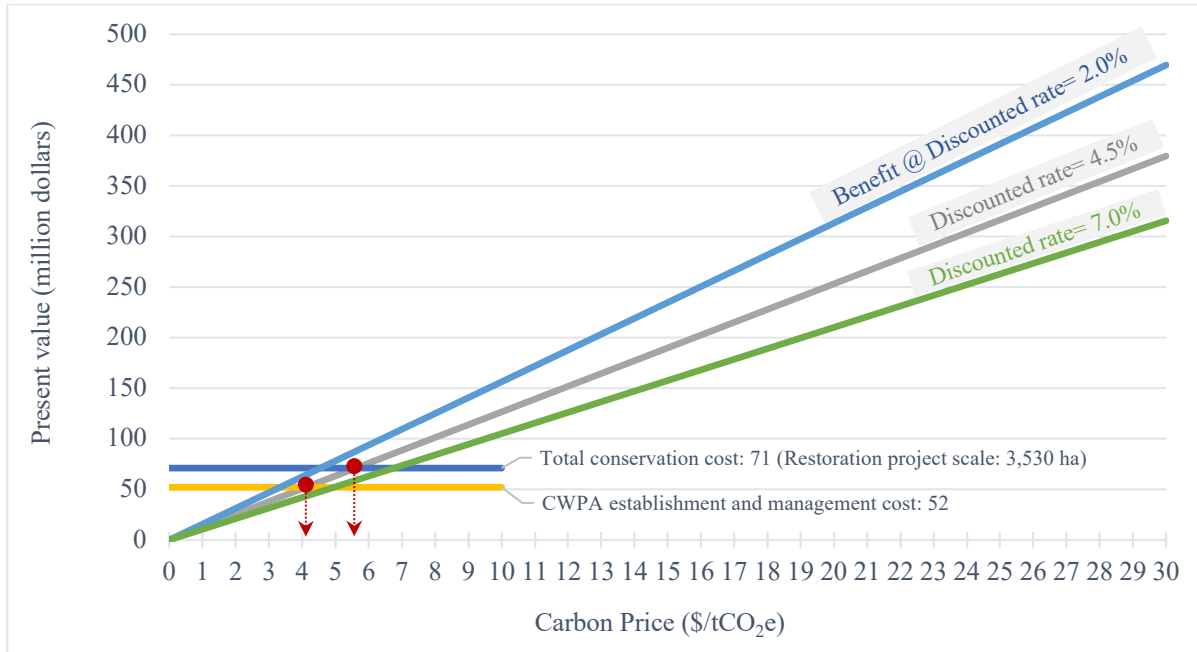
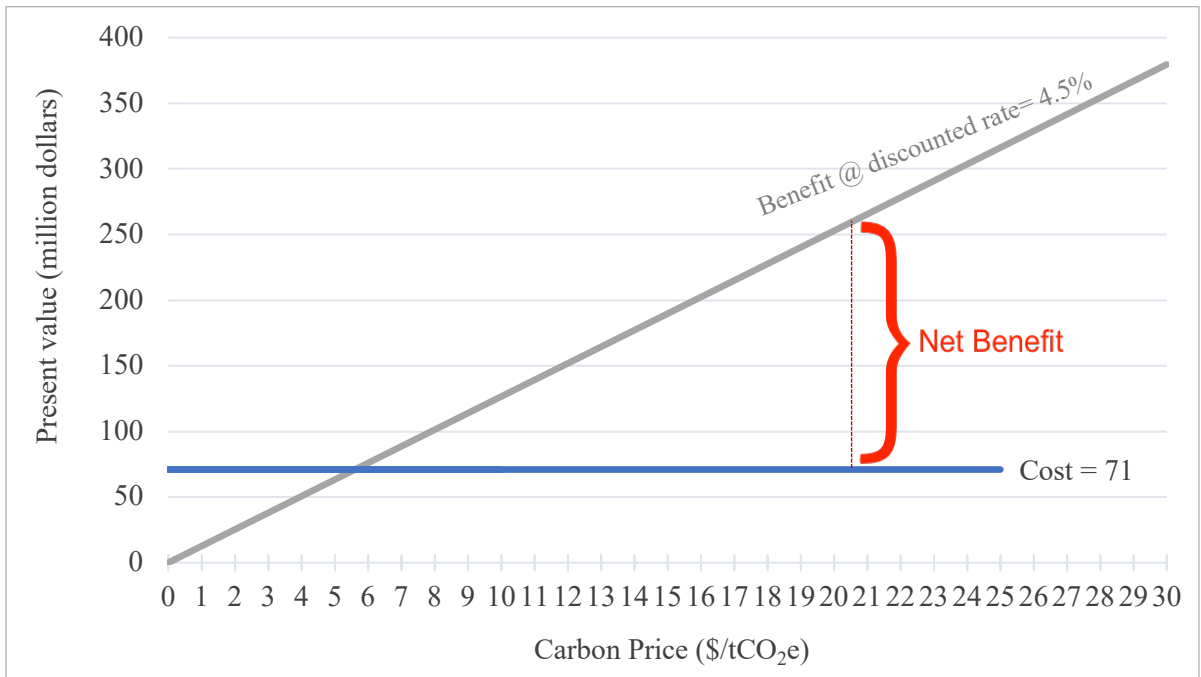


Figure 15. Break-even point between benefit and cost in the Ganghwa tidal flat.



Note: Break-Even Point between Benefit and Cost: \$ 4-6/tCO<sub>2</sub>e (@ discount rate= 4.5%)  
 Average Carbon Market Price in 2018, Korea: \$ 20.62/tCO<sub>2</sub>e

Figure 16. Net benefit when the average carbon market price in 2018 is applied.



This net benefit is estimated taking into account only the benefit of carbon storage service among the many benefits provided by tidal flats. Additional benefits comprise other market benefits (use values or direct use values) and non-market benefits (non-use values or in-direct use values). Use values include direct enjoyment or consumption of environmental goods such as fishing and tourism, and non-use values include the benefits of conserving resources for future generations and the joy of knowledge that can be obtained from something that exists (Keohane & Olmstead, 2007). Including these additional use and non-use values will result in greater net benefits and lower break-even points between benefits and costs. It is therefore important to ensure these other benefits are not overlooked in decision-making processes for coastal development.

Table 23. Costs-benefits comparison between no-conservation and conservation policy.

	No-conservation policy (developed)	Conservation policy
Cost	Opportunity cost - Carbon sequestration: \$ 244.7 million - Other market benefits and non-market benefits (excluded)	CWPA designation and management & wetland restoration: \$ 71.5 million
		Opportunity cost for development (excluded)
Benefit	Development benefit (excluded)	Carbon sequestration: \$ 253.1 million - CWPA creation and management: \$ 244.7 million - wetland restoration: \$ 8.4 million
		Other market benefits and non-market benefits (excluded)

Note: time period (25 years), discount rate (4.5%), carbon price (\$ 20/ t CO<sub>2</sub> e)

#### 4. Application of SCC (Social Cost of Carbon)

The previous calculations are based on the “market value” of carbon. There is another important value, the “Social Cost of Carbon (SC-CO<sub>2</sub>).” This is the cost for the long-term economic damage caused by a ton of carbon dioxide, and thus the cost to society. The US government set a country-level SCC of \$ 42 per tCO<sub>2</sub> for 2020 at a 3% discount rate (EPA). Science suggests that this cost is probably much higher. Recently Ricke et al. (2018) estimated that the median value of the global SCC (GSCC) is \$ 417 per tCO<sub>2</sub> (66% confidence intervals, range: \$177–805 per tCO<sub>2</sub>). When GSCC is applied, the net benefit for the Ganghwa tidal flat is \$ 5,204.8 million (Table 24).

Table 24. The net benefit for the Ganghwa tidal flat conservation, when GSCC is applied.

	Discount rate (%)	Cost (10 <sup>6</sup> USD)	Benefit (10 <sup>6</sup> USD)	Net benefit (10 <sup>6</sup> USD)	Remarks
- Total area of the Ganghwa tidal flat: 35,300 ha - Area restored: 3,530 ha (10% of the Ganghwa tidal flat)					- time period: 25 years - carbon price: \$ 417/ t CO <sub>2</sub> e
CWPA establishment & management	2	68.5	6,297.2	6,228.7	- annual monitoring cost included
	4.5	52.1	5,101.7	5,049.6	
	7	41.0	4,249.9	4,208.9	
Coastal wetland restoration	2	19.4	229.9	210.5	- annual monitoring cost excluded
	4.5		174.6	155.2	
	7		137.2	117.8	
Total	2	87.9	6,527.1	6,439.2	
	4.5	71.5	5,276.3	5,204.8	
	7	60.4	4,387.1	4,326.7	

The application of the GSCC shows a considerably higher net benefit even if the conservation activities of the tidal flats do not consider other ecosystem goods and services. However, even though the “market price” is applied, the conservation policy is still worthy in the sense of economic gains, as shown in Table 22.

## VII. Blue carbon related conservation policies

The economic value of blue carbon estimated in the previous section is enough to be used as a stimulant for conservation and restoration of coastal wetlands. Based on this economic value, this section examines how blue carbon can be used for climate change mitigation policies.

### 1. Building awareness of blue carbon

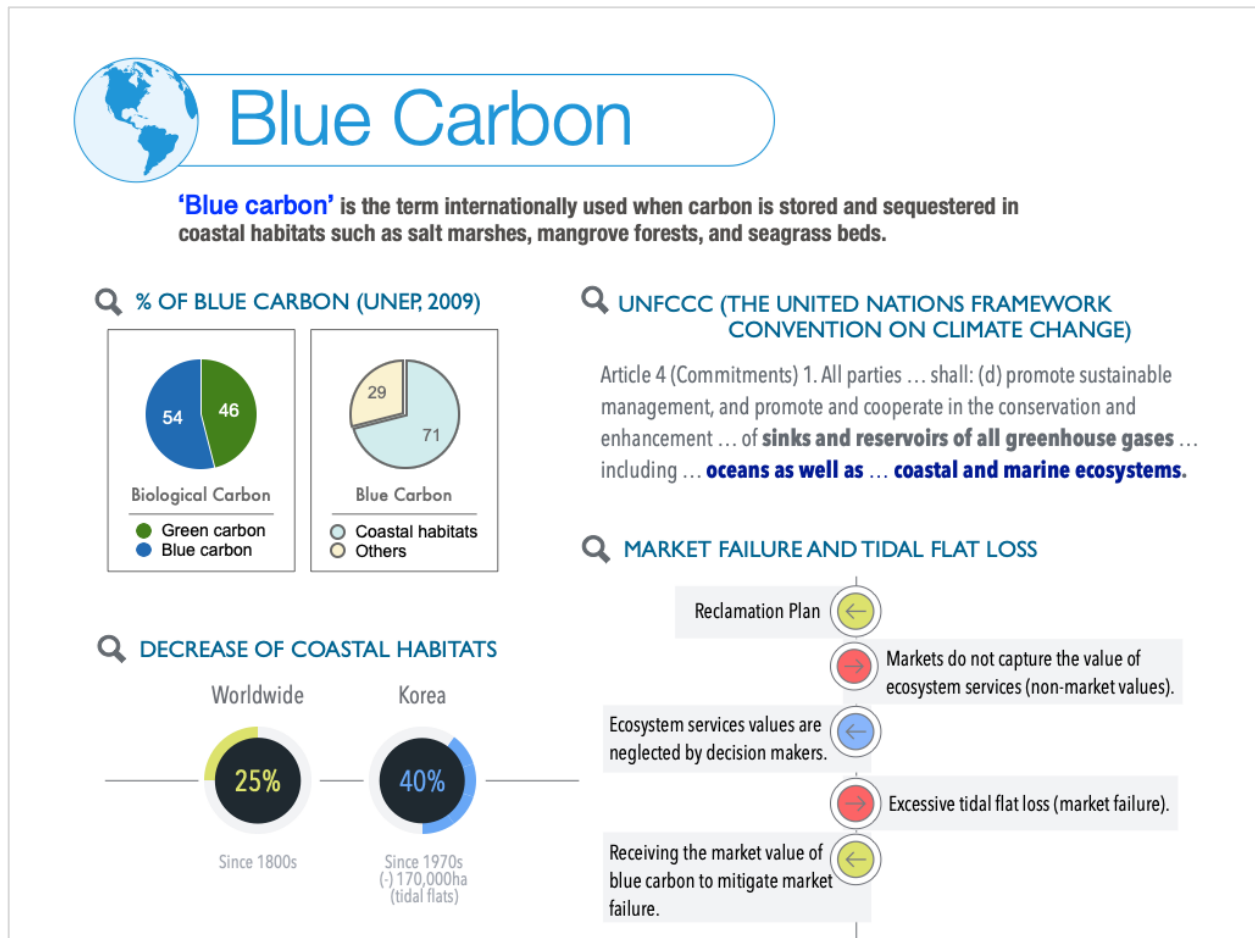
Blue carbon has been reported to be ten times as large in carbon storage than inland forests (McLeod et al., 2011). As relevant research progresses, it has been revealed that coastal ecosystems play an important role in natural greenhouse gas sinks and climate change mitigation opportunities. Given the previously estimated monetary value of carbon stored in the tidal flats, the use of blue carbon for tidal flat conservation policies is attractive. It is a cost-effective way to reduce greenhouse gas (GHG) emissions, and as well as a way to increase ancillary benefits of ecosystem services: water purification, shoreline protection, biodiversity conservation, and increases the possibility of ecotourism. The awareness of ‘blue carbon’ and its monetary value can protect tidal flats from development that does not take into account the value of coastal ecosystem services and biodiversity conservation. However, in Korea, compared to the growing awareness in science, the importance of blue carbon has not yet been widely recognized among policymakers and stakeholder groups.

In order to successfully use blue carbon in relevant policies, it is important to gain public support. This support can be obtained when sufficient information on blue carbon is available to the public and its importance is recognized. The incomplete or asymmetric information can cause market failure. Markets will not function efficiently with such incomplete information (Kotchen, 2013). The existence of information asymmetry, between regulators and stakeholders, makes it difficult for policy-makers to maximize net environmental benefits delivered by scarce public funds, due to adverse choice (de Vries, 2016). The interaction between information and economic behavior involves an information externality, which is defined as occurring when a decision-maker’s action affects the opportunities and choices of other decisions. To correct information externalities, government intervention—of the right kind—may help to improve market outcomes (Nakamura, 1993). Hence, efforts to inform policy makers, decision makers, and the public of the value of coastal habitat as a blue carbon repository are a top priority to correct the information asymmetry. Especially, it is important to share information with local governments who are responsible for the establishment of coastal management plans.

Considering that the nation-wide blue carbon survey is underway with a 5-year scheme (2018-2022) in Korea, the building awareness of blue carbon can be carried out in two stages. This stage distinction is divided between when the survey is underway and after the survey is over. That is, ① steps that can provide only general information, and ② steps that can provide specific information to enable policy reflection. The first stage is to inform the public of blue carbon, focusing on why blue carbon is important to climate change mitigation, and the advantages that can be gained from the use of blue carbon as tidal flat conservation policy. This activity can reduce incomplete information externality by building public awareness. Figure 17 shows an example of an infographic containing a summary of this paper to inform

the public of blue carbon. The second stage is to inform decision-makers and stakeholder groups, based on findings of research, of how blue carbon can be specifically used for coastal management. This activity can decrease asymmetric information externality by bridging the gap in information between blue carbon related agencies and organizations.

Figure 17. Example of an infographic for building awareness of blue carbon



# Net Benefit of Conservation Ganghwa Tidal Flat

Conservation: 1. Designate Protected Area  
2. Restore 10% of the Bare Tidal Flat to a Wetland

## NET PRESENT VALUE OF BLUE CARBON

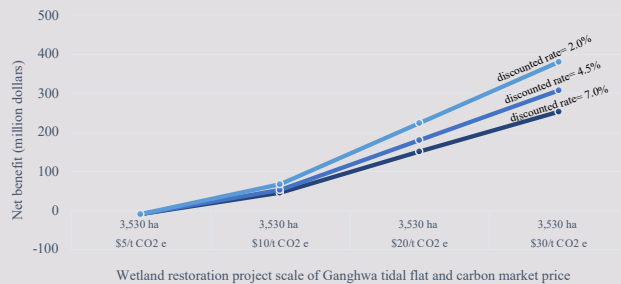
$$\sum_{t=0}^n \frac{\text{annual } CO_2 \text{ reduction (t } CO_2 \text{ e)} \times CO_2 \text{ price } (\frac{\$}{tCO_2e})}{(1+r)^t}$$

r: social discount rate (2, 4.5, 7)

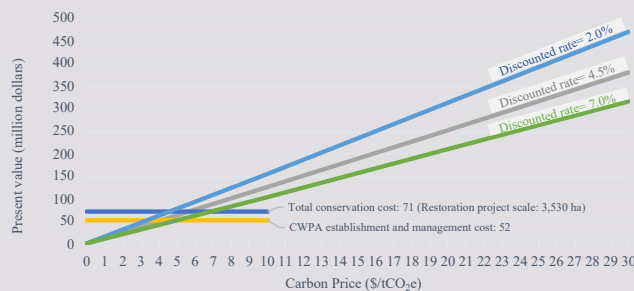
t: time horizon(25 years)

CO<sub>2</sub> reduction: emission avoidance + annual new sequestration

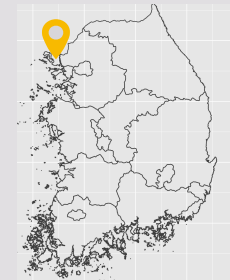
### The Net Benefit of Conservation



**Break-Even Point between Benefit and Cost: \$ 4-6/tCO<sub>2</sub>e at a Discount Rate of 4.5%**  
**Average Carbon Market Price in 2018 in Korea: \$ 20.62/tCO<sub>2</sub>e**



### Location



Area: 35,300 ha

✓ Mean Organic Carbon (2018 survey): 95.15 tC/ha

✓ Mean Organic Carbon (CO<sub>2</sub> equivalent): 349.20 tCO<sub>2</sub>e/ha

✓ Annual Carbon Burial Rate (global mean): 8.0 tCO<sub>2</sub>e/ha/yr

## 2. Participation in domestic and international network

The United Nations Framework Convention on Climate Change (UNFCCC) has recognized coastal conservation and restoration as an important aspect of climate change mitigation. It is, therefore, possible to integrate coastal ecosystems into UNFCCC mechanism in the form of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program that already exist, but this has yet to fully happen (Herr et al., 2012). However, international discussions on blue carbon have begun to bear fruit. At the 13th Meeting of the Conference of the Contracting Parties to the Ramsar Convention on Wetlands, held in October 2018, Parties adopted a resolution calling for the use of blue carbon as part of the conservation and restoration of coastal ecosystems by providing practical tools and support (Resolution XIII.14: Promoting conservation, restoration and sustainable management of coastal blue-carbon ecosystems). This is the first blue-carbon-related resolution in the international community; it is expected to affect other international-level discussions on climate change mitigation policy.

Blue carbon is not included in the Korean government's climate change mitigation policy, nor is it known in the inter-ministerial network in charge of climate policy. Domestically, it is important to include blue carbon in the inter-governmental network to reflect it in climate related policy at the national level. In this network, it is also necessary to discuss how to make



blue carbon feasible in the framework of domestic and international climate policy. This is to reduce the risk of failure of blue-carbon-related policies and to gain broad national support.

### 3. Inclusion in the carbon market

Carbon offsets have been introduced in response to climate discussions to provide mechanisms for least-cost global GHG abatement. The cost of reducing one ton of CO<sub>2</sub>e elsewhere is sometimes less expensive than reducing one ton of one's own emissions. Purchasing offsets is a readily available mechanism for individual companies or organizations to price their own carbon emissions (Second Nature, 2016). Offsets do not directly trigger changes in the aggregate quantity of an emitter. Therefore, offset is conventionally considered the last step for conservation (① avoid, ② minimize, ③ restore, ④ compensate or offset) after all other potential steps have been undertaken. However, knowing the price of their emissions can change people's behavior and decision-making. This incentive-based policy instrument can make an effective contribution to achieve least-cost implementation across all conservation or pollution mitigation channels (Squires & Garcia, 2018).

Carbon offset markets exist both under compliance schemes and as voluntary programs. Compliance markets are created and regulated by mandatory regional, national, and international carbon reduction regimes, such as the Kyoto Protocol and the Korean Emissions Trading Scheme (KETS). Voluntary offset markets function outside of the compliance markets and enable companies and individuals to purchase carbon offsets on a purely voluntary basis (Kollmuss et al., 2008). The KETS was designed to play an essential role in meeting Korea's 2030 NDC (Nationally Determined Contributions) target of 37% below BAU (Business As Usual) emissions (Cap: 536 Mt CO<sub>2</sub>e). The KETS covers 610 of the country's largest emitters, which account for ~68% of national GHG emissions. The average secondary market price in 2018 is KRW 22,692 (USD 20.62) / t CO<sub>2</sub>e (ICAP, 2019).

The Korean forest carbon offset market, which performs most similar functions to blue carbon, is covered by KOP (Korea Offset Program). This program has been established to support KETS participants as well as encourage voluntary emissions reductions in other sectors, reduce the costs of achieving the national emission target, and help stabilize the carbon market. In order for KOC (Korea Offset Credit) to be used for the KETS compliance, KOC has to be converted into KCU (Korea Credit Unit) and can only be owned and traded by KETS participating entities (Figure 18) (ADB, 2018). The Korean Forest Carbon Offset Scheme is currently operating only the social contribution scheme, which allows trading forest carbon uptake on the voluntary market or using them as promotion. The reduction certification (credit) scheme, which can be used in the emission trading system, is not yet being used. The social contribution scheme has a transaction and a non-transaction method, with the difference between the two being whether or not there is a 'verification' process (Figure 19, Table 25) (Korea Forest Service, 2019).

Figure 18. Conversion of Korea offset credits into Korea credit units (ADB, 2018).

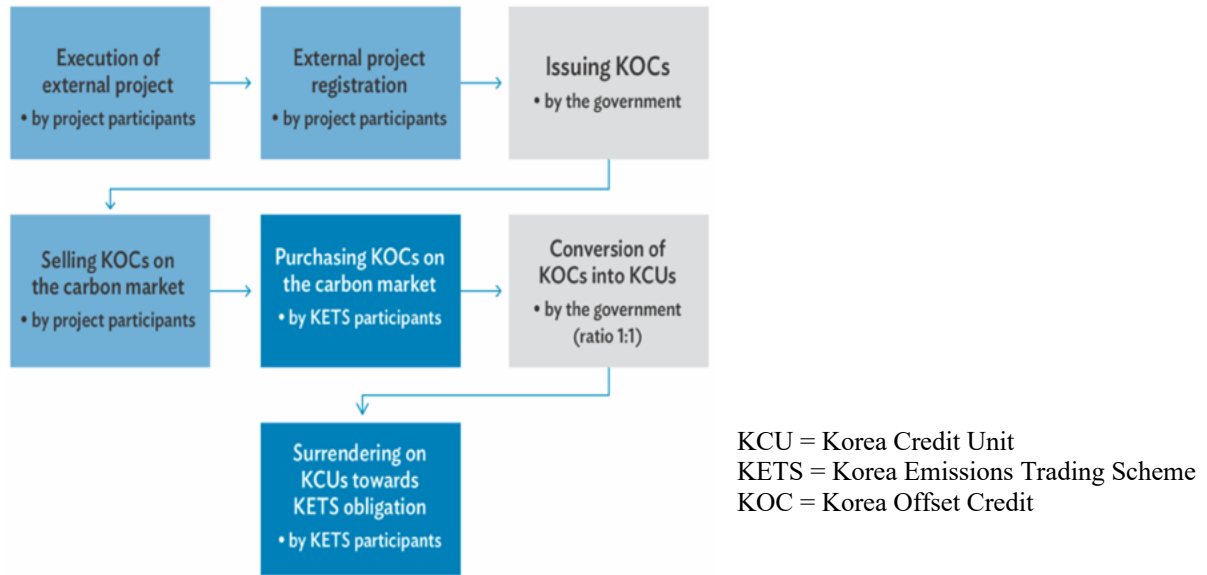


Figure 19. Korean Forest Carbon Offset Scheme.

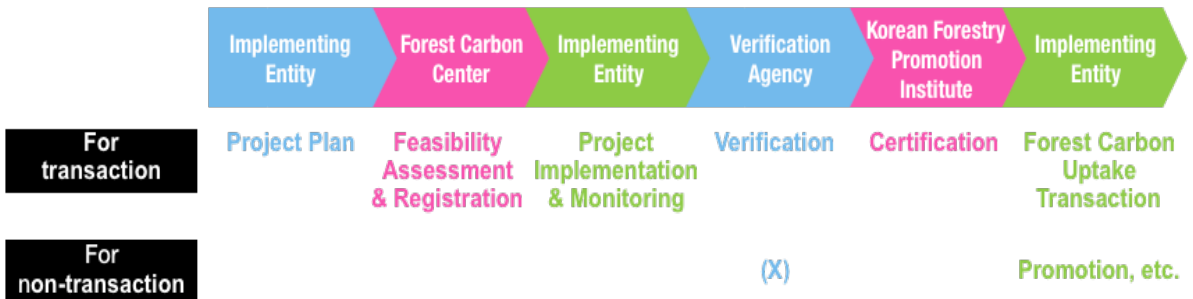


Table 25. Forest carbon offset project registration status (2013-present)

	Project registration status						Expected forest carbon sink (tCO <sub>2</sub> e)
	Afforestation	Reforestation	Forest management	Wood product utilization	Forest restoration	Total	
Transaction	6	17	92	4	22	141	5,680,553
Non-transaction	4	33	5	5	24	71	144,561
Total	10	50	97	9	46	212	5,825,114

Source: Forest Carbon Registry (<http://carbonregistry.forest.go.kr>). Accessed: April 24, 2019.

Given that the forestry sector has four offset project types, which are 1) afforestation and reforestation, 2) forest management project, 3) wood product utilization project, and 4) forest restoration project (Table 26), coastal wetland restoration project in the blue carbon sector could be considered for inclusion in the KOP.

Table 26. Forest carbon offset projects covered by KOP

Category	Project Types
Forestry (already covered by KOP)	<ul style="list-style-type: none"> <li>• Afforestation and reforestation project</li> <li>• Forest management project (increase carbon uptake of forests through sustainable forests management)</li> <li>• Wood product utilization project</li> <li>• Forest restoration project</li> </ul>
Blue carbon (future consideration for inclusion)	<ul style="list-style-type: none"> <li>• Coastal wetland restoration project</li> </ul>

In Australia, the Department of Environment and Energy (DEE) is exploring opportunities to use the emissions reduction fund (ERF) as an incentive for blue carbon sequestration activities. ERF is designed to reduce emissions at the lowest cost and support valid and additional emissions reduction projects. It provides incentives for businesses, farmers, landholders, and others to adopt new practices and technologies to reduce Australia’s greenhouse gas emissions. Projects registered under the Fund receive Australian carbon credit units for each ton of carbon abatement (DEE, 2019).

Table 27. Eligible emissions reduction activities Under the Emission Reduction Fund in Australia (blue carbon related contents are excerpted).

Sectors	Eligible emissions reduction activities
Agriculture	<ul style="list-style-type: none"> <li>• Estimating sequestration of carbon in soil using default values.</li> </ul>
Vegetation management	<ul style="list-style-type: none"> <li>• Avoided clearing of native regrowth</li> <li>• Avoided Deforestation</li> <li>• Designated Verified Carbon Standard projects</li> <li>• Human-induced regeneration of a permanent even-aged native forest</li> <li>• Native forest from managed regrowth</li> <li>• Plantation Forestry</li> <li>• Reforestation and Afforestation</li> </ul>

It may take a long time to bring blue carbon to the carbon market. However, internationally, related policy preparations are proceeding step by step, with specific achievements coming from the use of blue carbon for wetland restoration under the Ramsar Convention. In addition, a few countries, such as Australia, are preparing to include blue carbon in their own carbon markets. Korea also needs to seek opportunities for blue carbon to be included in the KOP so that it can contribute to the national GHG emission reduction target.

#### 4. Tidal flat conservation

##### **CWPA or MPA Designation**

Tidal flats are one of the most threatened ecosystems on earth, because they can be easily converted to land through reclamation. The creation of Coastal Wetland Protected Area (CWPA) or Marine Protected Area (MPA) is a powerful tool to protect tidal flats where they sequester significantly higher amount of carbon. It helps to secure stored carbon, reduce CO<sub>2</sub> emissions, and help country to achieve its climate change mitigation and adaptation goals (Howard et al., 2017).

CWPAs and MPAs are designated by the Conservation and Management of Marine Ecosystems Act (CMMEA) and Wetlands Conservation Act (WCA), respectively. To date, most protected areas have been designated for areas with high biodiversity. Both laws should be amended to ensure that tidal-flats with high carbon stocks are also designated as protected areas. The CMMEA has been revised on November 28, 2017 allowing it to be designated as MPAs for coastal areas where high amounts of carbon are stored, while the WCA remains unamended. There is no significant difference between MPA and CWPA in designation and management. However, the amendment of WCA needs to be considered, considering the restoration and conservation of wetlands are included in the Ramsar Convention, and the WCA has been enacted for the implementation of this Convention.

If tidal flats are designated as CWPAs and MPAs, they must be well managed to avoid degradation of the original carbon storage function. Degradation of blue carbon ecosystems can result in GHG (e.g. CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) emissions. A guideline is needed to provide specific MPA or CWPA management methods to prevent deterioration of this feature. This guideline needs to include the designation criteria, monitoring method of the amount of carbon stored, and vegetation and fishery management methods to maintain or increase its ability to sequester carbon. In order for newly sequestered carbon to be used for the acquisition of carbon credits in the future, a more sophisticated guideline for monitoring and assessment is required to calculate annual carbon stock changes.

##### **Coastal Wetland Restoration**

The restoration of coastal wetlands provides opportunities for carbon sequestration and greenhouse gas offset. The restoration activities here include creation, restoration, and enhancement. In Korea, tidal flat restoration projects are underway for salt ponds or fish farms that are no longer in use, dikes and seawalls that are disrupting natural tidal flows, and previously drained areas without completion of development. The projects are primarily aimed at improving water quality or tourism function, rather than increasing carbon sequestration.

Restoration to vegetated wetlands can enhance co-benefits such as water purification, coastal erosion protection, and tourism increase compared to unvegetated tidal flats. Among the co-benefits of wetland restoration, tourism benefit is expected to be more prominent. Table 28 shows the economic effect (based on production inducement effect) of tourism of

Suncheonman wetland that was estimated about ₩ 298.8 billion (\$ 267 million) nationally, and about ₩ 203.4 billion (\$ 182 million) regionally in 2015 (Hwang and Lee, 2017).

Table 28. Economic ripple effect of Suncheonman Wetland (2015)

	production inducement effect (million KRW)		value-added inducement effect (million KRW)		employment inducement effect (capita)	
	region	nation-wide	region	nation-wide	region	nation-wide
Total	203,356	298,810	97,793	130,393	4,494	5,248

Figure 20. Suncheonman Wetland



Source: traveli (<http://www.traveli.co.kr/>)

Source: MCST (<https://www.mcst.go.kr/>)

Coastal wetlands restoration is affected by many factors such as elevation (degree of tide influence), sediment accumulation rate, soil type, salinity, and vegetation types. These factors are closely related with carbon sequestration rate. Wetlands restored without consideration of interaction between factors may become carbon source than carbon sink. Therefore, thorough field surveys and detailed guidelines, which take into account specific characteristics of tidal flats, are required. Table 29 shows the considerations by factors for wetland restoration.

Table 29. Important considerations by factors for wetland restoration.

Factors	Considerations
Elevation (degree of tide influence)	Wetlands in ‘microtidal’ environments potentially have a higher percentage of carbon in soil than relatively well-drained marshes in coastal areas with large tidal ranges (Philip Williams & Associates, 2009).  Restoring natural hydrology (freshwater flows and tidal exchange) will maximize blue carbon sequestration (Macreadie, 2017).
Sediment accumulation rate (SAR)	The higher the SAR, the more carbon it can sink, but also the faster it can turn into land and become a carbon source.

Factors	Considerations																								
	SAR in salt marshes range from 2-10 mm/yr with a median of 5 mm/yr. Most marshes have SAR of 1-7 mm/yr (Alongi, 2018).																								
Soil type	Fine-grained sediment can store more carbon. (carbon sequestration rate (CSR): muddy > sand-muddy > sandy)																								
Salinity	<p>GHG emissions from coastal wetlands are strongly influenced by estuarine salinity gradients (Crooks et al., 2010).</p> <p>In highly saline wetlands (&gt;18 ppt), sediment’s CSR exceeds CH<sub>4</sub> emission rate in CO<sub>2</sub>-equivalent units (Poffenbarger et al., 2011).</p> <p>In lower salinity wetlands (salinity 5-18 ppt), CH<sub>4</sub> emissions and sequestration are approximately in balance (Krithika et al., 2008).</p> <p><i>Table 30. Carbon sequestration and methane production (Philip Williams &amp; Associates, 2009).</i></p> <table border="1" data-bbox="500 848 1401 1339"> <thead> <tr> <th data-bbox="500 848 667 930">Wetland type</th> <th data-bbox="667 848 943 930">Carbon sequestration potential (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</th> <th data-bbox="943 848 1219 930">Methane production potential (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</th> <th data-bbox="1219 848 1401 930">Net balance</th> </tr> </thead> <tbody> <tr> <td data-bbox="500 930 667 1012">Mudflat (saline)</td> <td data-bbox="667 930 943 1012">Low (184)</td> <td data-bbox="943 930 1219 1012">Low (50)</td> <td data-bbox="1219 930 1401 1012">Low C sequestration</td> </tr> <tr> <td data-bbox="500 1012 667 1094">Salt Marsh</td> <td data-bbox="667 1012 943 1094">High (184-917)</td> <td data-bbox="943 1012 1219 1094">Low (50)</td> <td data-bbox="1219 1012 1401 1094">High C sequestration</td> </tr> <tr> <td data-bbox="500 1094 667 1176">Brackish Tidal Marsh</td> <td data-bbox="667 1094 943 1176">High (183.3-1,650)</td> <td data-bbox="943 1094 1219 1176">High (125-2,500)</td> <td data-bbox="1219 1094 1401 1176">Unclear</td> </tr> <tr> <td data-bbox="500 1176 667 1257">Freshwater Tidal Marsh</td> <td data-bbox="667 1176 943 1257">Very High (1,833-3,700)</td> <td data-bbox="943 1176 1219 1257">High-Very High (1,000-2,500+)</td> <td data-bbox="1219 1176 1401 1257">Unclear</td> </tr> <tr> <td data-bbox="500 1257 667 1339">Estuarine Forest</td> <td data-bbox="667 1257 943 1339">High (366.7-916.7)</td> <td data-bbox="943 1257 1219 1339">Low (250)</td> <td data-bbox="1219 1257 1401 1339">High C sequestration</td> </tr> </tbody> </table> <p data-bbox="508 1346 919 1371">Note: 1gC≡3.67gCO<sub>2</sub>e; 1gCH<sub>4</sub>≡25gCO<sub>2</sub>e</p>	Wetland type	Carbon sequestration potential (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	Methane production potential (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	Net balance	Mudflat (saline)	Low (184)	Low (50)	Low C sequestration	Salt Marsh	High (184-917)	Low (50)	High C sequestration	Brackish Tidal Marsh	High (183.3-1,650)	High (125-2,500)	Unclear	Freshwater Tidal Marsh	Very High (1,833-3,700)	High-Very High (1,000-2,500+)	Unclear	Estuarine Forest	High (366.7-916.7)	Low (250)	High C sequestration
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Estuarine Forest	High (366.7-916.7)	Low (250)	High C sequestration																						
Vegetation type	<p>Introduction of single cosmopolitan genus—mostly <i>Spartina</i>—for coastal protection has led to decrease of biodiversity (Daehler &amp; Strong, 1996).</p> <p>In Korea, <i>Spartina</i> genus is non-native, and invasive species designated by law. Although they are known to have higher CAR, the balance between CAR and another ecosystem function (biodiversity) also needs to be considered.</p>																								
Others	<p>Shellfish reefs creation: See ‘6. Fishery management’ in this chapter.</p> <p>Reducing nutrient inputs and avoiding unnaturally high levels of bioturbation will minimize blue carbon losses (Macreadie, 2017).</p>																								

## 5. Coastal management

The coastal management policy involves key processes to determine the development and conservation of coastal areas. Here, this paper examines the relevant coastal conservation policies in which blue carbon can serve as an incentive, and how can it be used in those policies.

### **Coastal Management Plan**

Avoiding loss of tidal flats and increasing blue carbon stocks through coastal management activities has the effect of reducing greenhouse gases (GHG), which are on the rise. In Korea, the ecosystem value of the tidal flats has not been properly evaluated in the decision-making process of coastal area developments. As a result, a significant area of tidal flats has disappeared, and some of the reclamation planned areas have been drained and left without further development. This is a result of market failure. The market and non-market values that ecosystem provides—including blue carbon—need to be taken into account in the decision-making process to prevent such failures.

The basis of Korea's coastal management is the 'Integrated Coastal Management Plan,' which is established in accordance with the Coastal Management Act (CMA). The plan includes the goals and strategies of coastal management projects. The current plan is for 2011-2021 (as amended in 2016), and one of the main goals is "Awareness of the value of ecosystem services and the reduction of natural resources caused by changes in coastal environment." When a coastal development plan is established in accordance with this goal, it is necessary to include in the strategies that the valuation of blue carbon benefits must be conducted in individual development project. Another option is to include this valuation directly in the decision-making process. The reclamation decision process is managed by the Central Committee for Deliberation on Coastal Management (CCDCM), which was established based on the CMA. Since CCDCM has rules on its operation (e.g. Creation and presentation of the agenda of Article 8, Preliminary review of Article 9), it needs to be revised to include the valuation of blue carbon and other ecosystem benefits in the cost-benefit analysis for a reclamation project.

### **Coastal Maintenance Projects**

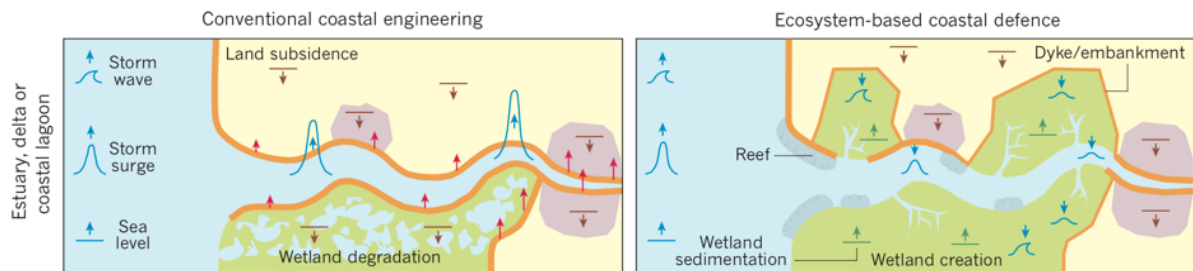
Improvement of blue carbon stocks is closely related to the restoration of coastal wetlands, which is a measurement of ecosystem-based coastal protection. In Korea, coastal maintenance projects are being implemented to protect coastal areas from storm and erosion. As the primary purpose of these projects is to mitigate and adapt to climate change, blue carbon can be used as an incentive for coastal maintenance projects.

The Korean government has continued to raise spending on coastal maintenance projects due to enhanced coastal erosion. The projects' budget, implemented by MOF, has increased from \$ 26 million (29.2 billion KRW) in 2012 to \$ 51 million (57.4 billion KRW) in 2015 (MOF, 2016). These coastal maintenance projects are designed to protect coastal areas from storm surges and coastal erosion. Most of the projects focus on waterfront renovation or revitalization by adopting 'hard' types of conventional coastal engineering such as seawalls and levees. These hard structures contribute to the tidal current changes and enhance coastal erosion in

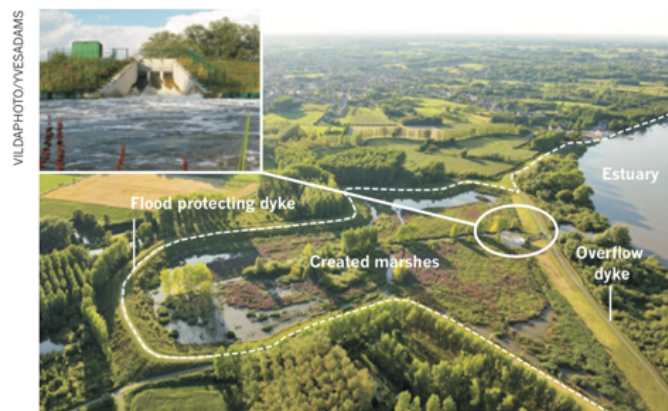
nearby areas. These unintended results eventually led to an increase in other spending for beach nourishment and installation of the submerged breakwater.

The hard structure, also called gray infrastructure, does not have many advantages in climate change mitigation and adaptation, which should be a key goal of coastal maintenance projects. Internationally, ecosystem-based flood protection is known to be more sustainable and cost-effective than conventional coastal engineering. Thus, this method has been implemented on a large scale in recent years, as solutions for many flooded and eroded areas around the world (Temmerman, 2013). The nature-based solutions can help protect coastal areas from flooding and erosion. In addition, they offer many benefits to the environment and local communities, including sustaining livelihoods, improving seafood security, and sequestering carbon (World Bank, 2017). Therefore, when decision-makers establish coastal maintenance plans, consideration should be given to the adoption of wetland creation, restoration, and enhancement. The area to be applied needs to be appropriately designed taking into consideration the interrelationship of ecosystem structure, function and environment so that coastal protection and carbon sequestration can be maximized.

Figure 21. Conventional coastal engineering compared with new ecosystem-based flood defense (Temmerman, 2013)



(Left) Aman-made marsh in the Scheldt estuary, Belgium, protects more landward, densely populated areas from storm surge flooding. The sluice (inset) allows daily tidal flooding of the marsh.



To implement efficient and systematic coastal maintenance projects, the Korean government updates the ‘Master Plan for Coastal Maintenance’ every ten years based on the CMA. This plan includes the direction-setting for the implementation of projects. As a basic principle, the plan should specify that the adoption of ecosystem-based climate mitigation and adaptation technologies be considered as a priority.



## Environmental Impact Assessment (EIA)

When a coastal development project plan is established, an EIA is conducted based on the ‘Environmental Impact Assessment Act (EIAA).’ The EIA is critical in the decision-making process. The primary purpose of implementing EIA is to provide important information to decision-makers, stakeholders, and the public. Insufficient information on the various benefits provided by tidal flats, such as blue carbon, may influence decision-makers’ choices. Korea has reclaimed a large area of tidal-flats, lacking consideration of the ecosystem benefits they provide. Some reclamation projects, which were not economically or environmentally justified, resulted in near-disaster environmental changes and waste of national resources. Monetary valuation for ecosystem services may avoid these problems. It is, thus, important to include in the EIA that the value of blue carbon is properly evaluated. More specifically, the ‘blue carbon valuation’ item needs to be included in the manual of ‘Items and Contents of EIS’ provided by the Ministry of Environment (MOE). To make it easier to achieve this valuation goal, government can provide information needed for this assessment. This information is: the amount of carbon stored in each regional tidal flat, and standard method required to assess the net present value of tidal flats. This paper can be used as a reference for how to estimate the net present value of blue carbon.

## Renewable Energy Projects

Currently, wind power projects are attracting attention as a part of coastal development in Korea. A cost-benefit analysis is conducted to compare the cost effectiveness between tidal flat conservation and wind power project in terms of CO<sub>2</sub> emissions preventions. For wind power, the average power production per unit area is 2 W/m<sup>2</sup>, with consideration of ‘capacity factor.’ The capacity factor is the ratio of the actual output over a period of time, to the maximum output when operating at full capacity. It depends on the site; a typical load factor is 30% in the UK, 22% in the Netherlands, 19% in Germany (MacKay, 2009). If a wind farm is constructed in a reclaimed area of the same size as the Ganghwa tidal flat (35,300 hectares), 700MW electricity can be generated. Applying 0.7 kg CO<sub>2</sub> e / kWh of a displaced emissions factor (Hawkes, 2010) for wind power results in the reduction of  $4.292 \times 10^6$  t CO<sub>2</sub>e yr<sup>-1</sup>.

$$2\text{W/m}^2 \times 35,300 \text{ ha} \times 10,000 \text{ m}^2/\text{ha} = 700\text{MW}$$

$$700\text{MW} \times 1 \text{ hours} = 700 \text{ MWh}$$

$$700 \text{ MWh} \times 0.7 \text{ t CO}_2\text{e/MWh} \times 24 \text{ hours} \times 365\text{days/yr} = 4.292 \times 10^6 \text{ t CO}_2\text{e / yr}$$

The annual carbon abatement (‘CO<sub>2</sub> reduction’) from the conservation of the Ganghwa tidal flat is  $0.421 - 1.450 \times 10^6$  t CO<sub>2</sub>e /yr for 25 years. This is equivalent to the amount of carbon that can be reduced by constructing a wind farm in 10 – 34% (annually 7% after 25 years) of the Ganghwa tidal flat. Compared to tidal flat conservation, wind power generation is more effective in reducing carbon dioxide. However, the cost benefit analysis (Table 31) shows that the net benefit of conservation of tidal flat is \$182 million, more than the \$ 163 million associated with wind farms. This suggests that tidal-flat conservation policy is the most effective way to achieve minimum cost implementation for prevention of carbon dioxide emissions. Note that this analysis does not take into account other benefits besides preventing

CO<sub>2</sub> emissions: The excluded benefits are fishing and other ecosystem services for tidal flat conservation, and electricity sales revenue for wind power generation.

Table 31. Net benefit for CO<sub>2</sub> emissions prevention between the Ganghwa tidal flat conservation and wind farm.

	million dollars	Remarks
<b>[Tidal flat conservation]</b>		
Total cost	71.5	- carbon emission reduction: 0.421 – 1.450 × 10 <sup>6</sup> t CO <sub>2</sub> e /yr
Total benefit	253.1	- time period: 25 years - discount rate: 4.5%
Net benefit	181.6	- carbon price: \$ 20/ t CO <sub>2</sub> e - restoration area: 10% of tidal flat
<b>[Wind farm]</b>		
Total cost	953.7	
- Construction cost	910.0	- unit construction cost: \$1.3 million per MW <sup>a</sup> - energy generation: 700MW
- Operation and maintenance cost	43.7	- unit operation and maintenance cost: \$4,800/MW/yr <sup>b</sup> - life expectancy of the turbine: 20 years
Total benefit - CO <sub>2</sub> emission reduction	1,116.7	- life expectancy of the turbine: 20 years - discount rate: 4.5% - carbon price: \$ 20/ t CO <sub>2</sub> e - carbon emission reduction: 4,292,400 tCO <sub>2</sub> e/yr
Net benefit	163.0	

Source: (a) windy.org (<http://www.windy.org>)

(b) NewEnergyUpdate (<http://newenergyupdate.com>)

Note: The analysis does not take into account other benefits besides CO<sub>2</sub> emissions prevention.

## 6. Fishery management

There is controversy as to whether shellfish is a source of CO<sub>2</sub> or sink. Considering that shellfish aquaculture is being carried out in some tidal flats in Korea, this paper examines the effect of the carbon fluxes on shellfish farming. According to Hickey (2008), shellfish can contribute to carbon fixation. Carbon is naturally absorbed from the ocean, as shells of shellfish form and grow. Shellfish sequester calcium carbonate (CaCO<sub>3</sub>) and form shells. Carbon takes up 12 grams per 100 grams of shell, depending on the molecular weight of CaCO<sub>3</sub>. His research shows that the oyster farms can fix 9.03 tC ha<sup>-1</sup> yr<sup>-1</sup>, with a median of 5.85 tC ha<sup>-1</sup> yr<sup>-1</sup>. Table 32 shows the values used in his calculations.

Table 32. Values used in calculations for carbon fixation from oyster farming (Hickey, 2008).

Plate oyster (g)	Meat weight (g)	Shell weight (g)	Spat weight (g)	Farmed mass (g)	Carbon per oyster (g)	Grow-out time (years)
83.33	13.5	69.38	0.131	69.699	8.36388	2

On the contrary, biosynthesis of calcium carbonate liberates protons from bicarbonate ( $\text{Ca}^{2+} + \text{HCO}_3^- \rightleftharpoons \text{CaCO}_3 + \text{H}^+$ ), and subsequently contributes to the formation of excess carbonic acid ( $\text{H}^+ + \text{HCO}_3^- \rightleftharpoons \text{H}_2\text{CO}_3$ ), followed by venting of carbon dioxide into the atmosphere ( $\text{H}_2\text{CO}_{3\text{aq}} \rightleftharpoons \text{H}_2\text{O} + \text{CO}_2$ ) (Fodrie et al., 2017). In addition,  $\text{CO}_2$  is released into the atmosphere through the respiration of shellfish. Due to these two processes (biocalcification and respiration), Munari et al. (2013) argued that shellfish farming is a source of  $\text{CO}_2$ .

Given all the chemical reactions, in the calcification process, are reversible and to be remained in equilibrium, there is no net increase of  $\text{CO}_2$ . In order to produce one molecule of  $\text{CaCO}_3$  in this calcification process, one molecule of  $\text{CO}_2$  is consumed ( $\textcircled{1} \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_{3\text{aq}}$ ;  $\textcircled{2} \text{H}_2\text{CO}_{3\text{aq}} \rightarrow \text{H}^+ + \text{HCO}_3^-$ ;  $\textcircled{3} \text{Ca}^{2+} + \text{HCO}_3^- \rightarrow \text{CaCO}_3 + \text{H}^+$ ), and one molecule of  $\text{CO}_2$  is released ( $\textcircled{2} \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_{3\text{aq}}$ ;  $\textcircled{1} \text{H}_2\text{CO}_{3\text{aq}} \rightarrow \text{H}_2\text{O} + \text{CO}_2$ ). Consequently, total one molecule of  $\text{HCO}_3^-$  is consumed (two molecules of consumption, and one molecule of production). Eventually, one molecule of carbon in the form of  $\text{HCO}_3^-$  turns into one molecule of carbon in the form of  $\text{CaCO}_3$ .

The controversy over whether shellfish are  $\text{CO}_2$  sources or sinks is still ongoing. However, the main ecosystem good provided by shellfish aquaculture is food production, and shells should be considered a by-product. Thus, it is important to independently quantify the  $\text{CO}_2$  flux of meat and shell in the  $\text{CO}_2$  cycle of shellfish (Filgueira et al., 2015). The background of this argument is that if shellfish are not supplied, they can be replaced with other kinds of meat, such as beef and pork that also produce large amounts of carbon. Given shellfish provide important co-benefits (e.g. water purification, coastal protection) in addition to food sources, it is better to find ways to minimize carbon emissions rather than avoid shellfish farming.

Previous studies have shown that there are many variables for the amount of carbon sequestration in shellfish farms. Factors for these variables include the grow-out time, farmed mass, water depth, sediment type, farming type, harvest cycle and method, and the amount of carbon flux in the process of shell forming and meat forming. In particular, farming types vary from off-bottom culture (e.g. floating rafts, bags, or suspended ropes) to on-bottom culture. To achieve carbon sequestration and fishery benefits together, it is important to minimize carbon emissions from the aquaculture process. More research is necessary to reduce  $\text{CO}_2$  emissions from shellfish farming, taking into account various factors affecting carbon sequestration.

## VIII. Legislative improvement

### 1. Current laws

Wetlands are internationally recognized for their high biodiversity value. Restoration of coastal wetlands provides a significant level of co-benefit opportunities in ecosystem services besides reducing greenhouse gas emissions. These benefits include protecting wildlife habitats, reducing water pollution and preventing coastal erosion from storm surges. Thus, coastal wetland restoration can play an important role in climate change mitigation and adaptation strategies (Philip Williams & Associates, 2009).

To meet Korea’s 2030 NDC (Nationally Determined Contributions) target for GHG emissions reduction, which is 37% below BAU emissions, governments strategically need to increase the opportunities of the carbon sequestration through coastal wetlands creation, restoration, improvement, and avoiding loss. Table 33 shows the recommendations for legislative improvements to increase these opportunities.

Table 33. Recommendations for blue carbon related legislative improvement.

Legislation	Tidal flat conservation related contents (KLRI, 2019)	Recommendations and comments
Wetlands Conservation Act (WCA)	<p>Article 8 (Designation of Wetland Areas)</p> <p>(1) a place that can be designated as a wetland protected area: 1. – 3. (skip)</p> <p>(2) a place that can be designated as a wetland improvement area: 1. – 2. (skip)</p>	<p>Add a subparagraph under Article 8 (1) to be designated “a coastal wetland that sequesters a large amount of carbon” as a ‘Coastal Wetland Protected Area’.</p> <p>Add a subparagraph under Article 8 (2) to be designated “a coastal wetland worth improvement in order to maintain or improve their function as carbon sinks” as a ‘Wetland Improvement Area’.</p>
Conservation and Management of Marine Ecosystems Act (CMMEA)	<p>Article 25 (Designation and Management of Marine Protected Areas)</p> <p>(1) a place that can be designated as a marine protected area: 1. – 7. (skip)</p> <p>Article 49-2 (Purposes of Marine Ecosystem Conservation Levy) The marine ecosystem conservation levy (MECL)<sup>¶</sup> shall be used for the following purposes: 1. – 8. (skip)</p>	<p>Article 25(1) has already been amended in Nov 28, 2017 to include the subparagraph “6. areas needed to be preserved, in order to maintain or improve their function as carbon sinks of marine ecosystems.”</p> <p>Add a subparagraph under Article 49-2 to allow the MECL to be used for coastal wetland creation, restoration, and improvement projects, which maintain or improve their function of ecosystem services such as climate mitigation and adaption.</p>

Legislation	Tidal flat conservation related contents (KLRI, 2019)	Recommendations and comments
Act on Conservation and Utilization of the Marine Environment (ACUME) and its Enforcement Decree	<p>Article 17 (Response to Marine Climate Change) The State and local governments shall prepare policies necessary for the following matters:</p> <ol style="list-style-type: none"> <li>1. the survey on the impacts of climate change on the ocean and its implications;</li> <li>2. climate change adaptation, such as expansion of carbon sinks in the marine and fisheries sector;</li> <li>3. the reduction of greenhouse gas emissions through the ocean.</li> </ol>	The law and its enforcement decree were enacted in Mar 21, 2017.
Coast Management Act (CMA)	<p>Article 3 (Basic Principles for Coastal Management) Coasts shall be preserved, used and developed under the following basic principles:</p> <ol style="list-style-type: none"> <li>1. – 5. (skip)</li> </ol>	Revise subparagraph under Article 3 to include the principle of which coasts shall be managed to improve the function of climate change mitigation and adaption. This inclusion can affect to the direction-setting of the “Integrated Coastal Management Plan” under the Article 6, “Plans for Coastal Management Areas” under the Article 9, and the ‘Master Plan for Coastal Maintenance’ under the Article 21.
Public Waters Management and Reclamation Act (PWMRA)	<p>Article 23 (Request for Reflection in Basic Plan for Reclamation) (2) the Minister of Oceans and Fisheries shall investigate or survey the marine environment, the current state of the ecosystem, and the feasibility of reclamation for the requested area.</p> <p>Article 24 (Details of Basic Plan for Reclamation) (1) A basic plan for reclamation shall include a plan for each predetermined area to be reclaimed specifying the matters falling under the following subparagraphs:</p> <ol style="list-style-type: none"> <li>1. – 4. (skip)</li> <li>5. changes in the environment and ecosystem, which may be caused by reclamation, and countermeasures thereon;</li> <li>6. the comparison of economic feasibility before and after reclamation relating to the land use plan.</li> </ol>	When MOF establishes Basic Plan for Reclamation based on the Article 23 (2), the monetary value of ecosystems service, including blue carbon, has to be counted in the economic feasibility according to the Article 24 (1) 5 and 6. To prevent omission of this, it is required to amend the Article 24 considering the following example: “6. the comparison of economic feasibility before and after reclamation relating to the land use plan and ecosystems service they lost.”

Note: (a) Marine Ecosystem Conservation Levy: The Minister of Oceans and Fisheries shall impose and collect the marine ecosystem conservation levy from any person who conducts development projects which remarkably affect marine ecosystems or reduce marine biological diversity.

## 2. Future consideration

As the discussion of the policy inclusion of blue carbon progresses, two major issues may arise. Those are related to ‘funds’ for restoration projects and payment for the service, and a ‘use right’ for the distribution of benefits.

### **Financing for projects and payment for the blue carbon service**

Internationally, there is growing interest in supporting restoration and conservation of coastal wetlands by governments, NGOs, communities and academia. Nonetheless, it is still ‘a challenge’ to find adequate funds to set up a blue carbon project or to develop a national plan for blue carbon (Herr et al., 2017). Funding for payments for carbon sequestration service can come from government that can effectively purchase this service on behalf of many beneficiaries, or also can come from private companies and individuals seeking to raise funds voluntarily for social contributions (Dunn, 2011). If a project to increase carbon sequestration is implemented by the government, payment may not be a major concern. However, if the restoration project is carried out in the private sector and the government purchases the carbon sequestration service provided by the project, the government should have a solid funding source for stable service purchases.

Climate regulation and biodiversity are depicted as pure public goods. The characteristics of these public goods are non-rival in consumption, non-excludable, and undersupplied because of the external benefits. Government intervention is required to ensure that these ecosystem services remain in the public interest. However, when such public goods turn into market goods that can be traded in the market, they become rival and excludable (Table 34) (Dunn, 2011). There is currently no market for blue carbon; nevertheless, there is potential for future trade depending on the outcome of international discussions. Given the nature of the public goods stated above, financing for coastal wetlands restoration needs to be led by the government before carbon trading, and once the market is available, the private sector lead is desirable.

*Table 34. Public good characteristics (Dunn, 2011)*

	Non excludable	Excludable
Non rival	<p><b>Pure public good</b></p> <ul style="list-style-type: none"> <li>- biodiversity</li> <li>- climate regulation</li> </ul> <p>→ requires government intervention            → scope for private led PES            (Payments for Ecosystem Services)            is limited</p>	<p><b>Club good</b></p> <ul style="list-style-type: none"> <li>- some water services</li> <li>- private eco-tourism</li> </ul> <p>→ scope for PES including private            financing opportunities</p>
Rival	<p>Common property resource</p> <ul style="list-style-type: none"> <li>- fish stocks</li> </ul> <p>→ create property rights at scale at            which benefits accrue</p>	<p>Market good</p> <ul style="list-style-type: none"> <li>- food provisioning</li> </ul> <p>→ existing markets</p>

In Korea, most of the coastal wetland restoration and coastal maintenance projects are funded by the central or local governments. Accordingly, for the time being, there is no need to worry about financing for projects or paying for the carbon sequestration service. The problem may arise when many companies and institutions want to do businesses of coastal wetland restoration for carbon offsetting in the future. This is because market transaction involves high costs. Pearson et al. (2014) suggested that the three largest cost categories are insurance (under the voluntary market; 41-89% of total costs), monitoring (3-42%) and regulatory approval (8-50%) for carbon sequestration projects in the tropical forest sector.

Table 35. The three largest cost categories of transaction costs (Pearson et al., 2014)

Category	Cost elements
Monitoring costs	<ul style="list-style-type: none"> <li>- Necessary measurements for baseline determination and preparation of project registration/ listing document</li> <li>- Measurements/monitoring for determination of emission reductions /sequestration benefits (every 1-5 years)</li> </ul>
Regulatory approval costs	<ul style="list-style-type: none"> <li>- Development of new methodology (if necessary)</li> <li>- Preparation of registration/ listing documents</li> <li>- Validation costs</li> <li>- Project registration fees</li> <li>- Verification costs</li> <li>- Issuance fees</li> <li>- Transfer fees of offsets to purchaser</li> </ul>
Insurance costs	<ul style="list-style-type: none"> <li>- Project liability insurance</li> <li>- Risk buffer/ risk insurance</li> </ul>

Reducing these costs may be a way to stimulate private participation. Institutional factors are likely to play a key role in transaction and information costs. Government can play a key role in eliminating some of the barriers that lead to high transaction and information costs. The use of intermediaries, including NGOs, may also be one way to help deal with high costs, improve coordination and reduce transaction and information costs (Dunn, 2011). To prepare for market transactions, the Korean governments should carefully consider their roles, institutional arrangements for cost saving, and approaches to encourage intermediaries and private participation.

### Use right

As stated previously, most coastal wetland restoration and coastal maintenance projects in Korea are funded by governments. Projects are mostly conducted in the government-owned areas or the areas where the government bought property rights from privates. In contrast, the private sectors will have difficulty purchasing property rights for wetland restoration projects

due to high costs. Thus, the private sector may want the project to implement in the property “in fee,” where the government grants a use right, and the user (beneficiary) pays the fee, in accordance with the Article 8 and Article 13 of the Public Waters Management and Reclamation Act (PWMRA).

*Article 8 (Occupancy or Use Permit of Public Waters) (1) Any person [...] shall obtain permission for occupancy or use [...] from the management agency of public waters [...]*

*Article 13 (Collection of Occupancy or Use Fees of Public Waters) (1) The management agency of public waters shall collect occupancy or use fees of public waters [...] each year from a person who has obtained an occupancy or use permit [...]*

Even if blue carbon is traded in the carbon market, it is likely to be recognized only for newly acquired carbon through the wetland restoration (creation, restoration, and improvement). Many areas of Korean tidal flats have TURFs (Territorial Use Rights for Fishery). Changes to make the tidal flat in which the TURF exists, to function only as a carbon repository, should involve full compensation for the TURF.

Alternatively, a contractor (company, institution, or government) may enter into a ‘management contract’ with an AMFC (Autonomous Management Fishing Community) to improve the carbon repository function of coastal wetlands with TURFs. The contractor may implement a wetland restoration project to enhance carbon sequestration and entrust the management of the wetland to the AMFC under the contract. If blue carbon trading is to succeed, there has to be a guarantee that those area dependent communities need to receive financial compensation for their wetland management services. The scope of financial compensation includes the loss of income due to the restriction of fishing activities, and the input of labor. This is based on the famous ‘Coase theorem’ which claims that the parties can reach a voluntary agreement without government intervention if there is a secure property right and the transaction costs (management costs) are sufficiently lower than benefits (Keohane & Olmstead, 2007).

What is important about giving a use right or management right is that it needs to clearly set out principles and guidelines in which governments make a decision to meet the public interest in the public resources involved decisions. These principles and guidelines involve payment of the use of public good (based on the PWARM), input of effort (restriction of activities, labor), distribution of benefit, and specific guidelines for use consistent with the public interest. These clearly stated principles and guidelines help prevent possible conflicts that may arise between the governments, beneficiaries (users) and fishing communities. Without prudent principles, transferring ownership of public goods to the private sector can negatively impact healthy fishing communities or be criticized for privatization of public goods.



## **IX. Barriers and Recommendations**

Currently, the most important barriers to the introduction of blue carbon policy in Korea are the lack of understanding of blue carbon, no involvement in the climate-related policy mechanisms, and low preference for carbon offsetting (referring to forest carbon). This section will examine recommendations for these barriers.

### **Lack of understanding of blue carbon**

Internationally, much research has been conducted to support the concept of blue carbon, but little research has been done in Korea, where related research was only initiated in 2017. More research, therefore, is needed to encourage the use of blue carbon in tidal flat conservation policies. These studies include the variance of carbon stocks by tidal flat characteristics, carbon fluxes associated with shellfish harvesting, as well as market trading methods and related procedures. Besides, to correct the market failure caused by neglecting ecosystem services, the government needs to provide the necessary tools for the decision-making procedure of tidal flat development. These tools should be designed to facilitate the use of essential elements that may be overlooked in the planning and assessing processes such as Coastal Management Plan and Environmental Impact Assessment. Tools may involve a database of carbon stocks and net present values of 63 tidal-flat areas (Coast Portal, 2019), manuals for their (carbon stocks and net present values) calculation methods, and designation of expert consultants.

### **No involvement in the climate-related policy mechanisms**

Although the importance of blue carbon has been recognized by the UNFCCC (United Nations Framework Convention on Climate Change), it is not fully included in policy mechanisms related to climate change. Internationally, therefore, to make blue carbon feasible, climate-related policy changes need to be accompanied. These changes should include integrating blue carbon into UNFCCC mechanism (e.g. REDD, LULUCF, CDM) by revising existing guidance, guidelines, agreements and mechanisms, with a focus on providing financial incentives for protection of soil carbon stocks and increases in carbon uptake through coastal wetland management (Crooks et al., 2010). Domestically, blue carbon needs to be included in the inter-governmental network to reflect it in the climate related policy at the national level. Based on the discussion in this network, the Korean government should contribute in discussions to help these international policy changes proceed faster.

### **Low preference for carbon offsetting**

As Korea has legislated the Act on Management and Improvement of Carbon Sink in 2013, additionally stored carbon in forests can be used as a means of offsetting emissions in both the voluntary and regulatory carbon markets. Currently, as KOC (Korea Offset Credit) to be used for KETS (Korean Emissions Trading Scheme) compliance, KOC has to be converted into KCU (Korea Credit Unit), and this process is rather complicated. Due to this complex procedure, a priority ranking analysis of carbon credits found that forestry projects are least likely to be a top priority for companies (Roh et al., 2014). Since the forest carbon offset scheme started in 2013, a total of 212 projects have been registered, with an expected amount

of carbon sink of 5,825,114 tCO<sub>2</sub> e (Forest Carbon Registry, Accessed: April 24, 2019). It is still a challenge to address the complex process of forest carbon offset for KETS compliance. However, the stable operation of the forest carbon offset market provides a positive example in preparing the blue carbon policies. In order to make blue carbon attractive to companies and institutions, the government should meticulously prepare by referring to lessons learned in the forest carbon offset scheme.

## X. Conclusions

The intertidal habitat is the most productive ecosystem on the planet, but its value has not been properly recognized. Thus, many intertidal habitats have been converted to other uses through development (land reclamation). Korea's tidal flats are no exception. Since the late 1970s, about 40% of the tidal flats have turned into land through reclamation. This result is since mostly only market values have been considered in development decision-making processes. Non-market values have been mostly excluded. Sometimes reclamation has had negative consequences, such as deteriorating water quality, threatening the livelihood of fishing community, and leaving the reclamation planned area drained without further development. These are types of market failure. Knowing the potential market value of ecosystem services can, therefore, correct these market failures, and, in addition, ultimately contribute to climate change mitigation and adaptation. It is not easy to value all ecosystem services properly. However, recently, the importance of blue carbon has been highlighted, and blue carbon could someday be traded in carbon markets. Considering this market transaction possibility, it is important to mitigate market failure by receiving the market value of blue carbon.

To estimate the net benefit of the tidal flat conservation, cost-benefit analysis was carried out using the 2018 nation-wide survey results. With a 25-year time horizon, the break-even point between benefit and cost of the Ganghwa tidal flat occurs when the carbon price is \$ 4 – 6/tCO<sub>2e</sub>. Given the average carbon market price in 2018 in Korea is \$20.62/tCO<sub>2e</sub>, the 'blue carbon' valuation is high enough to incentivize coastal wetlands conservation, and climate change mitigation and adaptation policies. There are several issues to consider in introducing blue carbon into policy: ① The existence of information shortage and asymmetry makes it difficult for decision-makers to maximize net environmental benefit. Thus, it is important to inform the public and relevant agencies about the benefits of blue carbon. ② To obtain the market value of blue carbon internationally and domestically, relevant agency (MOF) needs to actively participate in climate-related policy networks and discussions. ③ Given the Korean forest carbon offset market is covered by KOP (Korea Offset Program), consideration should be given to include blue carbon in KOP so that it can contribute to the national GHG emission reduction target. ④ Apparently tidal flats are important as carbon repository. They should be preserved and restored to improve carbon sequestration. ⑤ Valuation of blue carbon and restoration of coastal wetlands should be included in coastal management policies and decision-making processes, such as the 'Integrated Coastal Management Plan,' 'Master Plan for Coastal Maintenance Projects,' and 'Environmental Impact Assessment.' ⑥ Shellfish farming is taking place in many parts of Korea's tidal flats. To enhance carbon sequestration and shellfish farming benefits together, further studies should be undertaken to reduce CO<sub>2</sub> emissions from aquaculture, taking into account various factors affecting carbon sequestration.

Some legislative improvements and future considerations are required to reflect blue carbon in the policies for tidal flats conservation and climate change mitigation and adaptation. Legislative improvements for existing laws involve: ① designating protected areas (CWPA, MPA) in areas where carbon is stored in large amounts, ② allowing the MECL (Marine Ecosystem Conservation Levy), which is imposed and collected from any person who conducts development projects which remarkably affect marine ecosystems, to be used for coastal

wetland restoration projects, ③ setting basic principle to reflect climate change mitigation and adaptation technologies in coastal management projects, ④ including cost-benefit analysis—with the monetary values of blue carbon and other goods and services ecosystem provide—in the ‘Basic Plan for Reclamation.’ Successful inclusion of blue carbon in the carbon offset program could increase participation of the private sector. In this case, there are two things to consider: financing for market transaction and giving use rights. First, market transaction and information necessary for market trading involves high costs. Government can play a key role in eliminating some of the barriers that lead to high transaction and information costs. To prepare for market transactions, the Korean governments need to carefully consider their roles, institutional arrangements for cost saving, and approaches to encourage intermediaries and private participation. Second, when a use right or management right is given to private sector for coastal wetland restoration, it needs to be clearly set out the principles and guidelines on type of management effort (e.g., restriction of fishing activities, labor input), distribution of benefit, and specific guidelines for use consistent with the public interest. Clearly stated principles and guidelines can help prevent possible conflicts that may arise between the governments, beneficiaries (users) and fishing communities.

Currently, the most important barriers to the introduction of blue carbon policy in Korea are the lack of understanding of blue carbon, no involvement in the climate-related policy mechanisms, and low preference for carbon offsetting (referring to forest carbon). To encourage the use of blue carbon in tidal flat conservation and climate mitigation and adaptation policies, it is necessary to assess the variance of carbon stocks in tidal flats, participate in climate-related government and international networks, and conduct more research to examine market trading methods and possibilities by referring to Korean forest carbon offset scheme.

Blue carbon is economically important and can be used in various coastal conservation and management policies. The Korean government should actively support to achieve meaningful achievements of the blue carbon policy. This can lead to a virtuous cycle structure in which a cap-and-trade secondary market price could incentivize blue carbon.

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