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Memo

Blue carbon in the Dutch Caribbean

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Summary

Recently, the Dutch state of play regarding blue carbon in the Netherlands was reviewed (Tamis & Foekema 2015)[1]. Since the review was focussed on the North East Atlantic, the Dutch Caribbean was not included. Therefore an additional review was conducted providing information on blue carbon in the Dutch Caribbean, including a discussion on the relevance of ecosystems other than the internationally accepted blue carbon ecosystems (i.e. mangroves, salt marshes and seagrass beds) and the potential of blue carbon as an ecosystem service.
Marine molluscs and coral reefs cannot be regarded as blue carbon ecosystems. Other potential blue carbon ecosystems (i.e. open oceans, fish, kelp and algal mats) are unsure or unknown. Thus no other ecosystems were included. All three blue carbon ecosystems are found in the Dutch Caribbean, with mangroves containing the highest blue carbon stock. An estimated amount of nearly 564 thousand tonnes carbon is stored in these ecosystems, which is less than the estimated amount in the Netherlands. Mangroves are found on Aruba, Bonaire and Curacao but not on Saba and St Eustatius. On St. Maarten some mangrove vegetation is present, but most has been removed. Carbon sequestration is acknowledged as ecosystem service and the economic value of blue carbon ecosystems has been quantified in different case studies.

Nederlandse samenvatting
Recentelijk is de rol van Nederland rondom blue carbon gerapporteerd (Tamis & Foekema 2015) [1]*. Aangezien het onderzoek beperkt was tot de Noordoost Atlantische oceaan is Caribisch Nederland niet meegenomen. Daarom is een aanvullende studie gedaan naar blue carbon in Caribisch Nederland, inclusief een discussie over mogelijke andere blue carbon ecosystemen dan de internationaal geaccepteerde blue carbon ecosystemen (mangroven, kwelders en zeegrasvelden) en de potentie van blue carbon als* ecosystem service*.*
Schelpdieren en koraal kunnen niet als blue carbon ecosystemen beschouwd worden. De potentie van andere mogelijke blue carbon ecosystemen (i.e. oceaan, vis, kelp, algenmatten) is onzeker of onbekend. Er zijn daarom naast mangroven, kwelders en zeegrasvelden geen andere ecosystemen beschouwd. Alle drie de ecosystemen zijn aanwezig in Caribisch Nederland, waarbij mangroven de hoogste koolstof opslag vormen. Een geschatte hoeveelheid van bijna 564 duizend ton koolstof is opgeslagen in deze ecosystemen, wat minder is dan de geschatte hoeveelheid in Nederland. Aruba, Bonaire en Curaçao hebben mangroven, maar Saba en St Eustatius niet. Op Sint Maarten zijn veel mangroven verwijderd en is slechts een klein deel over. Koolstof opslag is een geaccepteerde ecosystem service *en de economische waarde van blue carbon ecosystemen is in verschillende case studies gekwantificeerd*.

[1] Tamis, J.E. & Foekema, E.M., 2015. *A review of blue carbon in the Netherlands*. IMARES Report C151/15

Introduction

The review of blue carbon in the Netherlands (Tamis & Foekema 2015) does not include the Dutch Caribbean, as the study was conducted within the context of the North East Atlantic (i.e. in addressing a request of OSPAR). This section provides information on blue carbon in the Dutch Caribbean. Furthermore, it discusses the relevance of ecosystems other than mangroves, salt marshes and seagrass beds, to blue carbon. Finally, the potential of blue carbon as an ecosystem service is described.

Blue carbon ecosystems

Introduction

Protecting key carbon-absorbing areas of the ocean are critical for tackling climate change. The review of Blue Carbon in the Netherlands (Tamis & Foekema 2015), focusses on mangroves, salt marshes, and seagrasses as blue carbon ecosystems as they are internationally recognised for their value for climate change mitigation (AGEDI 2014). However, the value of other (potential) blue carbon ecosystems was only limited addressed. These are discussed below.

Open ocean

Carbon sequestration is the process of increasing the carbon content of a reservoir other than the atmosphere (Nellemann et al. 2009). Carbon stored and sequestered in ecosystems is theoretically always vulnerable to release at some undetermined point in the future. The long-term residence of anthropogenic CO_2 in the oceans is uncertain, as this carbon does not penetrate deep enough to remain in the ocean over extended time scales. The carbon captured in oceans does remain stored for millennia, whereas for example rainforests only stores carbon for decades or centuries (Nelleman et al., 2009). Thus it does provide a valuable ecosystem service in carbon sequestration (Beukering & Wolfs 2012; K F Tieskens et al. 2014).

Marine molluscs

Other blue carbon systems may include marine molluscs. Cultivation of molluscs, and the preservation of their shells, is suggested as a mean of sequestering carbon dioxide (Wolff & Beaumont 2011). There have been ideas to see whether it would be possible to use shellfish farming as a means to sequester CO_2 (http://www.shellfishsequestration.org/). The overall carbon uptake was found in the same order as the carbon sequestration by salt marshes when only addressing the carbon content of the shell material (Fiselier & Vreeman 2012). However, in the process of biogenic calcification, one mole of CO_2 is released for each mole of generated CaCO3 (the carbonate counter-pump) (Munari et al. 2013). When CaCO3 is removed from seawater, its pH shifts toward the acidic, and the CO2 concentration and pCO2 of the water increases, leading to increased concentrations of CO2 in the atmosphere (Zeebe & Wolf-Gladrow 2001). Munari et al. (2013) evaluated CaCO3 and CO2 production/sequestration due to calcification by the Mediterranean mussel *Mytilus galloprovincialis* and showed that the CO_2 fluxes produced by the mussel were higher than CO_2 sequestered in shell formation. Results from this study strongly suggest that shell formation in cultivated shellfish cannot be part of carbon trading systems. Moreover, there is a growing evidence indicating that biocalcification can contribute substantially to temperate near-shore coastal ecosystems carbon cycling, and that numerous calcifying organisms living in such ecosystems are CO_2 generators (Munari et al. 2013).

Coral reefs

There are different points of view on the carbon storage of coral reefs, some consider the ecosystem as a sink (Mitra & Zaman 2015), others a source (Ware et al. 1992). Evidence has been provided that calcification in coral reefs, as well as in other calcifying ecosystems (e.g. molluscs (Munari et al. 2013), see above), is a long-term source of CO_2 for the atmosphere (Ware et al. 1992)(Gattuso et al. 1999). There is growing evidence indicating that biocalcification can contribute substantially to temperate near-shore coastal ecosystems carbon cycling, and that numerous calcifying organisms living in such ecosystems are CO_2 generators (Munari et al., 2013). However, recent blue carbon studies still regard coral reefs as a contribution to carbon sequestration (Beukering & Wolfs 2012; K F Tieskens et al. 2014; Mitra & Zaman 2015).

Fish

Fish carbon pathways are traditionally thought to contribute minimally to the oceanic carbon cycle and are thus not included in current carbon cycle models, aside from an implicit connection with plankton (Lutz & Martin 2014). However, fish carbon mechanisms demonstrate that, in healthy marine ecosystems, marine vertebrates facilitate uptake of atmospheric carbon into the ocean and transport carbon from the ocean surface to deep waters and sediment, thus providing a vital link in the process of long term carbon sequestration (Lutz & Martin 2014). Scientific research of the mechanisms presented in **Error! Reference source not found.** is required to improve understanding of marine vertebrates' contribution
to the carbon cycle, their links to other marine biota and physical processes, particularly the removal of carbon from the atmosphere (AGEDI, 2014; Lutz & Martin 2014).

Kelp and algal mats

These marine resources have not been rigorously explored for their connection to climate change mitigation and a scientific consensus on their consideration as part of blue carbon is lacking. They do present however, significant candidate areas for further research into blue carbon (AGEDI 2014).

Dutch Caribbean

The Dutch Caribbean is the Caribbean part of the Kingdom of the Netherlands, i.e. the countries Aruba, Curacao, St. Maarten and the islands of Bonaire, St. Eustatius and Saba (together also referred to as the BES-islands, three individual public entities within the country the Netherlands). Three of the six main islands presently under Dutch sovereignty are constituent countries of the Kingdom of the Netherlands: Aruba, Curaçao and Sint Maarten (which actually comprises only the southern half of the island of Saint Martin). The three remaining islands of Bonaire, Sint Eustatius and Saba are special municipalities of the Netherlands.

The presence of the three internationally recognised blue carbon ecosystems, i.e. mangroves, salt marshes and seagrasses (AGEDI 2014) in the Dutch Caribbean is presented in *Table 1* and described below.

Table 1 Extent of habitats in overseas countries and territories (OCTs) in the Caribbean region (Bettencourt & Imminga-Berends 2015)

Extent of habitats in the Caribbean region					
OCT	**Man-groves**	**Sea-grass**	**Wet-lands**	**Dry shrub/ forest**	**Remarks**
Aruba	●	●	●	**o**	Arid terrain, shallow coastal lagoons, Bubali pond and Spanish lake have mangroves, some of the reef islands on the south side of the island are arid and some are populated by mangroves, 4 IBAs.
Curaçao	●	**o**	**o**	**o**	Salinas, some wetlands and mangroves.
Sint Maarten	**o**	**o**	●		Large salt pond and fresh water lakes. Mangroves and sea grass beds rapidly disappearing due to development.
Bonaire	●	●	●	**o**	5 Ramsar sites, 6 IBAs, hyper saline lakes. Loss of forests.
Saba	○	**o**	○		Moist forest, 1 IBA.
St Eustatius		●	○	**o**	Moist forest, 2 IBAs.
● Extensive	**o** Some	○ None	IBA- Important Bird Area		

Mangroves

Mangroves are among the most carbon-rich ecosystems in the tropics (Alongi 2012). Aruba, Bonaire and Curacao all have mangrove areas (Spalding et al., 2010). Saba and St Eustatius are steep-sided volcanic islands with no mangroves (Spalding et al., 2010). The Simpson's Bay lagoon of St. Maarten once held extensive mangroves but because of human development virtually all mangrove vegetation has been removed.

Curaçao has about 55 ha of mangroves (0.12% of island's area) a significant portion of it is threatened by coastal development. The largest area with mangroves in Curaçao is found at Spaanse Water bay, however well-developed forests also occur along the eastern and north-eastern coastline (FAO, 2005). Main mangrove areas are located at Caracasbaai peninsula, Spanish Water Bay (15.5 ha), St. Jorisbaai (12 ha), Rif-Otrabanda (12 ha) and Schottegat (4.5 ha) (Debrot and de Freitas 1991, Dilrosun et al. 2012).

In Bonaire the only significant stand is found at Lac Bay (Het Lac), a shallow bay designated Ramsar site in 1980. The lagoon of Lac Bay on Bonaire covers an area of 700 ha and includes important habitats such as mangroves and seagrass beds (Debrot et al., 2010). Lac provides the only main mangrove area for Bonaire. Free expansion of mangroves seaward has essentially reduced the effective surface area of the lagoon by 82 ha during a 35 year period (average: 2.34 ha per year) as illustrated in the 2006 map by Erdman and Scheffers, Univ. Duisberg-Essen) (Figure 1). The total area of mangroves in the period 1961-1996 was 157 ha (see Figure 1).

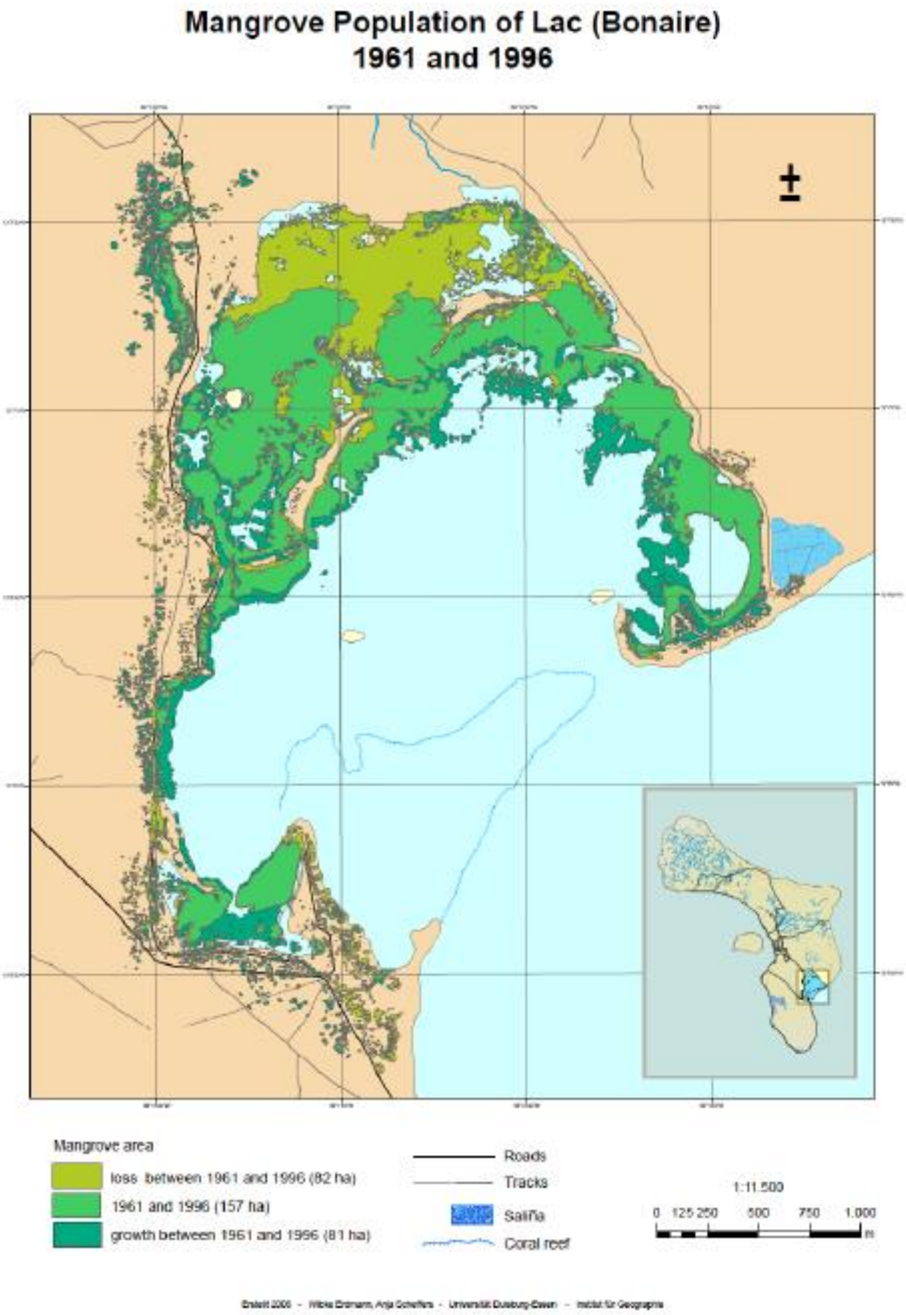

Figure 1 (Map from Erdmann and Scheffers 2006). The loss of mangroves in Lac has been balanced by new growth during a 35 year period, but in the process combined healthy open water surface of Lac has declined by the same (average of 2.34 ha per year). (Debrot et al., 2010).

The mangrove area of the Netherlands Antilles, formed up by the five islands, Curaçao, Bonaire, St Maarten, Saba and St Eustatius is 11.34 km^2 (Spalding et al., 2010). Aruba has a total of 0.71 km^2 mangrove vegetated area (Spalding et al., 2010), which adds up to a total of 12.05 km^2.

Salt marshes

Aruba, Bonaire and St. Maarten have extensive wetlands. Curacao has some wetlands and Saba and St. Eustatius have no wetlands (Bettencourt & Imminga-Berends 2015). Vegetation of salt flats and salinas has been found on Aruba, Bonaire and St. Maarten, but not on Curacao, Saba and St. Eustatius (Stoffers 1956). To quantify the salt marsh area of the Dutch Caribbean we thus focus on Aruba, Bonaire and St. Maarten.

For the Dutch Caribbean, quantitative values for the area extent of salt marshes have not been found in literature. For Bonaire, a habitat type referred to as 'salinas', i.e. salt flats located in close proximity of the sea, has been described which comprise 3% of the total surface (i.e. 288 km^2) (Freitas et al. 2005). Based on this information, we assume the salt marsh area of Bonaire to be 864 ha.
On Aruba, we assume that Bubali Wetlands (53 ha) and Tierra del Sol Salina (2 ha) (Devenish et al. 2009) could represent salt marshes. The vegetation of the great salt pond at St. Maarten has been classified as vegetation of salt flats and salinas (Stoffers 1956). The great salt pond covers an area of 188 ha (Devenish et al. 2009), which we assume to be the salt marsh area of St. Maarten. The total salt marsh area of the Dutch Caribbean is calculated at (864+55+188=) 1107 ha.

Seagrasses

Aruba, Bonaire, St. Eustatius have extensive seagrass habitats, whereas Curacao, St. Maarten and Saba have some seagrass habitats (Bettencourt & Imminga-Berends 2015). Only at Saba, seagrass beds have been mapped (*Figure 2*).

The seagrass area on Bonaire, Saba and St. Eustatius is 104, 56 and 82 ha, respectively (Smith et al. 2013). Curacao has an estimated seagrass area of 800 ha (Spalding 2003). In the same study, the seagrass area in Bonaire was estimated at 200 ha, which is twice as much as assed by Smith et al (2013). Because the study of Smith et al. (2013) is based on satellite images and Spalding (2003) provides estimated sizes, we here assume the seagrass area on Bonaire to be 104 ha. This could also mean that the seagrass area at Curacao is overestimated, especially considering Bettencourt & Imminga-Berends (2015) reported that there were no extensive seagrass habitats at Curacao (see above). We found no other reported values for seagrass area extent on Curacao. Quantitative data on the seagrass extent of Aruba and Sint Maarten could also not be found. We therefore base the total area of seagrass habitat in the Dutch Caribbean on the known areas of Curacao, Bonaire, St. Eustatius and Saba, which is a total of 1042 ha (Table 2).

Table 2 Seagrass area

Country	**Seagrass area**
Aruba	Extensive (Bettencourt & Imminga-Berends 2015), exact area unknown
Curacao	800 ha (estimate by Spalding (2003))
St. Maarten	Some seagrass (Bettencourt & Imminga-Berends 2015), exact area unknown
Bonaire	104 ha (Smith et al. 2013)
St. Eustatius	82 ha (Smith et al. 2013)
Saba	56 ha (Smith et al. 2013)
Dutch Caribbean	*1042 ha*

Figure 2 Seagrass beds at Saba (map based on data from the Dutch Caribbean Biodiversity Database (http://www.dcbd.nl/maps).

Estimated carbon stocks and burial rates in Dutch Caribbean

Based on the identified areas of blue carbon ecosystems of the Dutch Caribbean (see above) and mean values for carbon stock and carbon burial rate from literature, the carbon stocks and burial rates could be calculated for the Dutch Caribbean (*Table 3*). It should be noted that developing accurate C budgets for blue carbon ecosystems is complex and the calculated values should therefore only be used as an indication or rough estimate.

Table 3 Calculated carbon stocks and burial rates for the Dutch Caribbean

Blue carbon ecosystem	**Area (ha)**	**Carbon stock* (tonnes C ha^{-2})**	**Carbon burial rate** (tonnes C ha^{-2} yr^{-1})**	**Carbon stock (tonnes C)**	**Carbon burial rate (tonnes C yr^{-1})**
Mangroves	1205	468	1.39	563940	1675
Salt marches	1107	393	1.51	435051	1672
Seagrass	1042	72	0.83	75024	865

* (Nellemann et al. 2009) ** (Siikamäki et al. 2013)

Comparing the presence of blue carbon ecosystems in the Dutch Caribbean with those in the Netherlands (*Figure 3*) shows that the salt marsh area in the Netherlands (Wadden Sea and Delta) is by far the greatest area of blue carbon ecosystem. It also shows that the extent of seagrass beds is greater in the Dutch Caribbean compared to the Netherlands and that mangroves are obviously absent in the Netherlands. The three blue carbon ecosystem in the Dutch Caribbean have roughly the same area extent with mangroves having the greatest area, followed by salt marshes and seagrass.

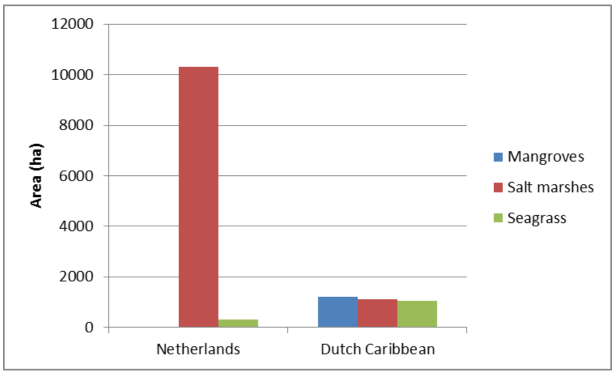

Figure 3 Area of blue carbon ecosystems in the Netherlands and the Dutch Caribbean.

Because of the relatively large area of salt marshes in the Netherlands, the carbon stock and carbon burial rate of this ecosystem in the Netherlands is by far the highest (*Figure 4*). In the Dutch Caribbean mangroves have the highest carbon stock (i.e. nearly 564 thousand tonnes C, see also *Table 3*). The carbon burial rate for mangroves and salt marshes in the Dutch Caribbean are almost the same at nearly 1.7 thousand tonnes C per year.

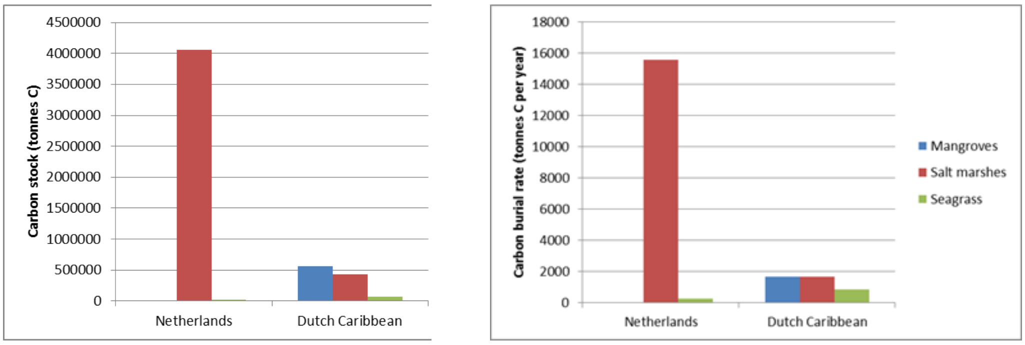

Figure 4 Estimated carbon stock (left) and carbon burial rate (right) in blue carbon ecosystems in the Netherlands and the Dutch Caribbean.

Blue carbon as an ecosystem service

Ecosystem services

An introductory guide to valuing ecosystem services (Defra 2007), defines ecosystem services as services provided by the natural environment that benefit people. Examples of well-known ecosystem services are food, fibre and fuel provision and the cultural services that provide benefits to people through recreation and cultural appreciation of nature. Other services provided by ecosystems are not so well known, such as the regulation of the climate, purification of air and water, flood protection, soil formation and nutrient cycling (Defra 2007). According to the guide by Defra (2007), carbon sequestration is valued as an regulating ecosystem service. Blue carbon can thus be regarded as an ecosystem service. The blue carbon ecosystems also provide other ecosystem services, see Table 4. All services contribute to the need for conservation of these ecosystems. An optimal coastal management strategy would seek to maximize both carbon storage and biodiversity benefits (Vierros 2013).

Table 4 Examples of the five characteristic ecosystem services provided by mangroves, seagrasses and salt marshes (Lau 2013)

Type of service	Type of ecosystem		
	Mangroves[a]	Seagrass[b]	Salt marshes[c]
Carbon Sequestration	Store carbon in aboveground tree biomass as well in belowground roots and soils	Store carbon in belowground root matrix and soil	Store carbon in belowground root system and soils
Shoreline Protection	Absorb wave and wind energy; reduce erosion and storm surges; accrete sediment for adaptation to sea level rise	Absorb wave energy	Absorb wave energy; accrete sediment for adaptation to sea level rise
Fish Nursery	Serve as nursery habitats, refugia, and feeding grounds for many tropical fish species and invertebrates	Serve as nursery habitats, refugia, and feeding grounds for many fish species	Serve as nursery habitats for fish, shellfish, and crustaceans
Biodiversity	Maintain important biodiversity on land (e.g., birds), coasts (fish and invertebrates), and oceans (e.g., coral reefs)	Sustain filter-feeding invertebrate species and particularly the endangered dugong	Provide feeding grounds for migratory birds and waterfowl and home to invertebrate species
Water Quality	Filter pollution and waste; treat excess nutrients (e.g., nitrogen and phosphorus from land); trap sediments	Filter sediment from water column; reduce turbidity	Treat and filter excess nutrients (e.g., nitrogen and phosphorus from land); trap sediments

[a] References (Nellemann et al., 2009; Bouillon and Kairo, 2011; Saudamini and Vincent, 2009; Aburto-Oropeza et al., 2008; Mumby et al., 2004; Saintilan et al., 2007).
[b] References (Nellemann et al., 2009; Waycott et al., 2009; Saintilan et al., 2007).
[c] References (Saintilan et al., 2007) and http://oceanservice.noaa.gov/facts/saltmarsh.html.

Blue carbon offsets

One way to recognize blue carbon as an ecosystem service could be by creating blue carbon offsets (Living Oceans 2014). The World Resources Institute defines a carbon offset (or a greenhouse gas (GHG) offset) as “a unit of carbon dioxide-equivalent (CO2e) that is reduced, avoided or sequestered to compensate for emissions occurring elsewhere” (Goodward & Kelly 2010). The use of carbon offsets is controversial and research continues into the appropriate use of offsets. The IUCN has developed a “mitigation hierarchy” that gives guidance on the appropriate parameters for the use of biodiversity offsets. Blue carbon offsets should specifically fund the conservation and protection of coastal and marine vegetation to promote carbon sequestration.

Managing Marine Protected Areas (MPAs)

Enhancing carbon stocks and addressing climate change has been recognised as a strategy to manage MPAs (Hastings et al. 2012). MPAs protect coastal carbon sinks, which can be lost very quickly when these habitats are damaged by human activities. By reducing stresses on habitats and promoting recovery, MPAs can increase resilience to climate change impacts and sustain benefits to people.

Payments for Ecosystem Services (PES)

PES is an emerging resource management tool that provides incentives for behavioural changes to increase the provision of ecosystem services, e.g., by discouraging overharvesting of resources or destruction and degradation of habitat (Lau 2013). It has been shown that mangrove forests are strong candidates for PES projects (Locatelli et al. 2014). National PES schemes with government as the buyer can be found in Mexico and in Costa Rica (Lau 2013). Potential buyers for ecosystem services are presented in *Table 5*.

Table 5 Potential providers and buyers for the five characteristic ecosystem services found in blue forest habitats (Lau 2013)

	Voluntary providers (seller)	Potential buyers or intermediaries
Carbon sequestration	• Various levels of government holding resource in the public trust • Indigenous/traditional communities with (de facto) use and access rights similar to forests • Coastal property owners • Private entities with co-management arrangements or concessions • Holders of underwater easements (rare)	• Developers, individuals or companies desiring voluntary carbon offsets • Governments for meeting emission goals • Carbon offset brokers
Shoreline protection	• *Same as for carbon*	• Coastal property owners • Insurance/re-insurance companies • Government agencies and municipalities responsible for disaster management • Coastal developers
Biodiversity	• *Same as for carbon*	• Natural resource management agencies • Non-profit organizations with biodiversity missions • Tourism operators
Water quality	• Upstream farmers • Upstream municipalities • Indigenous/traditional communities with (de facto) property, use or access rights to forests and wetlands	• Government management agency responsible for public health and safety • Coastal tourism industry (to maintain safety) • Fishing industry/fishermen (to maintain seafood safety and prevent closures) • Coastal communities (for aesthetics, recreational and health reasons)
Fish nursery	• *Same as for carbon* • Commercial and artisanal fishermen with legal or de facto fishing rights in habitats of interest	• Seafood industry, especially buyers, processors, and retailers • Commercial fishermen • Sports fishermen • Dive and snorkel industry

Case studies

The possibilities of carbon payments for mangrove conservation has been studied (Yee 2010). In Thailand, shrimp farming resulted in rapid mangrove deforestation. It was concluded that prices in existing carbon markets can cover the opportunity costs of *marginal* shrimp farmers in Thailand despite the high profits of shrimp aquaculture (Yee 2010).

The economic value of ecosystems on Bonaire (Beukering & Wolfs 2012), St Eustatius (K F Tieskens et al. 2014) and Saba (K F. Tieskens et al. 2014) has been calculated. For St. Eustatius and Saba these values were also mapped. Carbons sequestration was one of the identified economic values. A market based approach was taken to value carbon sequestration based on the average worldwide market price for a tonne carbon of 13.80 USD in 2012 (K F Tieskens et al. 2014). The studies considered six ecosystems that provide carbon-sequestering properties: salinas, dry forest, coral reefs, sea grass, mangroves and open ocean. The spatial allocation of the value of carbon sequestration of St. Eustatius and Saba is presented in *Figure 5*. Coral reefs were the only marine ecosystems that applied for St. Eustatius and Saba (K F Tieskens et al. 2014)(K F. Tieskens et al. 2014). A range between -0.04 and 1.06 t/ha/y was reported as the carbon sequestration rate of coral reefs (Beukering & Wolfs 2012). It should be noted that growing evidence suggests that calcification in coral reefs is a long-term source of CO_2 for the atmosphere (Ware et al. 1992)(Gattuso et al. 1999), therefore these ecosystems could not be regarded as carbon sinks.
For Saba, a value of 1.06 tonnes carbon per year for one hectare of coral was used, thus on average the reefs of Saba sequestrate carbon for a value of just less than $15 per year per hectare (K F. Tieskens et al. 2014). For St. Eustatius the carbon sequestration rate was not reported. Based on the value for one hectare presented in *Figure 5* (i.e. $4) and the market price for a tonne of carbon (see above), a value of 0.29 tonnes carbon per year was used. For Bonaire, the average of the reported range (-0.04 - 1.06 = 0.51) was used as the carbon sequestration rate (Beukering & Wolfs 2012).

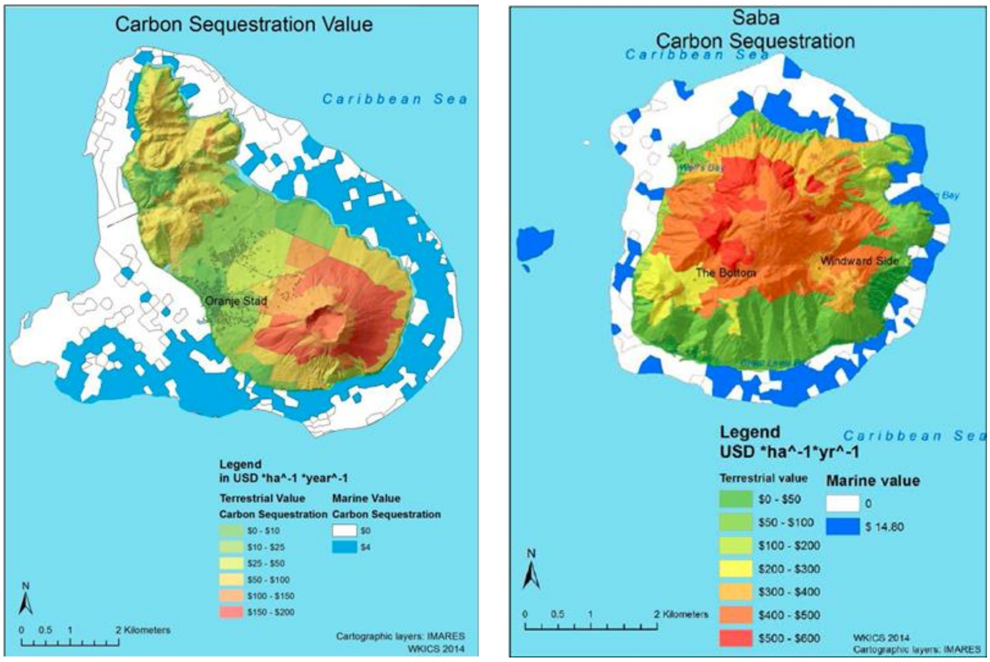

Figure 5 Spatial allocation of carbon sequestration value of St Eustatius (K F Tieskens et al. 2014) (left) and Saba (K F. Tieskens et al. 2014) (right).

Conclusions

Blue carbon ecosystems

Based on the literature reviewed, only the three ecosystems included in the review of blue carbon in the Netherlands (Tamis & Foekema 2015), i.e. mangroves, salt marshes and seagrass beds, can regarded as blue carbon ecosystems as they sequester carbon for extended time frames. Carbon is also sequestered in open oceans, but long-term residence of anthropogenic CO_2 in the oceans is uncertain. Marine molluscs and coral reefs do not contribute to climate mitigation but can be regarded as CO_2 sources. Whether fish, kelp and algal mats can be regarded as part of blue carbon is unknown.

Blue carbon in the Dutch Caribbean

All three blue carbon ecosystems are found in the Dutch Caribbean. The highest blue carbon stock in the Dutch Caribbean are the mangroves. An estimated amount of nearly 564 thousand tonnes carbon is stored in these ecosystems. Mangroves are found on Aruba, Bonaire and Curacao but not on Saba and St Eustatius. On St. Maarten some mangrove vegetation is present, but most has been removed. The estimated amount of blue carbon in the Dutch Caribbean is less than the estimated amount in the Netherlands. This is because of the large area of salt marshes of the Wadden Sea and Delta in the Netherlands.

Blue carbon as ecosystem service

Carbon sequestration is acknowledged as ecosystem service and the economic value of blue carbon ecosystems has been quantified in different case studies. Possibilities for addressing blue carbon as an ecosystem service are: using blue carbon offsets (i.e. carbon credits); implementing in MPA management; and using PES schemes.

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