AN ADDITIONALITY APPROACH TO GLOBAL BLUE CARBON CONSERVATION

by

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A Thesis
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DEDICATION

This is dedicated to my loving family, friends, and everyone else who has supported me throughout this journey. Thank you.

ACKNOWLEDGEMENTS

I would like to thank my family, more specifically my parents for their support and allowing me to pursue my dreams. Dr. Lovejoy for his mentorship and whose influence has always been a major inspiration. Dr. Dann and Dr. Parsons for their support and guidance. Steve Emmett-Mattox and Stefanie Simpson at Restore America's Estuaries for further inspiring my interests in blue carbon conservation. My sister for her honest critics. Thank you to my fellow ESP graduate students and friends for their words of encouragements. I would also like to thank the very patient staff at data services and various GIS graduate students for helping with issues with my data. Thank you to all the various supports that were of invaluable help and made this happen.

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LIST OF ABBREVIATIONS

Center for Environment Cooperation..CEC
Center for International Forestry Research...CIFOR
Clean Development Mechanism .... CDM
Global Environmental Facility...GEF
Global Land Survey ....GLS
Greenhouse Gas ....GHG
International Union for Conservation of Nature ....IUCN
Kilometers squared .... Km^2
Nationally Appropriate Mitigation Actions ....NAMAs
Non-governmental organizations...NGO
Parts per million... ppm
Payment for ecosystem services ....PES
Protected area Management Effectiveness Assessments .... PAME
Reduced Emissions from Deforestation and Degradation .... REDD+
Teragrams .... Tg
The Economics of Ecosystems and Biodiversity... TEEB
The World Database on Protected Areas .... WDPA
United Kingdom ....UK
United Nations Environment Programme .... UNEP
United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC)
United States .... U.S.
United States dollar ....USD
United States Geological Survey .... USGS
Verified Carbon Standard ....VCS
World Geodetic System ....WGS
World Meteorological Organization .... WMO

ABSTRACT

AN ADDITIONALITY APPROACH TO GLOBAL BLUE CARBON CONSERVATION

Myra T. Butt, M.S.

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Recent reports project an increase in atmospheric carbon dioxide levels significantly greater than what has been previously projected. One way to combat these changes is by conserving "blue carbon" ecosystems. Blue carbon ecosystems-- such as mangroves, seagrasses, and salt marshes-- have the capacity to sequester high levels of atmospheric carbon dioxide and combat climate change. While these are some of the most productive ecosystems, they are also some of the most threatened due to high rates of anthropogenic land conversion activities. It has been suggested that incorporating these ecosystems for carbon financing would benefit conservation efforts. The Verified Carbon Standard (VCS), a leading global carbon offset mechanism, has recently approved a methodology for carbon offsets for blue carbon habitat restoration in the United States. One of the requirements of all carbon offsets is that they are additional, or indication that these projects would not have been implemented without "additional" finances from carbon offset generation. Given the VCS threshold, the objective of this study is determine if less than 5% of global blue carbon has been conserved, establishing a predetermined criteria to deem blue carbon conservation project “additional”. Geospatial data were used to determine the extent of blue carbon ecosystems which fall into coastal and marine protected areas and were analyzed to determine what percent of global blue carbon ecosystems are being conserved. The results of this study indicate that around 4% of blue carbon is currently being conserved. Since the overall percent conserved results in less than the 5% threshold, this indicated that all new voluntary conservation projects could be considered additional and the results from this study could be incorporated into the development of a greenhouse gas offset methodology for tidal wetland and seagrass conservation. Based on the best available data, policy suggestions are provided to improve blue carbon conservation efforts. These suggestions target the incorporation of blue carbon ecosystems into the carbon market, and encourage policy makers to incorporate blue carbon conservation into climate change mitigation and adaption policies.

INTRODUCTION

Background

In recent years, it has become more evident that the global climate is rapidly evolving at an alarming rate. Along with this, atmospheric carbon dioxide levels are increasing at a faster rate than previously projected. According to the World Meteorological Organization (WMO), an organization that tracks annual greenhouse gas (GHG) concentrations in the atmosphere, carbon dioxide levels should remain below 400 parts per million (ppm) to prevent long-term disruptions to the global climate (WMO, 2015). However in 2014, the global average rose up to 397.7 ppm, and in early 2015, surpassed 400 ppm for the first time since data has been collected by the organization (WMO, 2015).

The leading causes of increasing carbon dioxide levels are anthropogenic activities, such as the combustion of fossil fuels and land use/land conversion activities. This includes deforestation, which accounts for 8-20% of all global emissions (Van der Werf ., 2009). There are many conservation efforts focused on restoring and preserving degraded terrestrial ecosystems which serve as carbon sinks, such as tropical rainforests. However, coastal wetland ecosystems, though lesser-known for their carbon sequestration abilities, could help combat the increase in atmospheric carbon dioxide levels.

Coastal ecosystems are one of the most productive systems on Earth, providing many services, such as coastal storm protection, nutrient cycling, shoreline stabilization, water filtration, fish nurseries, and serve as biodiversity hotspots (UNEP and CIFOR, 2014). One of the main services that coastal ecosystems provide is sequestering and storing “blue” carbon from the atmosphere, allowing them to play an essential role in global climate regulation and support climate change adaptation (UNEP and CIFOR, 2014).

Blue Carbon

The term “blue carbon” refers to the carbon sequestration and storage ability of coastal and marine ecosystems, such as mangroves, salt marshes, and seagrass. Mangroves are salt-tolerant arboreal forests (trees, shrubs, ground ferns, or palms) that typically grow above sea level in intertidal zones (CEC, 2016). Geographically, mangrove forests are found in the tropical and subtropical zones (Figure 1.0). Seagrass meadows are subaquatic flowering plants, which grow in marine environments along shallow water on all continents (Figure 3.0). Salt marshes are vegetated coastal ecosystems in upper tidal zones between land and open salt water which is regularly flooded by tides. Like seagrasses, salt marshes are found along most coastlines, but primarily occur in subarctic and temperate zones (Figure 5.0).

These ecosystems combined account for approximately 49 million hectares globally, and are able to sequester and store large amounts of carbon not only in the biomass, but primarily in the sediment below (Pendleton et al., 2012). Furthermore, blue carbon sinks have the ability to store carbon in sediment for up to millennia rather than for centuries as seen in rainforests (Nellemann et al., 2009). Blue carbon ecosystems cover less than 0.5% of the global sea bed, account for 0.05% of terrestrial plant biomass, but are responsible for 50%-71%, of all carbon storage in ocean sediments (Nellemann et al., 2009).

Every year, blue carbon sinks and estuaries store between 235-450 teragrams (Tg) of carbon, equivalent to half of all global transport emissions (Nellemann et al., 2009). With the conservation and restoration of these ecosystems, 3-7% of current fossil fuel emissions could be offset in 20 years, which is more than what is projected from reducing rainforest deforestation (Nellemann et al., 2009). By conserving and restoring both blue carbon sinks and slowing deforestation, 25% of emissions could be mitigated, and global CO_2 could be reduced 10% to put global levels below 450 ppm (Nellemann et al., 2009).

Threats

Globally, blue carbon's potential for reducing greenhouse gases is being threatened by anthropogenic land conversion/degradation activities, which have been rapidly accelerating the loss of these habitats in recent decades. Many coastal ecosystems are being converted for activities such as: aquaculture, agriculture, wood harvesting, industry, and urban development (Murray et al., 2011; Pendleton et al., 2012). In response, there is a critical loss of ecological functions in shoreline retention, water quality, and habitat support for species (Murray et al., 2011). The rate of loss of these ecosystems is higher than any other ecosystem on the planet in some areas. This loss is up to four times greater than that of rainforests (Nellemann et al., 2009). It is estimated within the last 50-100 years, there has been a cumulative loss of 25-50% of total global area of each type of blue carbon ecosystem (Mcleod et al., 2011).

Historically, there has been a 50% loss of tidal wetlands and 30% loss of seagrasses (Barbier et al., 2011). In the last 50 years alone, 50% of the historical global coverage of mangroves has been lost (Pendleton et al., 2012). Despite their prominence of providing ecosystem services, blue carbon ecosystem degradation is ongoing, with estimated losses of about 0.5%- 3% annually, based on the ecosystem type (Pendleton et al., 2012). The global annual loss rate is 1-2% for tidal marshes, 0.4–2.6% for seagrasses, and 0.7-3% for mangroves (Pendleton et al., 2012). Given current conversion rates, it is projected that in the next 100 years, 30-40% of tidal marshes and seagrasses and 100% of mangroves could potentially be lost (Pendleton et al., 2012).

Intense carbon-storing coastal ecosystems are also at risk of shifting from carbon sink to carbon emitters with continued disturbance. There are two main consequences that occur after blue carbon ecosystems are disturbed. First, carbon sequestration ability to store atmospheric carbon dioxide is lost (Murray et al., 2011). Second, depending on the intensity and scale of the disturbance, significant amounts of below-ground carbon can be released into the atmosphere as carbon dioxide (Murray et al., 2011; Macreadie et al., 2013). This phenomenon is likely to increase with continued degradation, especially with the threats of sea level rise, increase in erratic weather patterns, and coastal squeeze.

Coastal squeeze occurs when sea levels rise as coastal ecosystems lose area on their seaward edge and migrate further inland; this migration is eventually blocked due to some anthropogenic barrier, such as a wall or pavement, at the ecosystems upper edge (Macreadie et al., 2013; CEC, 2016). Also, depending on the rate of sea-level rise, slow-growing coastal species will as a result, die out. Therefore, it is important to minimize coastal infrastructure to allow the opportunities for at least the fast growing species to migrate inland and implement future marketable blue carbon projects.

Upon degradation and drainage of these ecosystems, the stored soil carbon can re-oxidize, turning this natural carbon sink into a carbon sources. It is estimated that the conversion and degradation of coastal ecosystem releases between 0.15 and 1.02 billion tons of CO_2 into the atmosphere annually (Pendleton et al., 2012). Mangrove ecosystems contain the greatest amount of per hectare carbon stock, and contribute to about half of estimated global blue carbon emissions (Pendleton et al., 2012). While seagrasses contain the lowest per-hectare carbon stock, they cover a larger global area and therefore are the second greatest contributor to global blue carbon emissions (Pendleton et al., 2012). Lastly, tidal marshes contain moderate to high carbon stocks, however given their relatively small total area, while still substantial, they contribute the least to global blue carbon emissions (Pendleton et al., 2012).

The rate of loss of salt marshes, seagrasses, and mangroves is estimated the highest of any ecosystem and needs to be managed more effectively in order to maintain maximal carbon sequestration and more importantly, conserve the large and old carbon pools in the soil. While these losses are ecologically significant, they also play a significant economic role (Barbier, 2007; Murray et al., 2011). These coastal ecosystems are key components in the development of interventions for climate change mitigation and adaption.

Economic Impacts

As previously stated, blue carbon ecosystems provide a variety of ecosystem services that would be extremely costly to replace. Coastal ecosystems can also be costly to protect, given the expenses in creating/managing protected areas, improving water quality, and the costs involved with alternative uses, such as development and aquaculture (Pendleton et al., 2012). Since markets cannot typically account for the values of ecosystem services, many land developers are clearing these habitats for industrial development (Murray et al., 2011). It is estimated that the current global cost of coastal ecosystem conversion is between $6.1 and $42 billion annually (Pendleton et al., 2012). Market forces are giving landowners incentives to convert their habitats, driving the loss of coastal ecosystems. In some parts of the world, governments are unwilling or unable to enforce clean water regulations and other efforts that would promote sustainability in coastal ecosystems (Murray et al., 2011). Because of this, many concerned stakeholders are looking for ways to enhance economic incentives to improve this issue (Murray et al., 2011).

It is important to remember that the economics of releasing stored carbon has significant global impacts. Coastal waters account for 7% of the total area of the ocean, but are the basis for the world's primary fishing grounds and supply an estimated 50% of the world's fisheries (Nellemann et al., 2009). They also provide nutrients for three billion people and 50% of animal protein and minerals to 400 million people in developing countries (Nellemann et al., 2009). Coastal ecosystems have an estimated value of $25 trillion United States Dollars (USD) annually, making them one of the most economically-valuable ecosystems (Nellemann et al., 2009). However, in some areas, the opportunity cost of development can be very high, requiring stronger economic incentives to combat land conversion in these areas (Barbier et al., 2011). To combat the high costs of protection, there has been an implementation of “carbon markets” for GHG emission reduction strategies similar to those seen in terrestrial ecosystems. By protecting coastal ecosystems for their carbon benefits, co-benefits such as coastal protection and biodiversity support can also take place (Pendleton et al., 2012).

With the growing awareness of the role of blue carbon in climate change mitigation and adaptation, many emerging projects and policy interventions are being developed to conserve and restore these ecosystems. The increased valuation of these natural resources has the potential to impact policy and market initiatives for the benefit of coastal habitat restoration and conservation. Currently, there are global efforts to reduce greenhouse gas emissions with the use of carbon markets, or emission trading systems (Murray et al., 2011). Carbon markets can create large economic incentives for coastal ecosystem land owners to avoid converting these habitats for a market commodity (Murray et al., 2011). While carbon markets have been operating globally since the adoption of the United Nation's Framework Convention on Climate Change's Kyoto Protocol, there have been no initiatives for carbon in coastal ecosystems (Pendleton et al., 2012).

There are mechanisms similar to this idea already established for terrestrial carbon sinks, such as Reduced Emissions from Deforestation and Degradation (REDD+). REDD+ uses economic incentives to encourage the protection of forest ecosystem carbon storage and strives to restrict forest clearing, especially in areas with high ecosystem services value, such as the tropics (Murray et al., 2011). By protecting these carbon sinks, biodiversity and other local/regional services are conserved as well. There is also an option to incorporate blue carbon conservation and management under established initiatives, such as REDD+ and Nationally Appropriate Mitigation Actions (NAMAs). While there are some measures that incentivize the protection of coastal carbon ecosystems and policy initiatives that acknowledge these ecosystems, they are currently still in the process of being implemented.

Restoration Methodology

Recently, the Verified Carbon Standard (VCS), a leading global carbon offset mechanism, approved a tidal wetland and seagrass restoration methodology that expanded eligible projects to include wetland restoration activities to generate carbon offsets. This is the first globally-applicable methodology for tidal wetlands and seagrasses that provides project developers with the procedure needed to generate carbon credits. This methodology outlines VCS-approved procedures to estimate net GHG reduction from tidal wetland and seagrass restoration projects.

The VCS Methodology for Tidal Wetland and Seagrass Restoration (VM0033) uses a standardized approach to additionality for U.S. based projects. In order to generate carbon credits, a project developer must be able to demonstrate that the restoration project would not have been implemented without “additional” finances from carbon offset generation (VCS, 2015). Additionality requires a project to prove net greenhouse gas reduction in order to prevent providing carbon credits for a project that would have been implemented without the generation of carbon credits. Typically, this would be accomplished with the use of the Clean Development Mechanism (CDM) Additionality Tool, which has a set of procedures to determine a baseline scenario (what would happen if no action was taken) and assess additionality. The other approach is to use a “performance method” or “activity method.” An activity method is a standardized method by the VCS that pre-determines additionality for projects that are not financially viable without carbon finances, have no other revenue streams besides carbon finance, or have low rates of acceptance in the marketplace (VCS, 2015). The main role of the activity method is to streamline additionality by allowing project developers to skip the step of providing evidence that their project would not have happened in the absence of the greenhouse gas market.

For the restoration methodology, researchers at Restore Americas Estuaries (RAE) analyzed data for tidal wetland restoration in the United States and calculated that the level of restoration of tidal wetland in the United States was about 2.71% (VCS, 2015). Since the level of restoration activity came out below the 5% threshold in the VCS standard, this means that all new tidal wetland restoration activities within the United States not required by law or regulation are considered additional. The low rate of restoration indicates that the country has a lower ability to finance restoration than is needed. Therefore, carbon financing in volunteer markets can help fund and increase the rate and quality of restoration.

Objective

This study examines the importance of coastal ecosystems in their role of combating GHG emissions. Similar to the restoration methodology, the main objective of this study is to determine the level of global blue carbon conservation in order to determine if a standardized approach to additionality can be established. Thus this study looks to examine what percentage of coastal ecosystems that could be conserved has been conserved, and if this falls within the 5% threshold established under the VCS standard, thereby implying that any further blue carbon conservation is considered "additional." The purpose of this study is to asses if a standardized approach to additionality is appropriate, thereby aiding conservation project developers and streamlining the process of determining what conservation activities are considered additional. Results from this research study could support and be incorporated into the development of a greenhouse gas offset methodology for tidal wetland and seagrass conservation. This study also encourages policy makers to incorporate blue carbon conservation into climate change mitigation and adaption policies.

METHODOLOGY

Data Collection

The best available data and information were compiled from secondary sources. This study primarily used geospatial data from United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC) for mangrove, salt marsh, seagrass ecosystems and world-protected areas. This is the most commonly used data in many global blue carbon studies (Murray et al., 2011; Pendleton et al., 2012; Atwood et al., 2015).

Mangrove

The mangrove dataset from the UNEP-WCMC shows the global distribution of mangrove forests. This dataset was prepared by the United States Geological Survey (USGS) with the temporal range from 1997 to 2000, and published in 2011 (Giri et al., 2011). This dataset was prepared by classifying satellite imagery of the earth using Global Land Survey (GLS) data and Landsat archives (Giri et al., 2011). About 1,000 Landsat scenes were interpreted using both supervised and unsupervised digital image classification techniques (Giri et al., 2011).

Figure 2.0 illustrates the global distribution of mangrove forests, which are mostly found in tropics and subtropics along the equator. These datasets mostly consist of small polygons along the coastline. For each mangrove ecosystem location, there is information on the country of mangrove location, surface area in squared kilometers, and surface area in squared miles (Giri et al., 2011).

Seagrass

The seagrass dataset was compiled by the UNEP-WCMC in collaboration with Dr. Fred Short, a researcher from the University of New Hampshire. This dataset ranges from 1934-2004 and published in 2005 and has been updated since this date (UNEP-WCMC and Short, 2005). Out of all available blue carbon ecosystem data, seagrass has the greatest data gap issues. Unlike some of the other datasets, this dataset consists of both polygon and point data. The polygon data is relatively comparable to the other blue carbon ecosystem data; however, there are issues with the seagrass point dataset. The main issue is that the point data only indicates the presence of seagrass, but not the aerial extent covered or a specific site of seagrass. This underrepresentation of data is most likely due to the challenges and costs of mapping submerged habitats, such as seagrass meadows. When analyzing, it is difficult to combine the point data with polygon data and calculate total blue carbon area. Therefore, point data was not utilized in this study.

Saltmarsh

The saltmarsh dataset is currently incomplete, but is the most recent available data dating to November 2015. This dataset is being prepared for a peer-review journal publication by researchers at the UNEP-WCMC and was acquired through special licensing permission. Metadata and limitations are still unknown at this time; however it can be interpreted that this data was collected via remote sensing techniques.

Protected Areas

The protected areas dataset from the UNEP-WCMC shows the global distribution of the world's protected areas. The World Database on Protected Areas (WDPA) is a joint project with UNEP and the International Union for Conservation of Nature (IUCN). The data is compiled and managed by the UNEP-WCMC along with governments and non-governmental organizations (NGO), and is the most comprehensive global database for terrestrial and marine protected areas (UNEP-WCMC, 2015).

This dataset provides spatial data with a well-documented associated attribute data table that is well formatted, since all data provide must meet the WDPA data standards. Given the location of the ecosystems at study, only coastal and marine protected areas were used for this analysis. Also, for the purposes of this study, IUCN protected area management categories III- national monument, V- protected landscape/seascape, and VI- protected area with sustainable use of natural resources, were excluded due to the assumption that these types of protected areas do not soundly conserve blue carbon (Juffe-Bignoli et al., 2014)

Similar to the seagrass dataset, this dataset also contains both point and polygon data. Sites reported as points have no digitized boundaries, because this information was not submitted by the data providers. Therefore the actual shape of the protected area is unknown. In some cases, the points can be buffered into polygons by the reported area field provided in the attribute table, but this does not usually coincide with the actual area of the protected site. This approach is more useful when assessing the geographic coverage of protected areas, not as much when trying to assess how well specific features in the landscape are covered by protected areas. Therefore, protected area point data was not used in this study.

RESULTS

ArcGIS

The geospatial software, ArcGIS 10.3.1, was used to view data, calculate geographic area, and produce maps of each blue carbon ecosystem for this analysis. Each blue carbon ecosystem dataset was intersected with coastal and marine protected areas to determine the areas that fell within protected boundaries. It is important to note that the raw data was often repaired while processing due to errors in the geometry of the raw datasets. Next, the geometric area was calculated for the protected ecosystems and total protected area was summed.

One study reported that only 24% of protected areas were managed soundly, 36% had basic management, 27% had major deficiencies, and 13% were deficient in management practices (Leverington et al., 2010; Juffe-Bignoli et al., 2014). Given the current available information, an assumption that 24% of protected areas are soundly managed was applied to the total protected area. The adjusted protected blue carbon area was then divided by the total blue carbon area to determine the percent of conserved blue carbon.

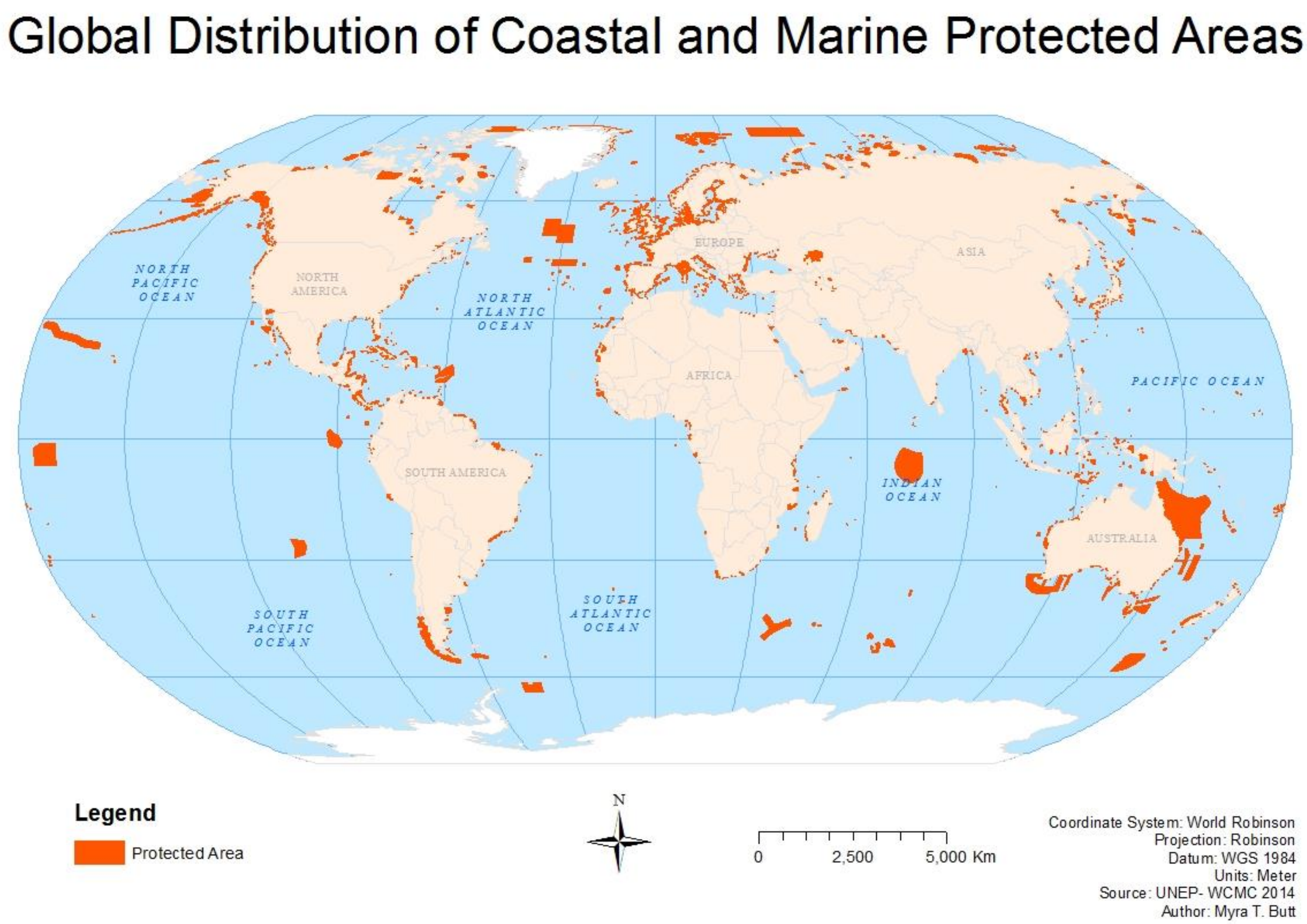

Figure 1.0: Map displaying the global distribution of coastal and marine protected areas excluding IUCN management categories III, V, and VI.

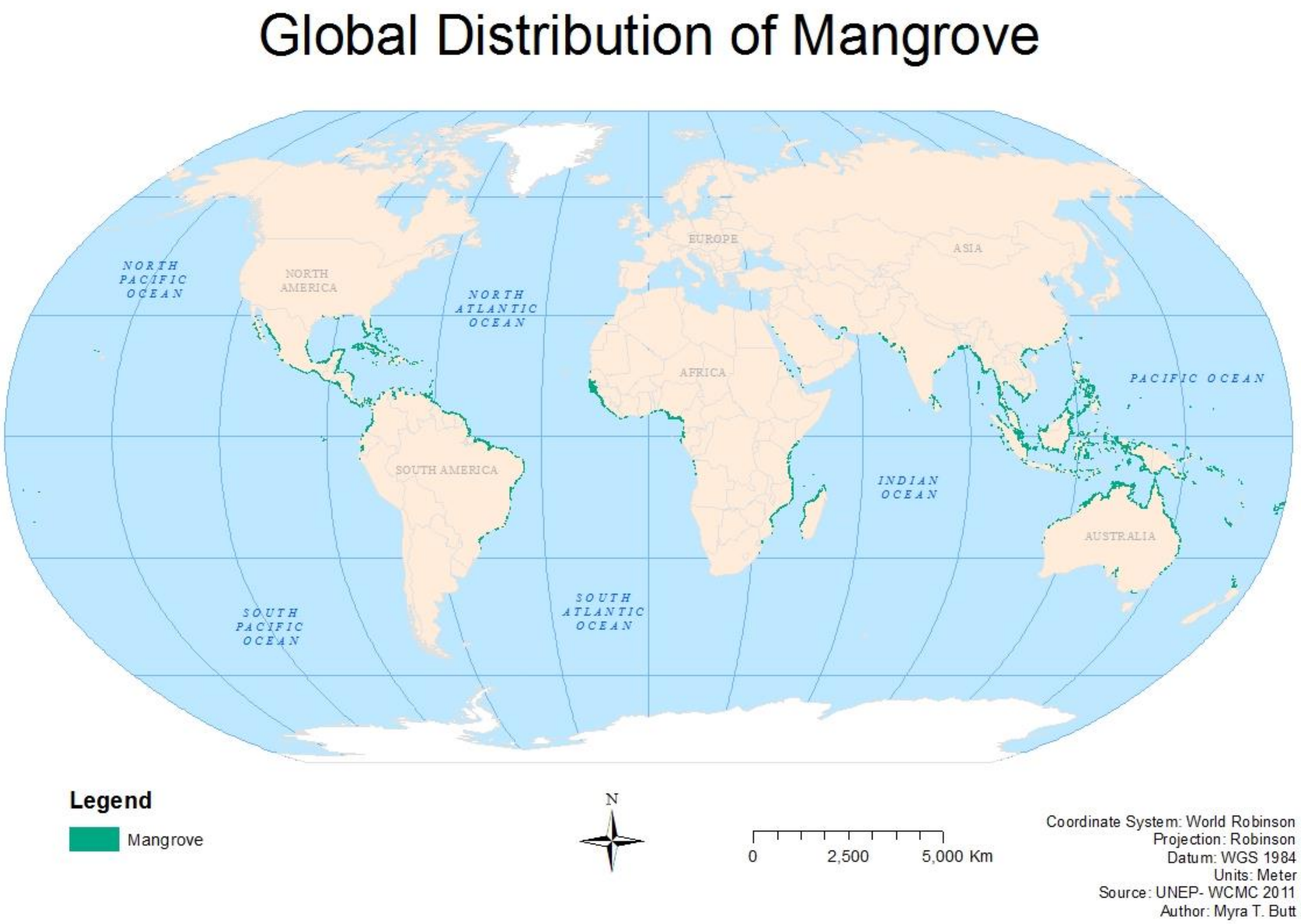

Figure 2.0: Map displaying the global distribution of mangrove ecosystems.

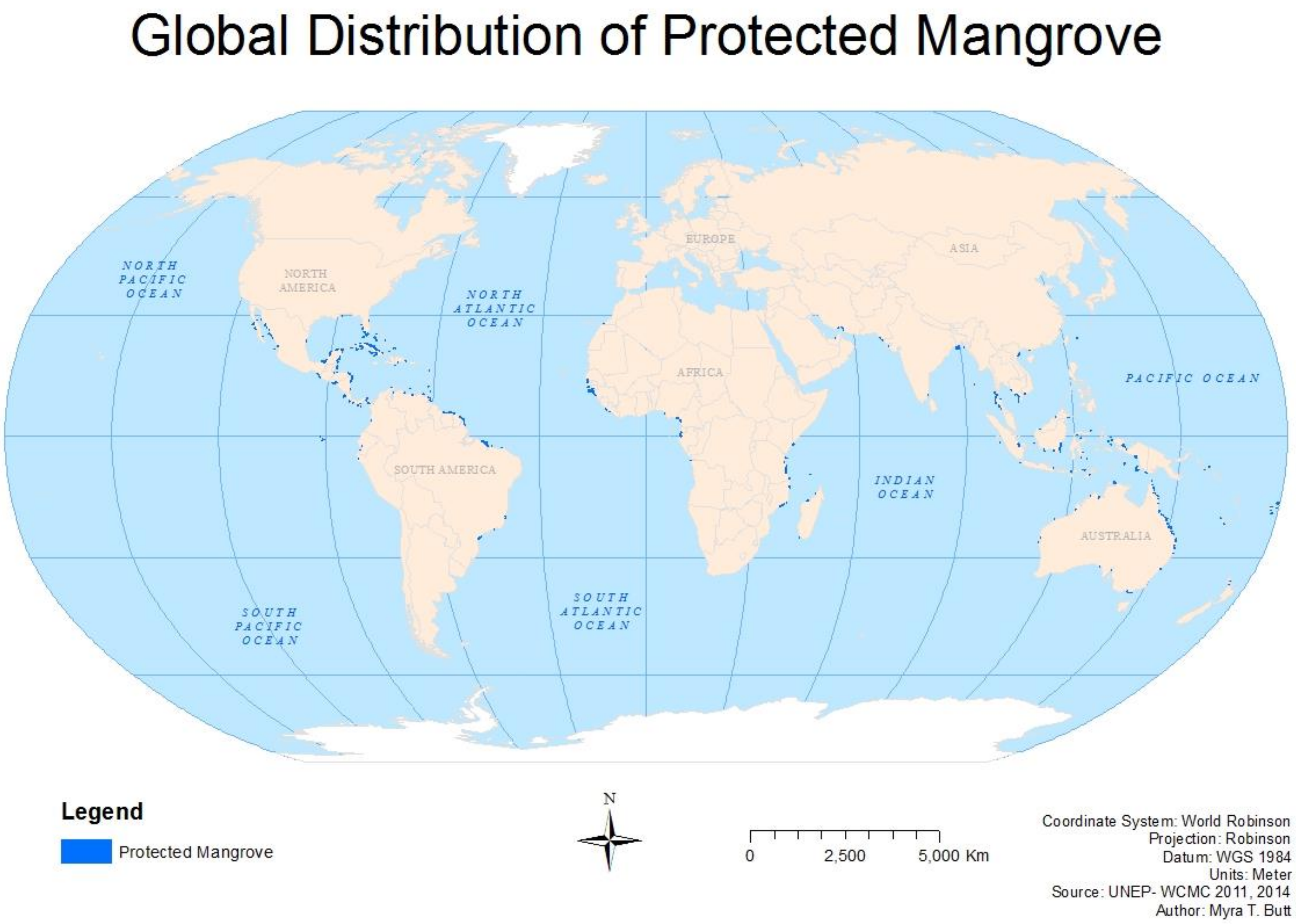

Figure 3.0: Map displaying the global distribution of mangrove that fall into coastal and marine protected areas.

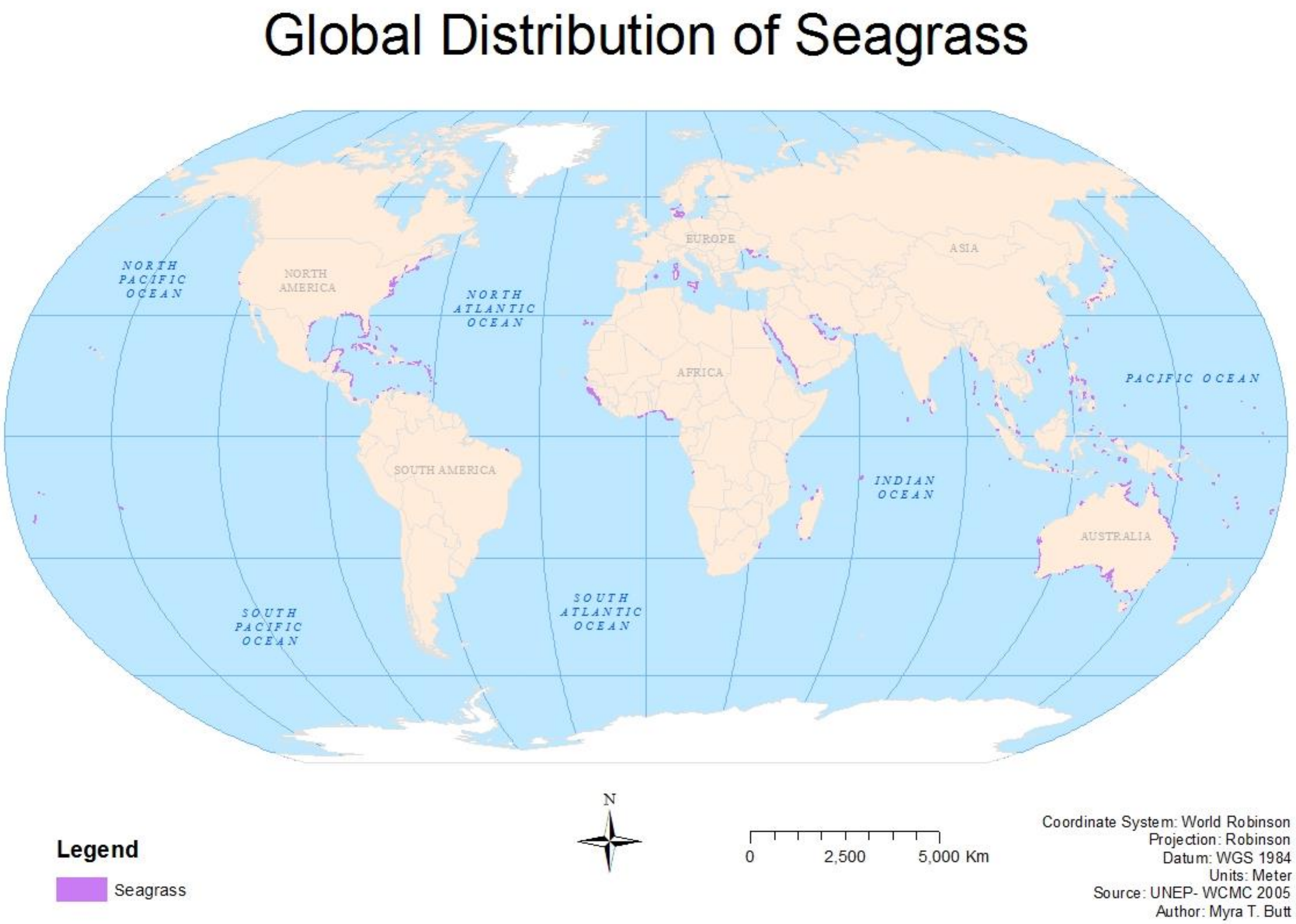

Figure 4.0: Map displaying the global distribution of seagrass ecosystems.

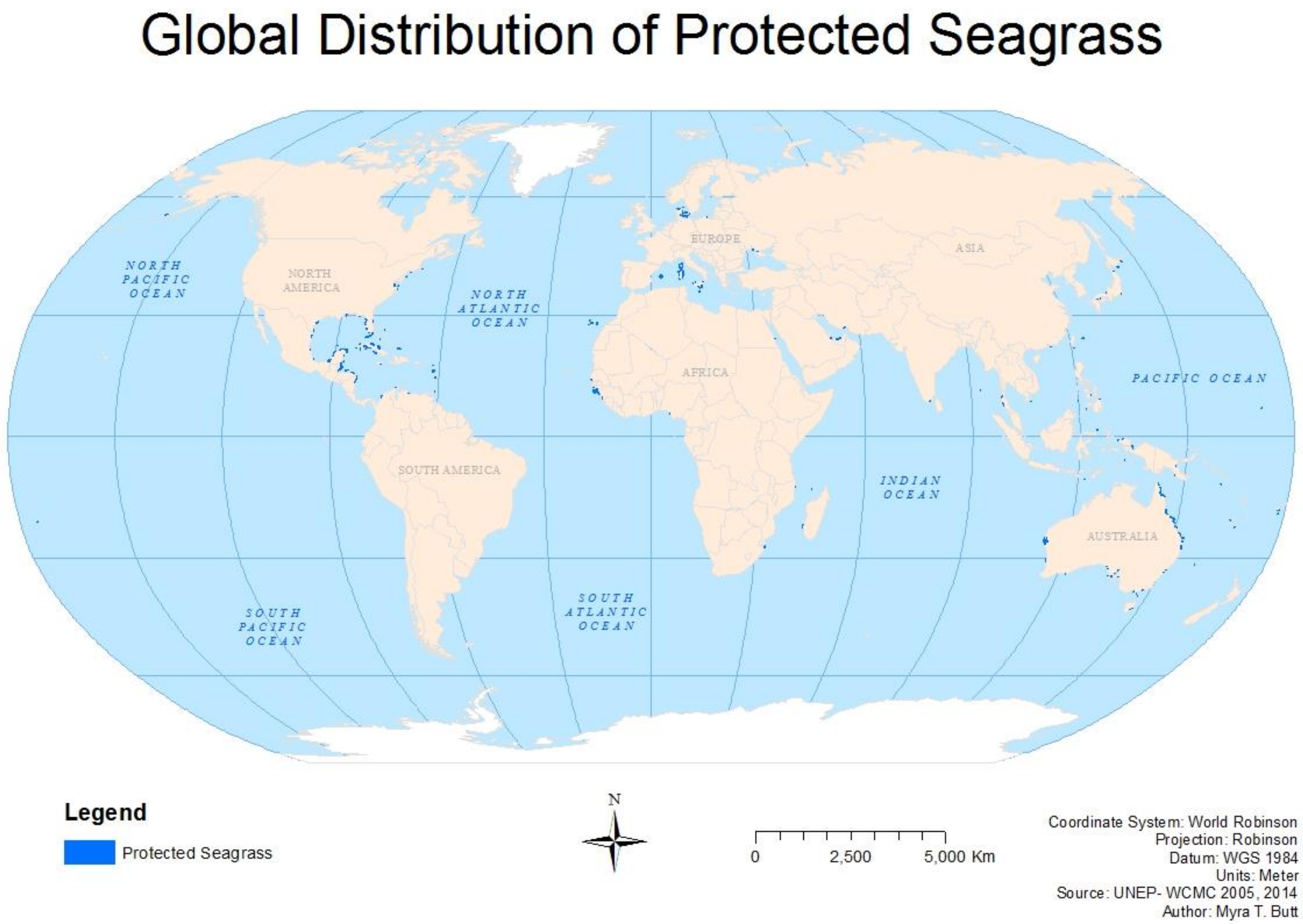

Figure 5.0: Map displaying the global distribution of seagrass that fall into coastal and marine protected areas.

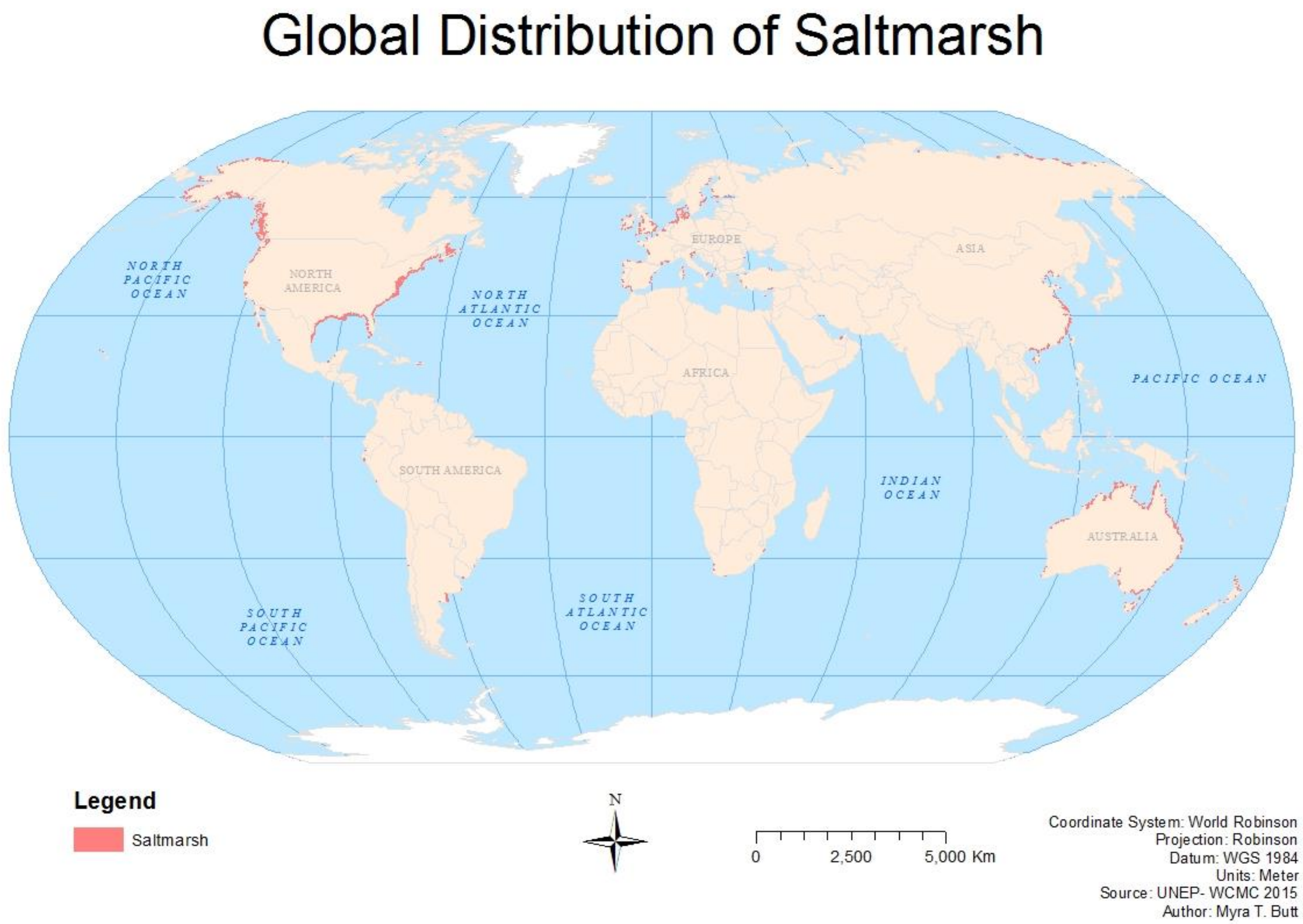

Figure 6.0: Map displaying the global distribution of saltmarsh ecosystems. This dataset is incomplete.

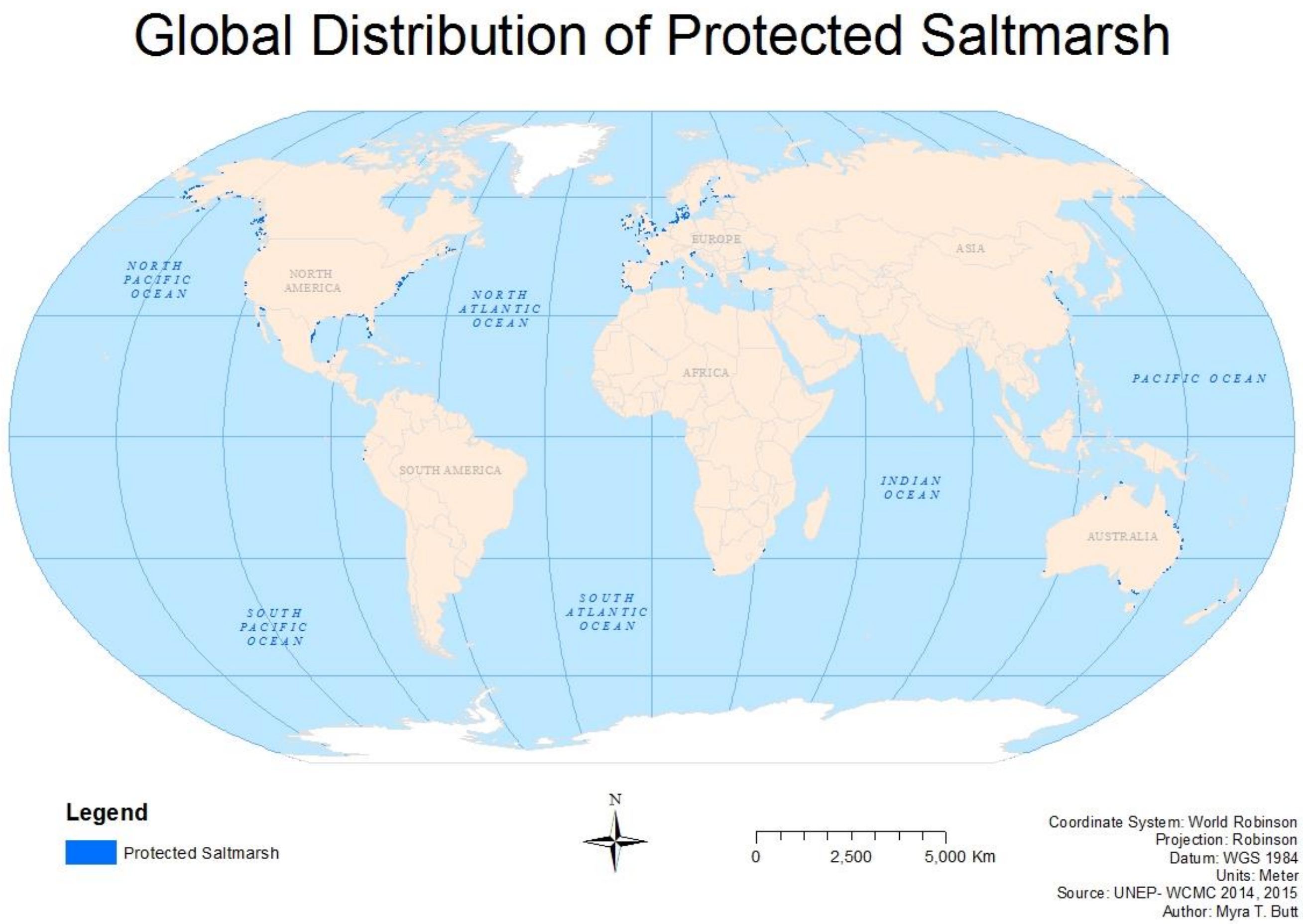

Figure 7.0: Map displaying the global distribution of saltmarsh that fall into coastal and marine protected areas. This dataset is incomplete.

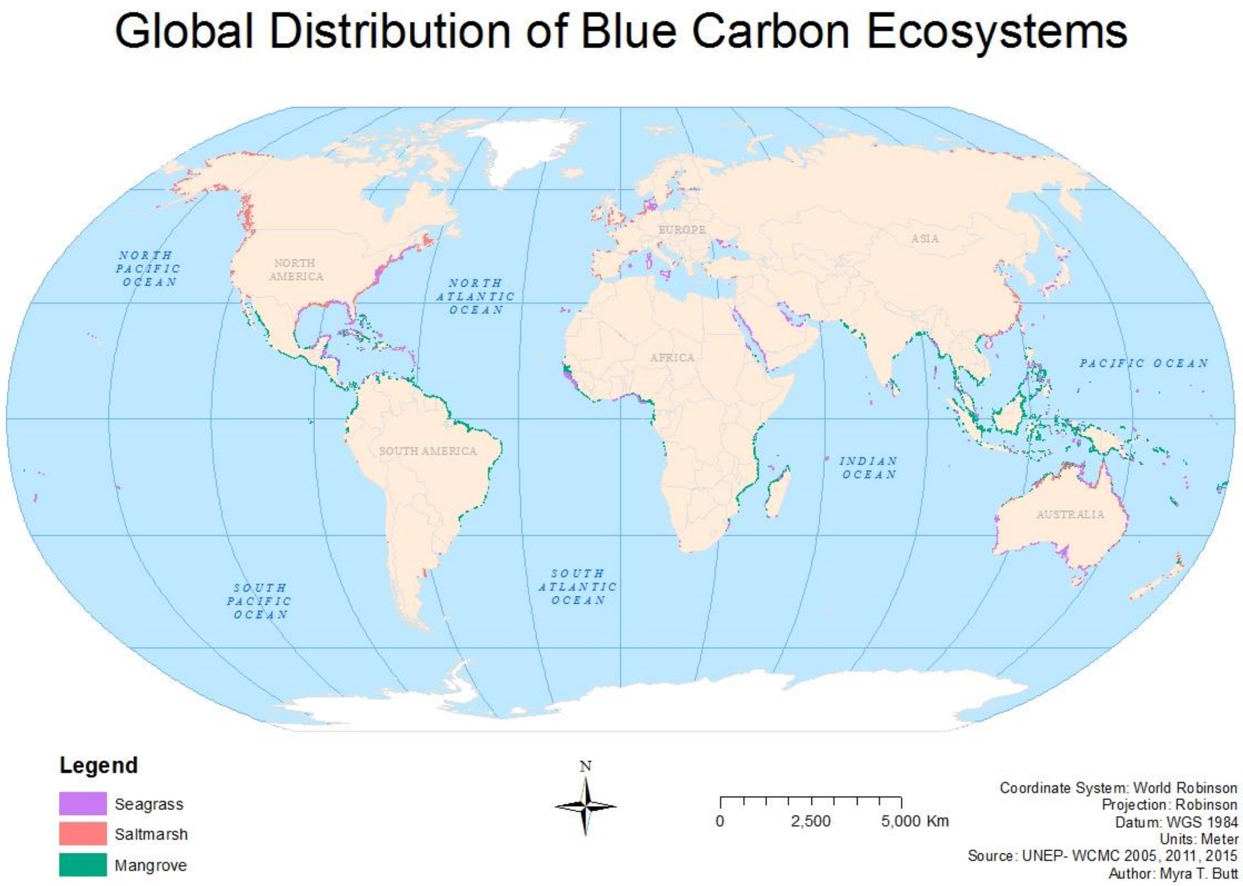

Figure 8.0: Map displaying the global distribution blue carbon ecosystems (seagrass, saltmarsh, and mangrove).

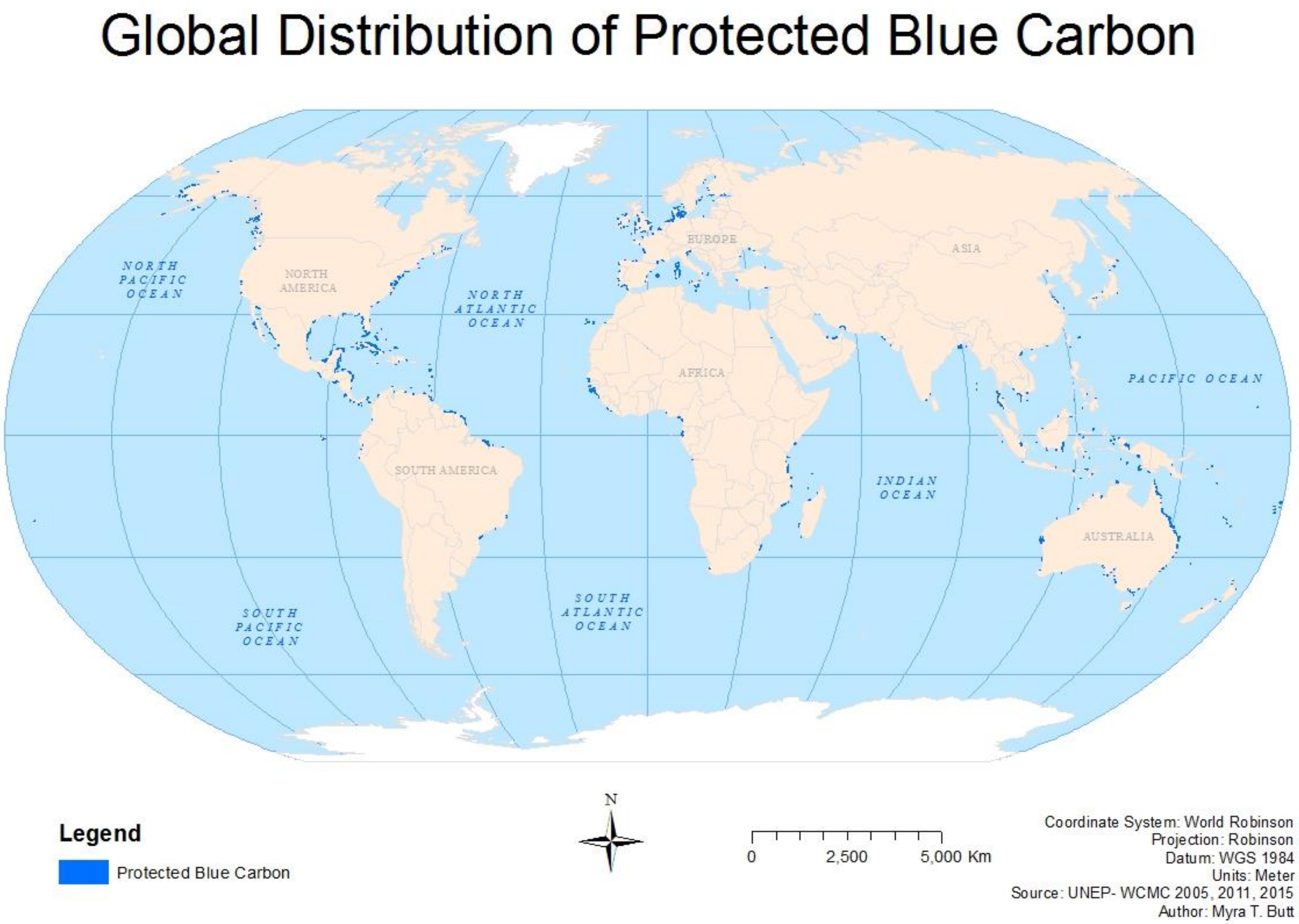

Figure 9.0: Map displaying the global distribution of blue carbon ecosystems that fall into coastal and marine protected areas.

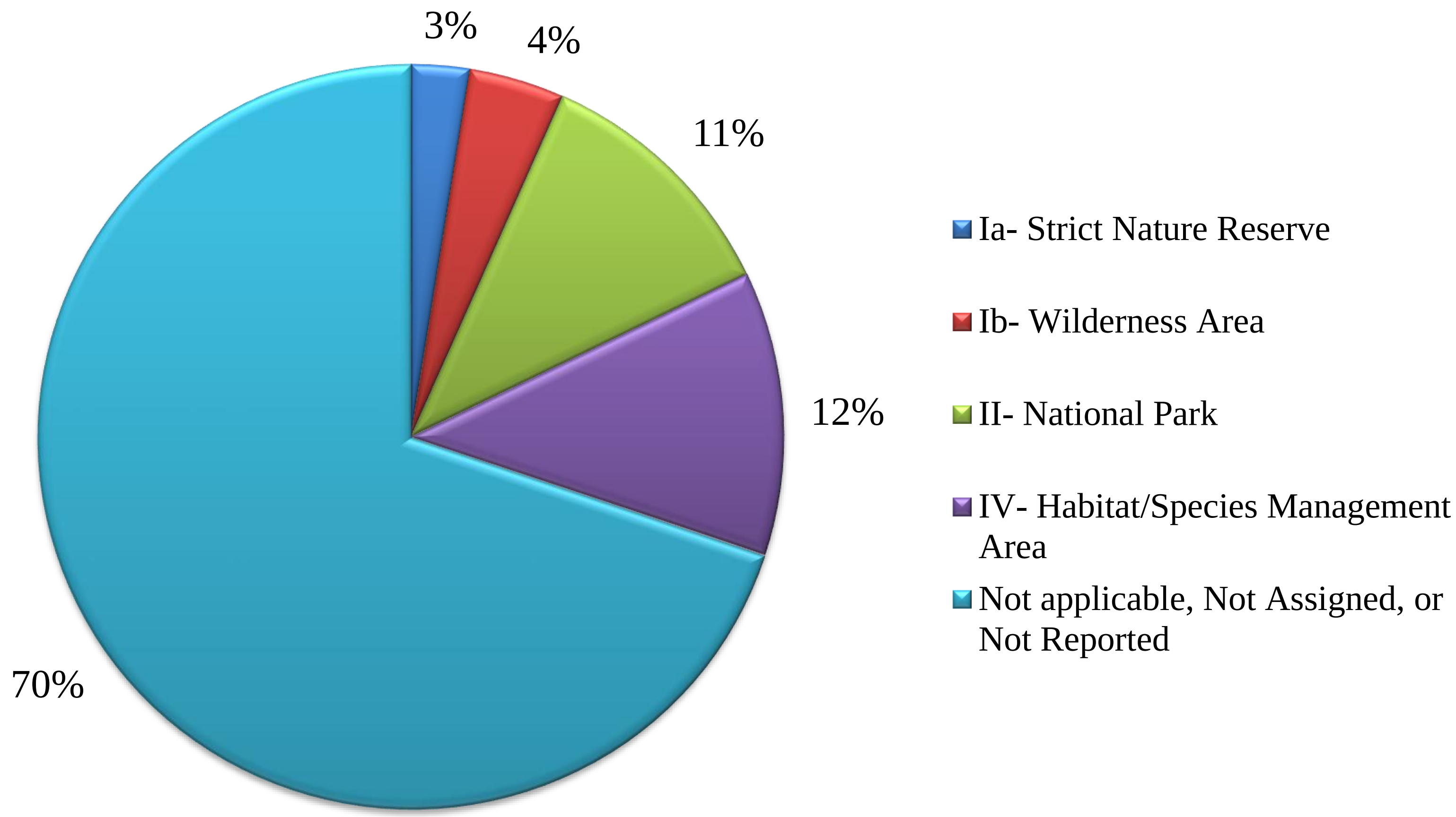

Figure 10.0: Graph displaying the percent of global protected blue carbon by IUCN management category

Table 1.0: Table showing the estimated, calculated, and percent of protected global blue carbon.

Blue Carbon Ecosystem	Estimated Global Area (km^2) (Pendleton et al., 2012)	Calculated Global Area (km^2)	Protected Global Blue Carbon Area (km^2)	Percent Blue Carbon Protected	Protected Global Blue Carbon Area (excluding IUCN management category IV) (km^2)	Percent Blue Carbon Protected (excluding IUCN management category IV)
Mangrove	138,000- 152,000 (145,000)	145,500	39,458 (+)	27 (+)	34,849 (+)	23 (+)
Seagrass	177,000- 600,000 (300,000)	365,155 (+)	63,148 (+)	17 (+)	57,753 (+)	15 (+)
Saltmarsh	22,000- 400,000 (51,000)	143,172 (+)	21,394 (+)	14 (+)	16,146 (+)	11 (+)
Total=		653,828 (+)	124,001 (+)	**19 (+)**	108,749 (+)	**16 (+)**

24% adjustment to protected global blue carbon area included category IV= 29,760 km^2, which equals to about 5%

24% adjustment Protected Global Blue Carbon Area (excluding IUCN management category IV) = 26,099 km^2, which equals to about **4%.**

DISCUSSION

Data Interpretation

The objective of this study was to determine if less than 5% of global blue carbon is currently being conserved, thus implying that any future conservation activities can be considered 'additional' and eligible for carbon credits under the VCS. From the analysis of the spatial extent of blue carbon ecosystems that fall under protected areas, it was determined that globally, approximately 124,000 square kilometers out of 650,000 square kilometers or around 19% of blue carbon ecosystems fall under coastal and marine-protected areas. After the assumption that 24% of protected areas are soundly managed from a reported study, the adjusted global blue carbon areas were determined to be about 30,000 square kilometers, or approximately 5% (Leverington et al., 2010; Juffe-Bignoli et al., 2014).

Miteva et al. (2015) tried to determine if protected areas have the potential to decrease blue carbon emissions by preventing the degradation of sequestration ability in blue carbon ecosystem – specifically the effectiveness of Indonesian protected areas at conserving mangroves and, thus, their carbon sequestration ability. It was estimated that marine-protected areas reduced mangrove loss and blue carbon emissions by 13 million metric tons in 10 years (Miteva et al., 2015). More significantly, the type of protected area versus success rate in conserving blue carbon was studied. Miteva et al. (2015) also found that marine-protected areas that are strict nature reserves, wilderness areas, and national parks (IUCN management categories Ia, Ib, and II) have a significant impact while species management protected areas (IUCN management category IV) that manage for a specific species and habitat did not have a significant impact.

Therefore, IUCN management category IV protected areas were removed from the protected blue carbon area extent in this current study. This updated protected blue carbon area was calculated to around 109,000 square kilometers, or 16%. The 24% adjustment of soundly managed protected area was then applied to the new total protected blue carbon area, which came out to about 26,000 square kilometers or around 4%. Overall, it can be estimated that only about 4% of global blue carbon areas are being conserved.

Since the level or global conservation activity came out below the 5% threshold of the VCS standard, this means that all new voluntary blue carbon conservation that is not required by law or regulation would be considered additional. If the results of this study are incorporated into a methodology and approved by the VCS, this will streamline the process of approving conservation projects for carbon offsets. Similar to the restoration methodology, the low rate of conservation indicates that the ability to finance conservation is arguably lower than needed. Carbon financing for blue carbon could help fund, and increase the rate and quality of, conservation.

Data Limitations

Gaps in the most current geospatial data were a main concern. For example, with the mangrove dataset it is important to note that using the current imagery method, small patches (less than 0.0009-0.0027 squared kilometers) of mangrove forests cannot be identified (Giri et al., 2011). Since most of these ecosystems are located in tropical areas, the challenges of cloud cover, and other noise, remotely classifying ecosystem types can result in some land misclassification (Giri et al., 2011). When using geospatial data in analyzing area extent, especially geospatial data that has been remotely acquired, it is important to remember there may be a difference between the data visually represented and the actual data present in the field. Thus extensive "ground truthing" is needed to gain a more accurate estimate.

Another issue with geospatial data is the temporal aspects of data capture, or time frame of data capture. Remotely compiling data can be time intensive, and it is unclear if lost data for ecosystems was removed when updated or only new data was added. In most of the dataset, data management and reevaluation information is not included. The UNEP-WCMC aims to update the WDPA data for a particular country every 5 years (UNEP-WCMC, 2015). This should be a common practice for the other datasets as well, and would prove beneficial to have a standard international agreement where countries update this data periodically.

There are also many irregularities between the datasets. Each dataset takes into account different factors, and provides different attributes, leaving an overall dataset that is not uniform. As previously mentioned, point data were excluded from this study due to lack of area extent information, which may result in an underestimation of seagrass and protected areas. The point dataset illustrates the discrepancy of how the data were collected versus who is interpreting the data. Spatial information from data providers has many complex variables, including how the boundaries were digitized or what scale was used; this can skew results and influence the accuracy of the data. Ideally, there should be a standard for data recording for mangrove, saltmarsh, and seagrass datasets, since these ecosystems are often combined when analyses of coastal or blue carbon ecosystems are conducted.

It is important to note that the 24% adjustment for soundly-managed protected areas includes all management categories and terrestrial protected areas (Juffe-Bignoli et al., 2014). It is also noted that the analysis had a relatively small sample and advise that more assessments need to be conducted globally to obtain a picture of the management practices of protected areas (Juffe-Bignoli et al., 2014). This lack of data could potentially increase or decrease the final percentage of protected blue carbon ecosystems. However, it can be argued that coastal and marine communities are more difficult to manage due to issues with enforcement; therefore this adjustment is an underestimate for coastal and marine protected areas. Many marine protected areas do not belong to individual countries and lack functional boundaries; therefore the legal frameworks for marine protected areas are often flounder (Boersma and Parrish, 1999). A great deal of marine protected area is found along coastlines near shipping lanes and human centers of activity, also making the strict management of these areas more difficult (Boersma and Parrish, 1999).

Furthermore, using IUCN management categories is not compulsory when providing data, therefore many countries may not have assigned IUCN management categories to their protected areas (UNEP-WCMC, 2015). This can either be due to choosing not to disclose this information, or that they have no capacity to do so. This is also a subjective process since each country is self-reporting and can interpret how to apply IUCN management categories differently.

Data Suggestions

While many of the global blue carbon datasets are workable, they are often not user-friendly and do not allow quality estimates. It is important to take certain steps to make the data more useable for researchers. Standardization for blue carbon ecosystem data is important, considering that these ecosystems are often combined and looked in collectively for blue carbon studies. It would also be helpful to have historical data compiled to conduct a change detection analysis. This would help illustrate the degradation of blue carbon ecosystems and indicate high-risk areas.

Because blue carbon studies are relatively new, and there are more studies that are currently being underway, and thus additional useful data might not be published yet; however, steps are needed to improve these datasets to support new research. Firstly, it is important to identify how much is known and to determine gaps in the data in order to begin further research to supplement the currently available data. Additionally, most of the global data have been recorded remotely, and while this has benefits in time and funding, it is not as accurate. This requires the need for field-surveying and ground truthing mechanisms to ensure the quality of the data.

Another question to ask is why are there gaps in the data to begin with? Is it due to the lack of political will, interest, or funding? Or are the gaps in the data due to challenges in the sampling and mapping in these habitats? The reasons behind data gaps vary between ecosystems and from country to country. It would be helpful to survey these questions to address the issues confronting the main drivers. Finally, once these questions are answered, it is important to look at how these gaps in the data impact the ability to meet global climate change targets.

While blue carbon research is making new strides, blue carbon datasets need to be continuously updated to support researchers. It is important for international organizations to start compiling blue carbon data in a standardized fashion. Proper data availability has the potential to increase valuable blue carbon studies that could support climate change mitigation and adaption strategies and policies.

Protected Area Policy Suggestions

Currently, protected areas are the dominant conservation methods in conserving blue carbon ecosystems. It is suggested that there should be a standard of reporting IUCN management categories, considering that they can be a very useful tool for researchers. There is also a need for better defined categories to remove the suggestive nature of some countries defining protected areas management differently when self-reporting the management approach. Given the results from the Miteva et al. (2015) study, more strict nature reserves, wilderness areas, and national parks should be established along with better enforcement, for the protection of blue carbon.

In the WDPA dataset, data provides have indicated the governance type of 88% of protected areas submitted (Juffe-Bignoli et al., 2014). The data indicates that 82% of reported protected areas are governed by either national or subnational agencies. Around 5% of reported protected areas were governed privately, 1% were under shared governance, 1% were governed by indigenous/local communities, and 12% of protected area governance type were not reported (Juffe-Bignoli et al., 2014). It is suggested to conduct a study looking at the effectiveness of coastal protected areas given the governance type to get a better understanding of optimal governance for blue carbon conservation.

Protected Area Management Effectiveness Assessments (PAME) should also be developed, adapted, and applied by more countries to ensure the effectiveness of their protected areas and effectiveness in protecting blue carbon. As of 2013, it is reported that only 29% of area covered by protected areas has been assessed for PAME and there are still 52 countries where there has been no recorded assessment (Juffe-Bignoli et al., 2014). Some of the goals of these studies include improving protected area management and increasing accountability (Leverington and Hockings, 2004; Juffe-Bignoli et al., 2014). These assessments are conducted by protected area agencies or conservation nongovernmental agencies, and are funded by bodies, such as the World Bank, Global Environmental Facility (GEF), and Worldwide Fund for Nature (WWF) (Juffe-Bignoli et al., 2014). Proper management information will improve the ability to identify and mange priority areas for blue carbon conservation and restoration activities.

All this policy and management change comes back to the need for better quality and quantity of data. There is still need for rigorous evidence under what conditions coastal and marine-protected areas can be successful in preserving blue carbon. The research that does exist indicates a need for more studies looking at what conditions make marine-protected areas successful in preserving blue carbon. Other studies that determine optimal size and high threat locations of protected areas also need to be conducted, along with more long-term research studies looking at the impacts of protected areas on blue carbon conservation over time.

Market Incentives

It is important to implement blue carbon credits into climate change mitigation and adaption policies by having sufficient incentives because of their potential to reduce habitat loss and global emissions (Murray et al., 2011; Miteva et al., 2015). It is important to further explore market-based instruments, such as payments for ecosystem services (PES), in the emerging global blue carbon market as a means to conserve these habitats. One of these mechanisms is REDD+. As previously mentioned, many terrestrial carbon storage providers, such as tropical forests, are protected by international mechanisms such as REDD+, which incentivize developed countries to financially compensate developing nations to reduce their emissions from deforestation and land degradation.

There are currently no international climate mechanisms for protecting blue carbon ecosystems; however, this leaves potential to include blue carbon ecosystem conservation in already existing climate policy mechanisms (Murray et al., 2011; Fourqurean et al., 2012; Luisetti et al., 2013). Instead of spending time to create a new international agreement to protected coastal ecosystems, as a stop-gap measure, it is suggested the REDD+ framework be extended to cover coastal areas as well. In some countries, mangroves fall under the definition of forests, further allowing their inclusion in REDD+ (Locatelli et al., 2014). Regions with low mangrove conservation, such as South East Asia (Figure 3.0), and high rates of mangrove loss would benefit from this course of action.

Mangroves are especially well-suited to generate carbon credits in schemes like REDD+, because of their undisputed role as carbon sinks, resistance and resilience to natural hazards, and extension of co-benefits to benefit both local communities and the global population (Locatelli et al., 2014). The Economics of Ecosystems and Biodiversity (TEEB) research the economic and cultural benefits of conservation and restoration of mangroves and wetlands (TEEB, 2009). In order to combat land conversion activities of mangroves due to market activities, such as shrimp farming, they suggest removing subsidies that encourage conversion and establish conservation compensation mechanisms (TEEB, 2009). TEEB also suggests that the potential social returns of return can reach up to 40% for mangrove and woodlands when taking into account the many ecosystem services provided by these ecosystems (TEEB, 2009). While it will take a great deal of time for blue carbon offset to be incorporated into regulated emission trading mechanisms, there is great potential of increased funding in the conservation of blue carbon ecosystems and that incorporation in the REDD+ framework is likely to be successful (Gordon et al., 2011; Lawrence, 2012, Ullman et al., 2012).

Since a great deal of these habitats are found in developing countries, there are challenges of local and national governance, land ownership and management, and environmental justice (Locatelli et al., 2014). There needs to be careful planning in the development of PES projects to ensure the most success. In order to have proper management of these coastal communities, many stakeholders need to be included, especially local communities. No social science study incorporating the human dimension in blue carbon has currently been conducted (Thomas, 2014). Another challenge is the risk that PES might promote the exploitation of blue carbon resources if the financial returns were not sufficient. Again, proper planning and community involvement in the early development stages is important in order to have a successful carbon offset scheme.

While large scale compliance is needed, voluntary carbon markets provide opportunities for the development of conservation schemes. While one disadvantage of volunteer markets is that they generate smaller amounts of funding than regulated market, voluntary markets make good case studies for larger initiatives. They can also help indicate what measurements are the most effective that can be scaled up to larger mechanisms. Volunteer markets can be used to strengthen the interests of national governments and other stakeholders.

The results of this study are aimed toward voluntary market for carbon credits. These markets cater to individuals, companies, or governments seeking to buy carbon credits not required by law or regulation (Ullman et al., 2012). The benefits of this market are that projects can be funded now rather than having to wait for a regulated scheme to become effective (Ullman et al., 2012). Voluntary carbon markets can be an effective mechanism for blue carbon ecosystem to initiate conversation activities, before large international agreements have taken effect.

CONCLUSION

The rapid increase in atmospheric carbon dioxide levels is an accelerating threat to global ecosystems. The objectives of this study were to illustrate the importance of coastal ecosystems in their role in GHG emissions and to determine the percentage of global blue carbon ecosystems are being conserved, and if this was less than 5%, to highlight the need for new, additional, voluntary conservation projects. The analysis found that globally, around 4% of blue carbon is being conserved. If approved by the VCS, the findings of this study can lead to a standardized approach to additionality for coastal conservation activities and help conservation project developers streamline the process of determining what conservation activities are considered additional. However, while the best available data were utilized in this current study, there were many gaps and uncertainties. It is important to have continued research and data collection on blue carbon ecosystems and marine-protected areas.

There is a disconnect between the value of ecosystem services that blue carbon ecosystems and their market valuation. This imbalance is driving land degradation and conversion, threatening these ecosystems. Threats of sea-level rise are only going to accelerate this loss. By introducing these ecosystems into carbon credit markets, and incorporating their conservation into climate change mitigation strategies, it will promote the generation of more conservation activities. While protecting these ecosystems for their ability to reduce net GHG emissions, supplementary ecosystem services and co-benefits will be protected as well. It is vital these valuable ecosystems be conserved, especially if global climate change targets are to be met in the future.

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