DEVELOPING A FRAMEWORK FOR BLUE CARBON PAYMENTS

by

M. Niles Barnes

Dr. Linwood Pendleton, Advisor

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I alone take full responsibility for any errors or omissions in this paper.

Abstract

Referred to collectively as 'blue carbon' ecosystems, salt marshes, seagrasses and mangroves sequester and store significant amounts of carbon which, when destroyed or degraded, release CO2 into the atmosphere contributing to climate change. The long term sustainable future of these ecosystems may rely in part, on the development of a framework to aid in the process of acquiring payments to protect and restore these ecosystems. Blue carbon ecosystems provide numerous values, services and benefits to humans; however, many of the services are not traded in a marketplace and are unvalued, which has led to overutilization and exploitation. This paper examines the concept of payments for blue carbon protection through the lens of three blue carbon research sites in Abu Dhabi, Madagascar and Mozambique. A literature review, coupled with research and interviews with practitioners at the three blue carbon research sites served to inform the development of this paper.

The overarching goal of payments for blue carbon is to aid in the protection of these vital ecosystems while also providing resources and a means for the people living in these sensitive areas. This paper uncovers various opportunities, constraints and issues of uncertainty related to financing blue carbon protection through the sale of carbon offsets from blue carbon ecosystems. These issues are applied and examined in the context of three blue carbon research sites to uncover potential solutions.

Keywords: blue carbon, ecosystem services, climate change, total economic value, environmental policy, coastal marine ecosystems.

Contents

Introduction

A commonly cited definition of blue carbon comes from Herr, Pidegeon, & Laffoley, 2011, "the carbon stored, sequestered and released from coastal ecosystems including tidal marshes, mangroves and seagrass meadows" (p. 5). Coastal marine ecosystems (CME's) which encompass blue carbon ecosystems, provide numerous ecosystem services including hazard mitigation by reducing the effects of floods and storms, supporting marine and terrestrial species, air and water cleansing, erosion and sediment control, and global climate regulation, among many other services (Barbier et al., 2011). Globally, many of these ecosystems are under threat of development and destruction from human activities. In many parts of the world, aquaculture, farming, property development and wood harvesting for charcoal production have dramatically and rapidly reduced these ecosystems (Murray, Pendleton, Jenkins, & Sifleet, 2011). This destruction is not only of serious ecological concern, but also has important long-term social and economic consequences (Nellemann et al., 2009). Globally, there continues to be a rise in the concentration of carbon dioxide and other greenhouse gases in the earth's atmosphere (IPCC, 2013). This is the result of the burning of fossil fuels, but also due to the deforestation of terrestrial and coastal forest ecosystems such as mangroves.

Further degradation and destruction of blue carbon ecosystems are also contributing factors to climate change. The effects of this growing concentration of carbon dioxide in the atmosphere is already being felt through the increased frequency and intensity of extreme weather events, sea level rise from melting polar ice caps, species migration and extinction, and shifts in the prevalence of different diseases among many other effects. (IPCC, 2013). Fully accounting for the total economic value of these coastal ecosystems and developing markets for their respective ecosystem service values could help prevent degradation and potentially restore these ecosystems. Such an approach requires identifying, quantifying, and monetizing unvalued (or undervalued) services these ecosystems provide to society.

Research from Murray et al., (2011) has suggested that fully accounting specifically for the carbon storage potential of these ecosystems (standing biomass and soils), coupled with new payment schemes for their protection, may serve as an effective method to reduce further destruction and degradation. Such an approach requires an understanding of the total financial costs of protecting these environments and the trade-offs and benefits that come from protection. While there are numerous ecosystem services provided by these coastal ecosystems, and potential to receive payments for some of these services, this paper focuses on the ability for blue carbon ecosystems to receive payments based on carbon sequestration and soil carbon sinks, and avoided emissions of carbon dioxide that result from their degradation and destruction. This protection could come as a result of the sale of carbon offsets on a variety of different markets, from other financial mechanisms and arrangements, or more generally from improving existing conservation and management practices.

In examining potential payments for blue carbon ecosystem protection, it is helpful to understand the full costs of protecting these resources. McCrea-Strub et al., (2011) established cost estimates for 13 marine protected areas (MPA) located in both developed and developing countries worldwide, in an attempt to quantify not only the establishment costs but also the routine maintenance costs of these areas. Of particular interest is the finding that a positive linear relationship exists between total establishment cost and the size of the MPA. In developing a framework for blue carbon payments, there is value in learning from the financial costs and experiences of MPA projects, especially as countries and regions attempt to protect these ecosystems on a landscape scale.

Distribution of Blue Carbon Ecosystems

Although coastal blue carbon ecosystems are spread throughout the world, specific types occur in different areas. Salt marshes primarily occur in more temperate zone tidal areas, while mangroves are primarily in tropical areas, with seagrasses being spread throughout and typically submerged underwater. Two additional ecosystem types include algal mats and coastal sabkha, which form along some arid coastlines; both have been identified and studied as part of the Abu Dhabi blue carbon demonstration project (AGEDI, 2013).

The figure below, from Pendleton et al., (2012) illustrates the distribution of three blue carbon ecosystems most thoroughly studied to date (seagrasses, tidal marshes, and mangroves).

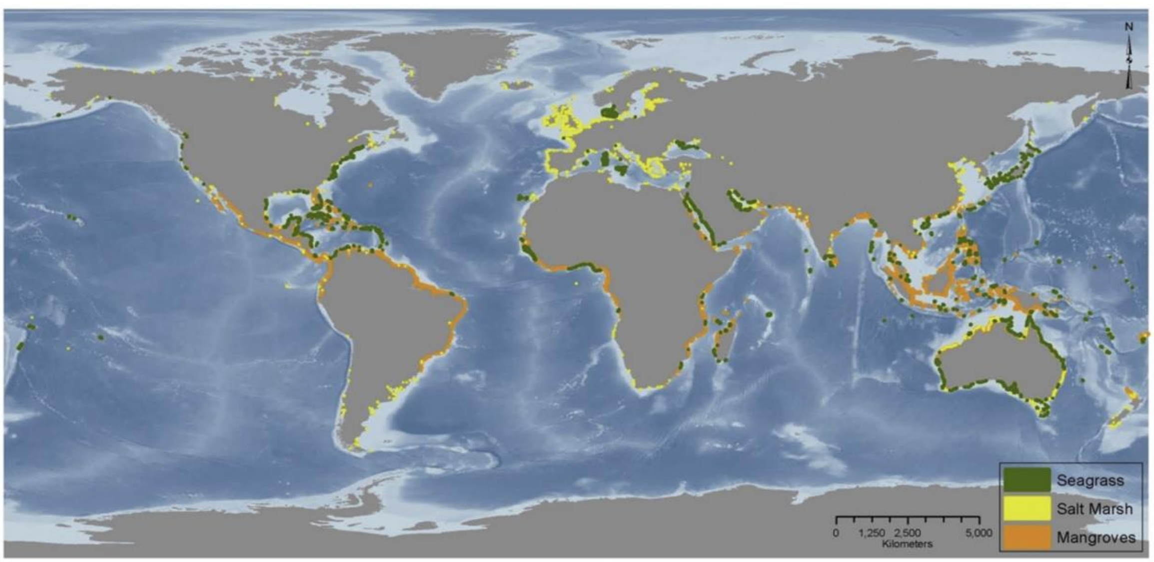
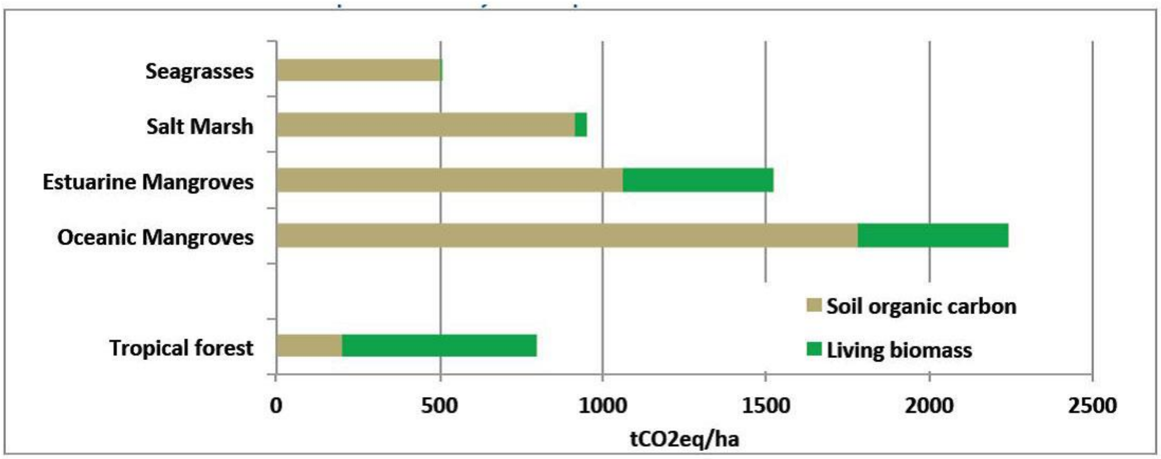


Figure 1: Global distribution of seagrasses, tidal marshes, and mangroves (Pendleton et al., 2012).

These ecosystems, while vital for many purposes, are under intense pressure globally from development for real estate, aquaculture and agriculture (Valiela, Bowen, & York, 2001; Waycott et al., 2009; Giri and Muhlhausen, 2008). The carbon storage capacity of these ecosystems is significant, even more than that of tropical forests. The below figure from Murray et al., (2011) compares the carbon storage abilities of different blue carbon ecosystems along with tropical terrestrial forests to illustrate this significant variance.



*Data is per unit area, where tCO2eq/ha is tons of carbon dioxide equivalents per hectare

Source: Murray, Brian, Linwood Pendleton, W. Aaron Jenkins, and Samantha Sifleet. 2011. Green Payments for Blue Carbon: Economic Incentives for Protecting Threatened Coastal Habitats. Nicholas Institute Report. NI R 11-04

Figure 2: Carbon storage abilities of different ecosystem types (Murray et al., 2011).

As can be expected, when these ecosystems are converted and degraded, they emit significant amounts of carbon dioxide, a greenhouse gas, in addition to losing the other ecosystem services they provide such as buffers to protect against floods and storms. The growing increase in the global release of carbon dioxide is a major contributing factor to climate change (IPCC, 2013). Pendleton et al., (2012) have provided global estimates of the impact of this conversion and have estimated that,

> . . . 0.15–1.02 billion tons of carbon dioxide are being released annually, several times higher than previous estimates that account only for lost sequestration. These emissions are equivalent to 3–19% of those from deforestation globally, and result in economic damages of $US 6–42 billion annually (p. 1).

The research demonstrating these emissions rates, economic impacts and growing rates of degradation and destruction help illustrate the importance and urgency of developing solutions to protect these ecosystems. In the following sections, the concept of total economic value of these ecosystems will be examined along with the opportunities, constraints and issues of uncertainty facing blue carbon payments and protection. These factors will be examined and applied to three blue carbon research projects in Abu Dhabi, Madagascar, and Mozambique.

Direct and Indirect use Values of Blue Carbon Ecosystems

From an economics perspective, it is helpful to think of blue carbon ecosystems in terms of total economic value (TEV), that is, by both the direct use and indirect (or non-use) values that they provide (Pearce, 1993; Turner, Georgiou, & Fisher, 2008). Included in the concept of TEV, are future direct and indirect use values referred to as "option values" (Turner et al., 2008). The components of TEV are illustrated in Figure 3 (adapted from Turner et al., (2008).

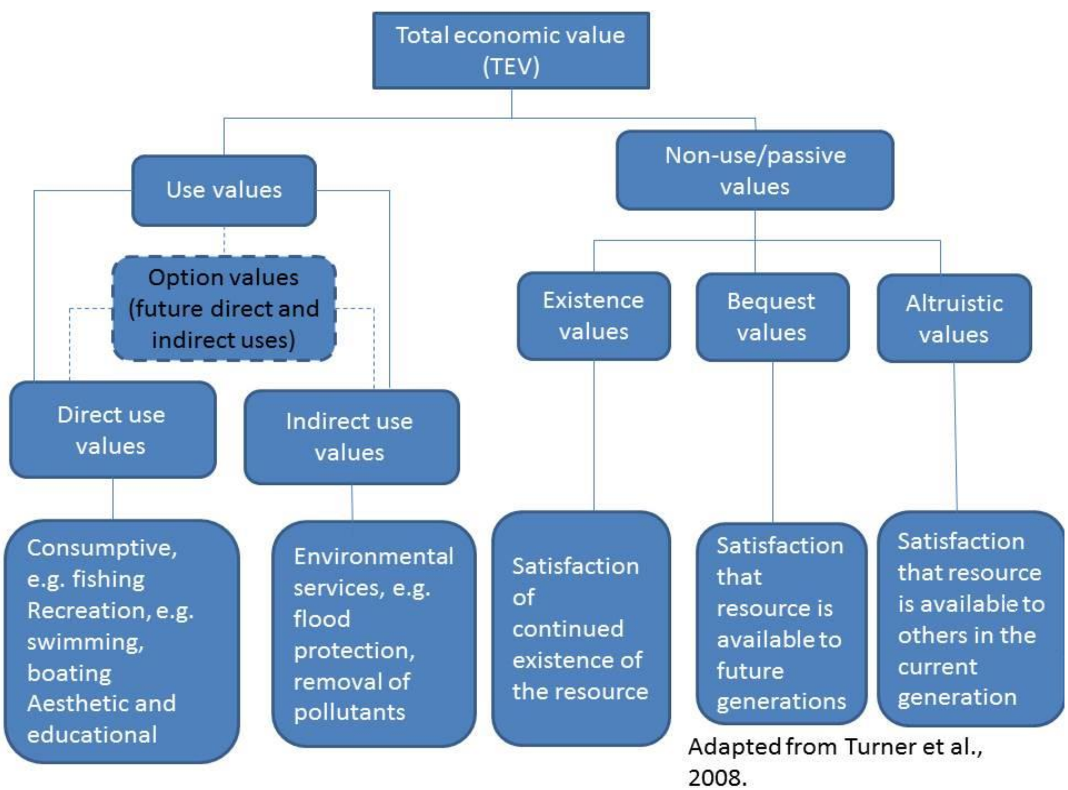


Figure 3: Components of total economic value (Turner et al., 2008).

In the case of blue carbon ecosystems, direct use values include the retention of nutrients and in the case of mangroves specifically, important flood control values that can protect areas from rising tides. Mangroves can also serve as shoreline stabilization while providing a habitat for various species of animals, including fish nursery habitats. Barbier et al., (2011) identified seven direct use ecosystem services along with the processes and functions provided by mangroves, salt marshes and sea grasses. These ecosystem services include: 1) Raw materials and food; 2) Coastal protection; 3) Erosion control; 4) Water purification; 5) Maintenance of fisheries; 6) Tourism, recreation, education, and research; 7) Carbon sequestration.

Attempts to quantify and monetize these ecosystem services have also been conducted to varying degrees of precision and success. A few relevant coastal marine ecosystem service valuation studies include MacArthur and Boland’s (2006) work to associate the degradation of 12,700 hectares of sea grass meadows in Australia with a loss of $235,000 annually in fishery values. Additionally, Costanza et al., (2008) and Barbier (2007) published two separate estimates of the value of coastal protection provided by salt marshes and mangroves to help dissipate wave energy, thereby reducing hurricane and storm damage, ranging in value from $8,236 to $10,821 per hectare per year respectively. Furthermore, Das and Vincent (2009) have demonstrated the importance of healthy mangroves in protecting human life, “. . . mangroves were associated with statistically significant reductions in human deaths during a super cyclone that struck the eastern coast of India in October 1999” (p. 1).

Studies to estimate the water purification services of salt marshes have also been completed with range of value from $785-15,000 per acre due to the “capitalized cost savings over traditional waste treatment” in the U.S. (Breaux, Farber, & Day, 1995, p.1). These studies highlight the various values of these ecosystems and the potential financial costs and benefits that can come from retaining healthy, coastal marine ecosystems.

In addition to providing numerous direct-use values, these blue carbon ecosystems also have important non-use values. For example, relationships to cultural heritage and other existence values cannot be discounted even if they can be difficult to quantify and monetize. It is the case that some countries and regions feel an obligation or desire to preserve blue carbon ecosystems for the benefit of future generations. In Abu Dhabi, now the largest of the seven United Arab Emirates' (UAE), mangrove forests retain cultural and historic significance due in large part to the replanting efforts of the late Sheikh Zayed bin Sultan Al Nahyan, the founding president of the UAE (AGEDI, 2013). These ecosystems can be bestowed with high intrinsic value in addition to recognizing the instrumental value they provide.

Although there are financial values for these resources, there is a lack of incentives, markets or institutions currently viable enough to stem the ongoing loss of these ecosystems globally. This is due, in large part, to the majority of these ecosystem services being unvalued in existing markets. In the following sections, the constraints for payments for blue carbon protection will be examined and opportunities for overcoming them discussed.

Identifying Opportunities, Constraints and Overcoming Issues of Uncertainty

The growing interest in blue carbon projects and the potential to receive payments for the ecosystem services they provide has resulted in the need for many concepts and areas of uncertainty to be addressed. Fortunately, the increasing number of research projects and initiatives occurring globally focused on blue carbon, is helping to overcome some of the scientific and technical challenges currently facing payments for blue carbon protection.

There are a variety of opportunities, constraints and issues of uncertainty facing payments for blue carbon that are identified and described below. These factors emerged from a review of the relevant literature on blue carbon ecosystems, coupled with research and interviews at three blue carbon demonstration projects in Abu Dhabi, Madagascar and Mozambique. Many of the identified issues affect all blue carbon projects, such as uncertainty regarding a new 2015 United Nations Framework Convention on Climate Change (UNFCC) protocol, while other factors are specific to a blue carbon project, such as in-country scientific capacity. Table 1 captures a range of opportunities, constraints and issues of uncertainty facing payments for blue carbon. Items in **bold** indicate issues applicable to a broad spectrum of blue carbon projects while those not bolded are often project or country-level specific. Two categories are explored in more depth: 1) carbon methodologies and standards applicable to blue carbon offsets; 2) potential carbon markets and other financial transactions for blue carbon protection. These two categories are discussed in more depth due to their critical importance in creating opportunities for payments for blue carbon. The other issues identified in the chart are discussed, when relevant, in the three case studies focused on the Abu Dhabi, Madagascar and Mozambique blue carbon research sites.

Opportunities	Constraints	Issues of Uncertainty
1. Growing international awareness via media reports, published papers, conference presentations 2. Increasing financial support for scientific research (private foundations/philanthropies, government and NGO funding) 3. Success of recent blue carbon demonstration projects (Murray et al., 2011) **4. Growing momentum to have blue carbon officially recognized in UNFCCC processes (Murray and Vegh, 2012)** 5. Soil carbon data leading to more comprehensive information **6. Interest in accounting for blue carbon ecosystem services and carbon offset potential**	1. Political stability in-country 2. Threats and sources of degradation changing in time scale and intensity 3. Lack of in-country ability to measure, monitor, report and verify changes to ecosystems **4. Emerging methodologies for developing carbon offsets from these ecosystem types** **5. Barriers to access existing carbon offset markets** **6. Behavior leading to degradation and destruction not easily changed without markets for blue carbon payments for protection** 7. Startup costs associated with initial assessment of suitability of a blue carbon offset site.	**1. Regulatory environment** **2. Issues of carbon supply (both in terms of area and how supply/quantity can change over time)** 3. Confusion identifying what payments will be for (carbon offsets or other ecosystem services) 4. Lack of clearly defined property rights of blue carbon ecosystems **5. Competitiveness of blue carbon offsets versus other carbon mitigation strategies (Murray et al., 2011)** 6. Developing buy-in of local communities and current ecosystem user groups (ex. fishing communities) **7. Difficulty demonstrating "Additionality" (Murray and Vegh, 2012), "Permanence" (for mangroves: Alongi 2008; for seagrasses: Short and Wyllie-Echeverria 1996; for salt marshes: Bertness, 1999; Adam 2002; Gedan et al., 2009), and dealing with "Leakage" (Henders and Oswald, 2012)** 8. Rates of degradation over time; rates of sequestration and size of carbon sinks **9. General carbon market uncertainty (what price/demand for offsets will be)**

Table 1: Identifying opportunities, constraints, and issues of uncertainty for blue carbon payments.

Carbon Methodologies and Standards Applicable for Blue Carbon

One important step in creating carbon offsets from the carbon storage and sequestration provided through blue carbon ecosystems is ensuring the necessary information and data is available. The research projects in Abu Dhabi, Madagascar and Mozambique are helping to refine carbon pool and sequestration estimates from blue carbon ecosystems, which can serve as critical data for potential carbon offset creation.

The lack of information and data can be a constraining element in the creation of any carbon offsets project, but is particularly acute in the nascent area of blue carbon offsets. Regardless of where a carbon offset is sold (on a compliance or voluntary market) certain basic requirements must be met in order to qualify as a carbon offset. Table 2 identifies the most common terms relevant to carbon offsets traded on both regulated and voluntary markets.

Key carbon offset terms	Term description
Real	Actual reduction in GHG emissions can be demonstrated
Additional	Reduction results from activities that would not have happened in the absence of the project under a reasonable or business-as-usual scenario
Permanent	Mechanisms in place to manage and eliminate the risk of reversal of CO_2 reductions
Measurable	Project results in measurable reductions of CO_2 emissions
Leakage	Project takes into account any direct or indirect increases in carbon emissions that result from the existence of the carbon offset project
Verified	Independent audit by a third party to ensure project meets eligibility requirements for specific carbon offset
Transparent	Project details are clear and communicated transparently to ensure legitimacy

Table 2: Key carbon offset terms and definitions (World Resources Institute and World Business Council for Sustainable Development, 2004).

The terms described in Table 2 help provide legitimacy to a carbon offset project and any claim of an actual emissions reduction from a particular activity. A carbon offset, while relatively intangible, is “a unit of carbon dioxide-equivalent (CO2e) that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere” (Goodward and Kelly, 2010, p. 1). The terms in Table 2 come together to help ensure that necessary conditions are met to accurately account for a carbon offset claim. While these seven concepts are relevant to any carbon offset project, they can pose particular challenges to coastal marine ecosystems (CME’s). Three of the concepts in particular, have been studied in depth including the ability to demonstrate the “additionality” of blue carbon offsets (Murray and Vegh, 2012), ensure the “permanence” of blue carbon offsets (for mangroves: Alongi 2008; for seagrasses: Short and Wyllie-Echeverria 1996; for salt marshes: Bertness, 1999; Adam 2002; Gedan, Silliman, & Bertness, 2009), and for dealing with issues of “leakage” (Henders and Oswald, 2012). The ability to address and control for these three issues in a way that provides credible assurance, will be necessary for the creation and sale of a blue carbon offset. This can be challenging, given the numerous constraints and issues of uncertainty identified in Table 1 that relate to these concepts. While not insurmountable challenges, these are fundamental to the ability of blue carbon offsets to be traded on either voluntary or regulated carbon markets.

An issue contributing to blue carbon offset uncertainty, has been the lack of internationally accepted methodologies for accounting for emissions from coastal wetlands. This issue has been partially overcome with the recently released methodology update entitled, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (IPCC, 2014). This important supplement builds on the 2006 IPCC Guidelines by “filling gaps in coverage and providing updated information reflecting scientific advances, including updating emission factors…. organic soils and wetlands on mineral soils, coastal wetlands including mangrove forests, tidal marshes and seagrass meadows" (IPCC, 2014, p. iv).

In addition to this IPCC methodology guidance on emission factors, there also exist numerous standards being used in the voluntary and regulated carbon markets that are relevant for blue carbon projects. While beyond the scope of this paper to examine all possible offset methodologies and standards, three are particularly appropriate for blue carbon, in part because of their use in estimating terrestrial Reducing Emissions from Deforestation and Forest Degradation (REDD+) carbon projects (Estrada, 2011). These three standards include the Verified Carbon Standard (VCS), Plan Vivo, and the Climate, Community and Biodiversity Project Design Standards (CCB Standards). Two of these standards are being applied to blue carbon projects currently. According to a scientist working in Madagascar as part of the Blue Ventures blue carbon study, two separate VCS standards are being "road tested and implemented". In addition, the Plan Vivo standard is being implemented in the Mikoka Pamoja mangrove blue carbon project in Kenya (Lutz, Neumann, Glavin, Shamayleh, & Bredbenner, 2013).

According to Estrada (2011), taken together, these three standards "represent significant shares of the forest carbon market, applied alone and in combination with other standards, and qualify among the best forest standards available in the market . . ." (p. 1).

The broad acceptance and use of these standards in existing terrestrial forest carbon offset projects is in part why they are important for potential blue carbon offset creation.

Carbon Markets and Other Financial Transactions for Blue Carbon Payments

There are numerous possible markets and non-market mechanisms in which payments for blue carbon protection either are currently possible or have the potential to be possible in the future. In the last three years, a growing body of literature focusing on the technical hurdles and options facing various financing schemes for blue carbon has been published (Herr et al., 2011; Gordon, Murray, Pendleton, & Victor, 2011; Murray et al., 2011; Murray & Vegh, 2012; Lutz et al., 2013). Although not capturing every possible market for blue carbon offsets, the following figure captures existing opportunities for blue carbon protection via carbon offsets or other transactions that could provide ecosystem protection.

Figure 4: Example of markets and mechanisms which could enable payments for blue carbon.

One of the most critical issues of uncertainty facing the potential for blue carbon offsets is the lack of "specific mechanisms within the UNFCCC that focus on blue carbon" (Murray & Vegh, 2012, p. 5).

With the expiration of the Kyoto agreement in 2012, a new United Nations Framework Convention on Climate Change (UNFCCC) climate change agreement that legally binds developed and developing countries to reduce greenhouse gas emissions has, as of yet, failed to come to fruition. It is possible that such an agreement and new framework could provide an opening for blue carbon offsets to be included in compliance markets and in national level greenhouse gas accounting. This would have the positive effect of potentially providing funds to help protect these blue carbon resources and/or lead to better management practices.

To better understand the status of coastal marine ecosystems as a potential regulated, tradable carbon offset, a brief discussion of recent UNFCCC processes to achieve a successor to the Kyoto agreement is included below.

In 2009, at the United Nations Climate Change Conference in Copenhagen (COP15), it was the meeting's stated intention to develop a successor to the Kyoto protocol, a binding global agreement to reduce greenhouse gas emissions from industrialized countries. While this did not occur in 2009, at the Durban, South Africa meeting in 2011 (COP17), participating countries agreed to develop a new agreement by 2015, but that future agreement would not go into effect until 2020. At the most recent COP19 in Warsaw, Poland, participating countries put off committing to an agreement until the next conference in Paris, France in 2015. As a result of pushing the issue further into the future, along with major disagreements among many participating countries including the United States and China regarding the role and responsibilities of developed and developing countries in reducing emissions, there is reason to believe that between now and a new agreement taking effect in 2020, a significant amount of these blue carbon resources will be degraded and destroyed. This degradation will, by extension, contribute to increasing levels of global CO_2 emissions further contributing to climate change and its negative effects. Without an internationally facilitated agreement binding countries to reduce greenhouse gas emissions, blue carbon offsets continue to face market uncertainty.

Carbon Offset Markets

Regulated Markets:

United States

The failure of the United States to ratify and participate in the Kyoto protocol along with the failure to pass cap and trade or carbon tax legislation at the federal level has reduced the viability of carbon markets generally. However, at the state level, most notably in the state of California, there have been attempts to move ahead with a form of a state-based, regulated carbon market. However, at this time in the California scheme, there is not the inclusion of blue carbon as an offset source for emissions and carbon offsets are being positioned to only be used to meet a small percentage of regulated industries compliance (Center for Climate and Energy Solutions, 2014).

Europe, New Zealand & Korea

In Europe, there exists the European Union Emissions Trading System (EU ETS) a cap and trade compliance carbon market directly linked to commitments the European Union made under the Kyoto Protocol. The EU ETS does not currently allow for blue carbon offsets. While the EU ETS is a possible market, there would need to be changes to the structure to allow blue carbon based offsets to be sold in that trading system. The same is also true for New Zealand’s’ emissions trading system. Other emerging regulated markets, such as the South Korean ETS, also do not appear to be opening to blue carbon offsets in the near term. The Korean ETS for example, will allow only up to 10% of compliance to be met through offsets and no international offsets will be allowed during the first two phases of the system (Mansell & Sopher, 2013).

Voluntary Carbon Markets

Although a relatively small market globally, it is possible in the near term, that the voluntary carbon offsets markets could serve as a place for blue carbon offsets to be traded. The voluntary market could also prove to be a testing ground for blue carbon offsets trading in regulated markets in the future as well. As Peters-Stanley & Hamilton (2012), illustrate, voluntary carbon markets have been useful in their flexibility and ability to innovate and experiment with financing, monitoring of projects and methodologies that have helped to inform regulated markets. Many of the methodologies and standards developed for the voluntary carbon markets are currently being tested for inclusion of blue carbon ecosystems, including the Verified Carbon Standard and Plan Vivo as described previously.

Reducing Emissions from Deforestation and Forest Degradation (REDD+)

In addition to voluntary and regulated carbon offset markets, another important potential mechanism to receive payments for blue carbon protection is the United Nations collaborative program on Reducing Emissions from Deforestation and Forest Degradation (REDD+). REDD "is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development" (UN-REDD Programme, 2009). The "+" in REDD+ is intended to capture and "includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks" (UN-REDD Programme, 2009).

Recently, there is recognition that mangroves could be included under REDD+. However, there is a lack of clarity and inclusion of all blue carbon ecosystems such as salt marshes and sea grasses and if the carbon stored in the soils of these ecosystems could also be included. Research from Gordon et al., (2011) has suggested that if REDD+ protocols were to evolve to include soil carbon as an offset, it could have the potential to help scale up blue carbon protection. Olander, Galik, & Kissinger, (2012) illustrate the operational issues and constraints associated with expanding the scope of reducing emissions from deforestation (RED) but also how the framework has a history of expanding in scope. Such expansion could bode well for some specific blue carbon ecosystems such as mangroves which are essentially coastal forest. The Blue Ventures led pilot programs in Madagascar for example, is seeking to develop mangrove REDD+ projects (Blue Ventures, 2013).

Other Financial Transactions for Blue Carbon Ecosystem Protection

In addition to the markets and mechanisms discussed above, there are other possible financial agreements that could also be beneficial to protecting these ecosystems. Although the full suite of possible financial transaction types to protect for blue carbon could be extensive, a few example are given below. A very basic possible transaction could be, for example, bilateral agreements between buyers and sellers for the ecosystem services these coastal marine ecosystems provide. Conservation organizations or other entities purchasing the land to conserve and protect the ecosystems is possible and has been done to protect other ecosystem types. Another possible financial transaction could be a ‘debt-for-nature swap’ agreement where the foreign debt of a lower income and less industrialized country with these ecosystem resources could be purchased (for example by an environmental organization or other third party) and sold back to the issuing governments in exchange for protection of the ecosystem. Sheikh (2010) identifies numerous debt-for-nature swap examples and describes the different ways such transactions are used to fund projects, "ranging from national park protection in Costa Rica to supporting ecotourism in Ghana and conserving tropical forests in Bangladesh" (p. 1).

Research Methods

This project included a literature review along with research on three blue carbon project sites (Abu Dhabi, Madagascar and Mozambique) with accompanying interviews conducted with scientists and program management staff who had worked in-country at each site. A series of semi-structured interviews were conducted via telephone and in-person with scientists and staff who had worked in-country in Abu Dhabi, Madagascar and Mozambique (See Appendix 1 for a list of questions). Questions were developed and selected based on their ability to elicit information helpful for developing a framework for blue carbon payments.

The source of contacts for the demonstration sites came via the Global Environment Facility (GEF) Blue Forests project, a collaboration with the United Nations Environment Program (UNEP), GEF and GRID-Arendal.

In addition, email and telephone communications with scientists involved in blue carbon policy and research related to the international blue carbon policy working group were also conducted.

Examining Case Studies to Unearth Commonalities, Differences and Lessons Learned

The examination of three blue carbon research sites helped to uncover additional opportunities, constraints, and issues of uncertainty related to payments for blue carbon protection. Many of these issues were initially identified through the literature review discussed previously (Table 1) but were also augmented through the research on the three sites.

The GEF Blue Forests project includes three advisory panels chaired by UNEP, Duke University, and the International Union for Conservation of Nature (IUCN).

Included in the GEF Blue Forests project are five contributing blue carbon demonstration sites total, each managed by a separate in-country organization. These five blue carbon sites are highlighted in the map below.

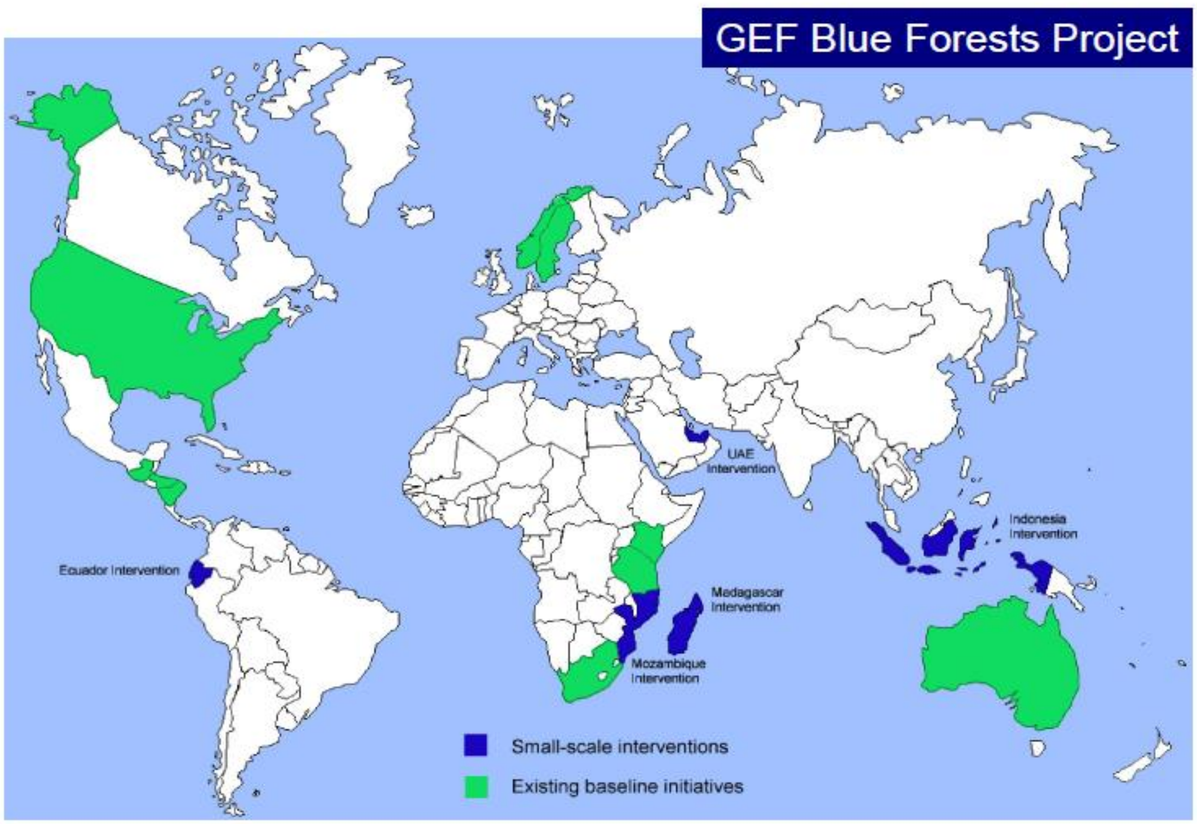


Figure 5: GEF Blue Forest demonstration sites (map courtesy of GRID-Arendal)

Selected Research Sites

The three sites chosen for this study included Abu Dhabi, Madagascar, and Mozambique. These sites were selected based on perceived accessibility of data and researchers, along with an attempt to have some geographic, economic, and political diversity of sites.

Abu Dhabi

Site Description:

The Abu Dhabi blue carbon demonstration project involved many organizations and stakeholder groups, but was primarily implemented by GRID-Arendal on behalf of the Abu Dhabi Global Environment Data Initiative (AGEDI). This one-year research project began in November 2012 with final results and publications released in late 2013 (AGEDI, 2013). The intent of this demonstration project was to " . . .develop an integrated assessment of the extent of coastal and marine ecosystems, the carbon they sequester and store, the further ecosystem services they provide, as well as the policy and financial options for recognizing blue carbon ecosystems' value in Abu Dhabi's decision making" (Lutz et al., 2013, p. 51). The Abu Dhabi project included research on the blue carbon potential of mangroves, sea grasses, salt marshes and two additional ecosystems of local interest: algal flats and coastal sabkha (AGEDI, 2013).

Figure 6: Map of Abu Dhabi (Google Maps, 2013).

Site Characteristics:

Abu Dhabi	
Ecosystem types included in research	Mangroves, seagrasses, salt marshes, coastal sabkha, algal mats
Geographic scope	Limited to Abu Dhabi
Length of study	All project components completed (11 month project)
Project partners	Primary: GRID-Arendal, UNEP, UNEP-WCMC, Forest Trends, AGEDI. Additional team of scientists with various affiliations.
Funding sources	AGEDI

Table 3: Overview of Abu Dhabi blue carbon research site characteristics.

Opportunities for Blue Carbon Payments

The Abu Dhabi blue carbon research project benefited from many of the opportunities identified from the literature review in Table 2. These include financial support for conducting scientific research, growing interest in fully accounting for blue carbon ecosystem services, and the ability for soil carbon data to contribute to more comprehensive information to aid in conservation and management. The Abu Dhabi project has also helped to strengthen two of the identified opportunities by contributing to growing international awareness of blue carbon ecosystems and through demonstrating a successful blue carbon research project.

According to GRID-Arendal researchers, the three focus areas of the Abu Dhabi blue carbon demonstration project included: 1) attempts to improve scientific understanding of blue carbon ecosystems; 2) develop valuation of ecosystem services in addition to carbon and; 3) improve policy mechanisms for blue carbon ecosystem protection. These focus areas are intended to help overcome some of the issues of uncertainty identified in Table 2, such as the amount of blue carbon ecosystems in Abu Dhabi and the sources of ecosystem degradation.

In addition to the three core focus areas, developing an understanding of the major sources of blue carbon ecosystem degradation in Abu Dhabi was also a priority. According to GRID-Arendal researchers, in Abu Dhabi, the degradation and destruction is the result of rapid development over a relatively short period of time. In roughly 40 years, Abu Dhabi has transformed from a small fishing based community to the largest of the seven United Arab Emirates (AGEDI, 2013). This rapid development links the coastal degradation directly to building development and oil exploration, but not, as the case in some other areas of the world, from nutrient release from fertilizers. This property development, which can lead to blue carbon ecosystem degradation, corresponds to the constraining element identified in the literature review, which links the negative behavior to a lack of markets and valuation of these ecosystems. The blue carbon research project has been an opportunity to value these ecosystems and provide information that could lead to improved management and conservation practices.

Although development pressures exist, Abu Dhabi is unique in that mangrove stands are increasing in some areas of the emirate according to researchers. As mentioned in the introduction, the first Sheik instituted a large mangrove plantation planting effort that is one reason Abu Dhabi retains some healthy mangrove ecosystems today. In researching the Abu Dhabi blue carbon demonstration project, it became clear that the interests in blue carbon are in part to answer the question of how to value the ecosystems in policy and management efforts that are relevant to the emirates development goals. By financially supporting the Abu Dhabi blue carbon research project, AGEDI provided an important opportunity for the project to be successful from a research perspective and the results beneficial for future blue carbon projects. The financial research support from the UAE also helps to position Abu Dhabi as a leader in international research efforts related to blue carbon.

Although benefitting from many opportunities, there exist numerous constraints and issues of uncertainty impeding payments for blue carbon in Abu Dhabi. These are explored in more detail below.

Constraints and Issues of Uncertainty Related to Blue Carbon Payments

The uncertain regulatory environment enabling payments for blue carbon along with barriers to access existing carbon offset markets remain issues of uncertainty in Abu Dhabi, as they do across other blue carbon research sites. Competiveness of blue carbon offsets as compared to other carbon mitigation strategies are also an issue of uncertainty in Abu Dhabi. While benefitting from many opportunities, the Abu Dhabi research site illustrates how many constraints and issues of uncertainty remain before payments for blue carbon can become a reality.

Although the user groups contributing to the degradation are very different in Abu Dhabi as compared to Mozambique or Madagascar, this remains an issue of uncertainty. It is important to note, that as opposed to less wealthy countries, such as Mozambique and Madagascar, Abu Dhabi does not require the payments that could come from the sale of blue carbon offsets to begin blue carbon ecosystem restoration efforts or improve management practices.
In addition, the unique political structure of Abu Dhabi and the UAE (absolute monarchy), has lent itself to stability and not, as is the case in some other regions, to the constraining issue of political instability.

The findings from the one year demonstration project helps to overcome the issue of uncertainty related to carbon supply, both in terms of quantity and rate of change over time. The research found that the value of the blue carbon storage and sequestration is relatively low. The final report from the project suggests that, " . . . the net present value from the blue carbon ecosystems are very significantly negative, as the estimated discounted costs dramatically exceed the estimated discounted revenues. . .blue carbon stocks in Abu Dhabi are likely to be insufficient for the generation of carbon credits" (AGEDI, 2013, p. 50). This assessment, while a constraining element for the creation of blue carbon offsets, also means that the complicated issues of proving additionality, permanence and dealing with issues of leakage in order to create an offset, will not need to be pursued or demonstrated. The results also suggest that the general carbon market uncertainty related to prices and demand, are not as critical an issue for Abu Dhabi.

There is still interest in and an opportunity to include the carbon values in national level greenhouse gas accounting. Since the UAE and Abu Dhabi's economy is primarily fossil fuel based, accounting for the blue carbon resources could be one tool for potentially lowering national level emissions.

Given the results of the Abu Dhabi carbon studies, it is unlikely that the supply of blue carbon ecosystems would make it competitive on existing carbon markets. Furthermore, Abu Dhabi would not qualify for participation in the UN-REDD+ program focused on developing countries given the economic wealth of the United Arab Emirates. However, despite these constraints, there is the possibility of an innovative funding mechanism, described below.

Lessons Learned and Application to Other Blue Carbon Sites:

The one year rapid demonstration project resulted in an impressive body of knowledge related to blue carbon and the release of numerous reports (listed below). These reports are valuable in understanding the steps that can be taken when undergoing a blue carbon research project. The

Abu Dhabi blue carbon research project benefited from being well financed and clear in its scope of work and purpose. Although it does not face the constraints and issues of uncertainty of some other blue carbon sites, it has unique challenges and threats to the ecosystems which will have to be overcome in order to better manage and conserve blue carbon ecosystems in the future.

Although not included in the list of markets or financial transactions for blue carbon protection discussed previously, one outcome that could result from valuing blue carbon in the Abu Dhabi context is the potential of that value to be used in creating a fund to provide financing for future restoration efforts. The creation of such a fund is not guaranteed, yet the idea is that it could help compensate for the degradation from coastal development. The creation of this fund would require developing buy-in not only of the government, but of property developers that contribute to blue carbon ecosystem degradation. If the ecosystem service values of blue carbon, including carbon storage and sequestration, can be used as justification for creating such a fund, the financing of restoration efforts may be able to happen more quickly and through the payment of entities participating in development projects.

List of supporting reports from the Abu Dhabi blue carbon research project:

- Baseline Assessment Report
- Financial Feasibility Assessment Report
- Spatial Data Assessment Report
- Ecosystem Services Assessment Report
- Abu Dhabi's Blue Carbon Policy Report

Above reports supported by:

- Building Blue Carbon Projects – An Introductory Guide
- Abu Dhabi Blue Carbon Mapping Tool

Madagascar

Site Description:

In Madagascar, blue carbon research is focused on mangrove ecosystems, but it is the intention of the Blue Ventures research team to "extend mangrove management to neighboring seagrass beds, combining the management of both of these blue carbon ecosystems and maintaining existing ecological synergies" (Blue Ventures, 2013, p. 6). In 2011, staff at Blue Ventures was responsible for setting up the initial blue forests research program and team in Madagascar. This included all aspects of the research programs development including recruiting local Malagasy for the research teams, obtaining equipment for the studies and launching the research projects in five designated sites. This long-term commitment in-country differs substantially from the 11 month rapid assessment project of the Abu Dhabi project.

The below map, courtesy of Blue Ventures, illustrates the primary areas of focus in which active mangrove blue carbon research is currently underway. Partner organizations and funding vary across the five primary research sites seen in the below map. The distribution of the sites is intended to cover the variability of change being experienced in Madagascar's mangrove forest ecosystems.

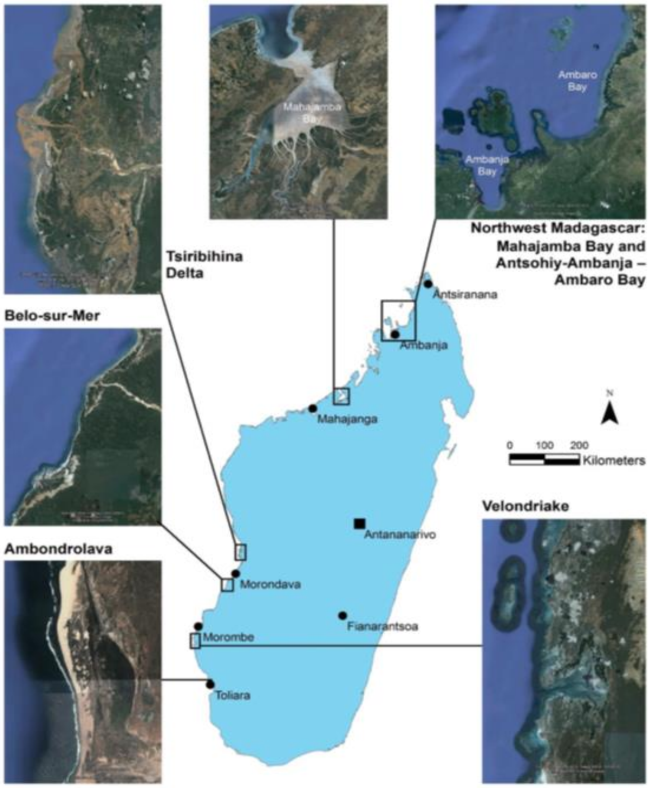


Figure 7: Map of mangrove research sites in Madagascar (Blue Ventures, 2013).

Site Characteristics:

Madagascar	
Ecosystem types included in research	Mangroves primarily (intend to also include seagrasses)
Geographic scope	5 research sites spread throughout the western and northwest coast of Madagascar
Length of study	Carbon pool data collection completed, other project components ongoing.
Project partners	Blue Ventures
Funding sources	Varied

Table 4: Overview of Madagascar blue carbon research site characteristics.

Constraints and Issues of Uncertainty Related to Blue Carbon Payments

Although sharing in some similar blue carbon ecosystems as Abu Dhabi, the two sites are drastically different from an economic and governance standpoint. While Abu Dhabi has one of the highest per capita incomes of any state in the world, Madagascar has a population of a little over 22 million with a gross national income (GNI) of $430 US dollars (World Bank, 2014). These differences in wealth impact human decisions when it comes to resource use, conservation and management and interests in blue carbon. The buy-in and support of local communities is also critical, as many rely on the ecosystems directly to provide a livelihood. The threats and primary sources of degradation are also a constraining issue. While the level of threat is variable depending on where in Madagascar destruction is occurring, it is typically not the same threats and sources as in Abu Dhabi. As in other cases, developing buy-in of local communities is an issue of uncertainty, but Blue Ventures has made a direct effort to develop this buy-in as will be discussed in more detail below.

Political stability has also been a critical constraining element in Madagascar. A 2009 coup led to a vacuum in political governance, and much of the scientific funding from industrialized countries was withdrawn due to uncertainty at the national governing level according to researchers. In a country already dealing with issues of extreme poverty, this coup and the following years of uncertainty did not improve the economic situation for everyday Malagasy citizens. Elections were held in 2013 and as of January, 2014, Madagascar has a new internationally recognized president, Hery Rajaonarimampianina, the first since the coup in 2009. Strengthening political governance and stability and developing in-country capacity, are critical elements that will hopefully lead to better management and conservation of blue carbon ecosystems.

Opportunities for Blue Carbon Payments

Despite these political and governance challenges, Blue Ventures has continued to work in-country and, according to Blue Ventures researchers, has worked to be "at the table with government agencies about how REDD+ will manifest in the country, and [is] working to ensure that mangroves are included in existing national level plans". Traditionally, for mangrove ecosystems specifically, the height and canopy cover requirements have excluded these coastal marine ecosystems from inclusion in national level accounting of forested areas in Madagascar. This lack of inclusion means less is known about the rates of mangrove degradation over time in the country.

A large focus of the blue carbon research project in Madagascar since its inception in 2011 has been developing a team in-country to complete the necessary scientific studies related to the country's mangrove carbon stocks. Today, 16 full-time staff, many of whom are native to Madagascar, are a part of the blue carbon research team. The efforts to hire and employ local Malagasy can help to develop buy-in for blue carbon protection efforts. This growing capacity presents an important evolution and opportunity for improving ecosystem conservation and management in Madagascar.

Following many years of work and data collection, the first report estimating total carbon stocks for mangroves in Madagascar was released in 2014 (Jones et al., 2014). The study helps to further "support the growing body of studies that mangroves are amongst the most carbon-dense tropical forests" (Jones, 2013, p.1). This new research is an important step in overcoming uncertainty as to the amount of carbon contained in mangroves across Madagascar.

The national level analysis of the forest dynamics indicate that one-fifth of the mangrove distribution has been highly degraded or destroyed since 1990 (Jones et al., 2014). However, there are noticeable differences in different areas of the country. According to scientists, in the Mahajamba bay mangrove ecosystem, despite large scale shrimp aquaculture occurring in the mud flats, the mangroves are relatively intact; however, there are indirect influences of such large, industrial scale shrimp farming that do require further research.

Other areas in Madagascar, such as Ambaro and Ambanja bay, have experienced significant degradation from the overharvesting of mangroves for the production of charcoal. In the Northwest parts of the country, some areas were clear-cut over 10 years ago have not had natural regeneration due to the low ability for propagules to redisperse after such significant disturbance. After charcoal production, other significant drivers of mangrove degradation include conversion for different types of agriculture and aquaculture. As opposed to some parts of the world where shrimp farming has been the cause of rapid deforestation, there are significant amounts of rice farming applying pressure to the mangrove ecosystems in Madagascar (Blue Ventures, 2013). This variance is similar to Mozambique, and corresponds to the constraining issue of threats and sources of degradation having different rates in time scale and intensity. Deforestation from charcoal production is a relatively new phenomenon in Madagascar according to Blue Ventures scientists. The lack of strong governance, increasing population growth and demand for charcoal have all contributed to the increased intensity level in the last decade. Despite the variance, the blue carbon research in Madagascar is helping to clarify these previously unknown threats, sources, and intensity rates which are critical to future protection and potential payments to support protection.

There is recognition in Madagascar that REDD+ projects and the creation of carbon credits ready to be sold on a market take significant time and resources to develop. For this reason, according to Blue Ventures scientists, there is a focus on working on multiple approaches for payments for ecosystem services focusing energy on improved management of these ecosystems and working to ensure that land tenure rights are secured for future possible payments. The lack of clearly defined property rights is an issue of uncertainty facing the Madagascar blue carbon site. As discussed previously, the land tenure and property rights issue is critical to any payment for blue carbon resource protection. Although de facto control relies with the government, Blue Ventures researchers suggest that some land rights "appear to be transferable to the communities participating in the pilot REDD+ project". In general, the rights are the control of the government unless one can prove long term status access of these communities. Clearly defined property rights will be necessary to enabling payments for blue carbon protection in the future.

The choice of a carbon accounting methodology is also currently being examined by Blue Ventures. The recent report by Jones, et al. (2014) on carbon stocks and deforestation analysis helps to fill a key knowledge gap necessary for a carbon offsets methodology to be pursued. According to Blue Ventures scientists, the Madagascar team is studying the use of the Verified Carbon Standard methodologies, specifically "VM 0009 along with doing a side comparison of the VM0015 methodology". These methodologies are being explored for future potential carbon market and REDD+ participation of the mangrove blue carbon storage and sequestration in-country. Pursuing REDD+ for mangroves could an appropriate strategy given the recent success in Madagascar in selling its first government controlled and owned carbon offsets via the REDD+ mechanism for a terrestrial forest project (Butler, 2013). There appears to be traction and a desire for successful REDD+ projects in Madagascar, and Blue Ventures is diligently working to take advantage of this opportunity.

Lessons Learned and Identification of Ecosystem Co-benefits

For the Madagascar blue carbon project, the internal in-country capacity has been growing at a steady pace, although there remain some skills gaps. In addition to the 16 member full-time staff, there continues to also be a diverse participation from Malagasy graduate students, interns and volunteers participating in the research projects. Highlighted by researchers is one small, yet important community driven project of rotating temporary closures of certain mangrove sites to help allow crabs to grow larger in size to improve their value when sold. These temporary closures are monitored by the communities themselves, choosing which areas become closed and showing the tangible benefits that come with such closures. This alternative, which enhances livelihoods, is one tangible example of successful co-benefits in managing mangrove ecosystems, in addition to the carbon related sequestration and storage these ecosystems provide. This opportunity will potentially more fully account for the ecosystem services provided by blue carbon ecosystems, while also providing immediate and tangible benefits to the local people. In the quest to enable payments for blue carbon, these two opportunities cannot be discounted and are as important and necessary as the carbon storage and sequestration these ecosystems provide.

The Madagascar site also illustrates how important developing in-country capacity is for any payments for blue carbon offsets. This is due in large part to the necessity of ongoing monitoring, reporting and verifying of claims of emissions reduction.

One additional recent success in Madagascar has been the opening of a soil lab at the University of Antananarivo’s department of forestry. With this new lab, another skills gap will be closing as there will be opportunities to conduct robust soil carbon estimates in-country and report and monitor ongoing changes. This added scientific capacity could help to ensure the long-term ability to monitor, report and verify changes to blue carbon ecosystems. While the constraints and issues of uncertainty for enabling payments for blue carbon in Madagascar remain significant, the research that is occurring is positioning the country and Blue Ventures to take advantage of emerging and growing opportunities for improved ecosystem conservation and management.

Mozambique

Site Description:

The Mozambique blue carbon project provides an example of various partner organizations working on discrete components of blue carbon research. Similar to the carbon stock research in Madagascar, in Mozambique, the blue carbon research is focused on mangrove ecosystems, specifically in the Zambezi Delta region. The World Wildlife Fund (WWF) is the overall managing organization for the blue carbon research project in Mozambique, although other groups, such as the U.S. Forest Service (USFS) have provided essential in-country research expertise. According to USFS scientists, the USFS has been working in Mozambique for a number of years related to terrestrial forests and partly as a result, WWF approached the USFS to help lead the carbon stock research in the Zambezi Delta for the blue carbon research program. Funding for the Zambezi carbon pool data studies came through the U.S. Agency for International Development (USAID) as part of the Sustainable Wetlands Adaptation and Mitigation Program (SWAMP). SWAMP is a "collaborative program between the Center for International Forestry Research (CIFOR), the US Forest Service (USFS) and Oregon State University with financial support from the US Agency for International Development (USAID)" ("About SWAMP", 2014).

In addition to staff at WWF, primary points of contact included USFS researchers who completed the in-country carbon pool research for the Zambezi Delta.

Figure 8: Map of Zambezi River Delta (NASA, 2013).

Site Characteristics:

Mozambique	
Ecosystem types included in research	Mangroves
Geographic scope	Zambezi Delta
Length of study	Carbon pool research components complete. Additional project components ongoing.
Project partners	WWF, USFS
Funding sources	USAID for carbon pool studies

Table 5: Overview of Mozambique blue carbon research site characteristics.

Opportunities for Blue Carbon Payments

According to USFS researchers, the objective of the research team was to provide an estimate of the carbon pools of the mangrove forests in the Zambezi delta. Achieving this objective is an important component in developing a more comprehensive understanding of soil carbon data and provides data necessary for any potential future carbon offset development.

USFS researchers described the first step in achieving the research objective was defining the Zambezi delta to get a representative sample of the total area. The geographic area of the Zambezi Delta can be described as “broad as north of the town of Chinde to the Marromeu Reserve south, or as small as the outer edge of the Marromeu reserve to Chinde. The latter was determined to be adequate for the purposes of the study (roughly 50 kilometers following the coastline)”.

The research began in 2011 with inventory data sharing similarities with other mangrove carbon studies: researchers worked to quantify soils, vegetation, and dead sediment pools. According to the lead scientists on the project, there were not any “. . . huge surprises from the data gathering process”. However, there were numerous logistical challenges that made the data gathering and research project difficult. One particular issue, for example, was the scale and remoteness of the Zambezi Delta which the team worked to overcome.

The most important objective of the carbon stock research in the Zambezi Delta was to obtain a representative sample which proved difficult given the sheer size of the delta. There was the necessity of finding adequate camp sites during the data gathering stages and having fuel delivered from over 60 km away. Moreover, there was a thorough process of identifying areas where researchers and support staff could camp overnight, mindful of transit areas, and significant tidal fluctuations. In 2013, researchers returned with the objective to sample an additional 40 plots across different canopy heights. The team of researchers experienced high tidal fluctuations but also high levels of interest from the local communities in the region. Despite these challenges, USFS was successful in obtaining an adequate sample.

Of particular significance, and for purposes of comparison, the depth of soil samples is one factor in understanding soil carbon supply. In the Madagascar carbon stock study, the soil samples were collected to 1.5 m (Jones et al., 2014). In Mozambique, the samples went to 2 meters. This helps provide a basis of distinction from some studies that went to 3 m or beyond (Donato, et. al., 2011) and the resulting carbon estimates. The issue of carbon supply uncertainty is critical, along with understanding how the quantity can change over time. The research in the Zambezi is helping overcome these issues, which is one step closer to the potential to develop blue carbon offset projects or participate in a program like REDD+.

As a neighbor to Madagascar, Mozambique also shares similar economic and development issues and as a result, the REDD+ program is an appropriate mechanism to possibly receive funding to help protect mangrove blue carbon ecosystems. Learning from the hurdles facing Madagascar could be helpful if Mozambique wishes to pursue REDD+ as a financial mechanism to protect its mangrove ecosystems.

Constraints and Issues of Uncertainty Related to Blue Carbon Payments

While the Mozambique research on blue carbon is addressing issues of uncertainty such as the supply and quantity of carbon in the Zambezi, others issues of uncertainty remain. Of particular relevance to possible payments for blue carbon offsets, is the issue of property rights of these ecosystem types which share commonality with Madagascar. The mangrove ecosystems are essentially government owned and controlled and thus, treated as public land. USFS researchers indicated that introductions of the research team through local chiefs were necessary to access the Zambezi delta area where research occurred. Essentially, the local communities have functioning jurisdiction over the land.

The region has very low population density due to its remoteness. Small fishing camps of a few families in the range of 100 people are scattered throughout different areas according to USFS researchers. For payments for blue carbon to become a reality, developing buy-in of the local communities and current ecosystem user groups will be necessary. The active engagement of the local community in the carbon pool research studies is an important first step in long-term sustainable ecosystem management.

Similar to Abu Dhabi and Madagascar, the Mozambique case faces numerous barriers to access existing carbon markets and general issues of uncertainty related to its supply of blue carbon. Furthermore, the in-country capacity is very limited and has relied on outside expertise. This will be an ongoing constraining element, particularly if blue carbon payments are pursued due to the necessity of ongoing monitoring, reporting and verification of ecosystem changes over time. The additional carbon offset specific terms and issues identified in Table 1 and 2 could also prove to be difficult given existing capacity (demonstrating additionality, permanence and overcoming issues of leakage as examples).

The component of the research study led by the USFS was discrete in its objectives of understanding the carbon pools in the Zambezi Delta. However, USFS scientists indicate that there remain numerous questions to be addressed. Some of these include: What are the annual rates of carbon accumulation in the Zambezi Delta? What are the deforestation rates and how much of the degradation is natural versus human caused? The answers to such questions and others will require additional study. They are also important issues of uncertainty and possible constraints disabling the potential for payments for blue carbon.

Lessons Learned and Application to Other Research Sites:

A take away for the USFS research team, which came out of participation at the Western Indian Ocean Marine Science Association Scientific Symposium (WIOMSA) in Fall of 2013, was that accommodating additional expertise on the research expedition could have provided more robust information on other issues in addition to carbon stocks. For example, it may have been possible, given the benefit of additional researchers, to gather information and provide perspectives on the marine life and animals. For a relatively minor cost increase, additional data and more robust information could have been gathered and possibly contributed to overcoming some of the constraints and issues of uncertainty discussed previously.

The results of the carbon pool data studies, when published, will be of benefit to future research sites. This is because it will contribute to improved refinements in mangrove soil carbon data, while also contributing to the growing international awareness of the importance of this blue carbon ecosystem type. The study removes one critical barrier (lack of data/knowledge of carbon supply) to access carbon offset markets which hopefully will enable payments or other arrangements to protect the resources to occur more quickly and effectively.

Conclusions

This paper identified opportunities, constraints, and issues of uncertainty for blue carbon payments through a review of the literature and an examination of three blue carbon research sites. Despite the numerous challenges facing payments for blue carbon, the three sites all demonstrate some net positive results from the research and growing opportunities to sustainably manage these ecosystems. Many of the case study sites are taking advantage of existing identified opportunities and overcoming many of the constraints and issues of uncertainty that remain.

Financing blue carbon protection through the sale of carbon offsets can become a reality as both regulated and voluntary carbon markets, along with international agreements and emerging standards and methodologies that support such markets, come together to strengthen the viability of payments for blue carbon offsets. The sale of blue carbon offsets however, is but one strategy to address the complex problem of degradation and destruction of coastal marine ecosystems. By itself, it is likely not to be a comprehensive and effective enough solution to reverse the current trends of degradation. The many constraints and issues of uncertainty yet to be addressed also indicate the need to pursue other strategies in the near-term. A robust and multi-faceted approach to conservation and management which encompasses the many co-benefits these ecosystems provide will likely be necessary.

Across the blue carbon research sites examined as part of this study, there exist many commonalities. These include significant or sole focus on mangrove ecosystems and broad interest in developing mechanisms to conserve and protect coastal marine ecosystems generally. Specifically:

- Each site had a focus on carbon pool data collection.
- All sites shared international and outside expertise in managing, conducting and analyzing research data.
- There was overlap in the opportunities, constraints and issues of uncertainty facing each of the three sites (overlaps could suggest broader applicability of some of these components to other blue carbon sites).

While sharing many similarities, the sites also differed in some significant areas, primarily in the area of political and economic governance structures and culture. All three of these components are important in influencing attitudes towards the concept of blue carbon ecosystem protection and carbon offsets. Furthermore, the interactions of the people living in and around these ecosystems can help to create values and also influence perceptions. This can occur, in part, through the ways in which people interact with the various ecosystems, for example, those reliant on mangroves to provide a livelihood, versus those enjoying their value for existence or recreation purposes. Strategies intended to protect these ecosystems must be aware of these cultural, political and economic structures and norms and the ways in which they can impede and advance conservation and management.

Additional differences across the three sites included:

- High variability in the amount of blue carbon ecosystems in-country.
- Although mangroves were studied in all three sites, differences in the mangrove species and others ecosystems studied in each country.
- The time scale and rate of intensity of degradation were also highly variable (between and within countries).
- Sources and threats to the ecosystems also varied across sites.
- The scope of studies varied greatly in terms of geographic scale, stated research objectives, and length of time spent in-country.

Taken as a whole, this research suggests that many hurdles and issues of uncertainty must be overcome before the sale of blue carbon offsets are able to play a role in protecting these ecosystems at the scale that is needed. The protection of these coastal marine ecosystems must also be balanced with the ability to provide resources and a means for the people living in these sensitive areas, especially the most poor and vulnerable populations. Future research examining other strategies and tactics to sustainably manage and conserve these resources will be necessary to establish long-term solutions.

Appendix 1:

Questions asked of in-country practitioners in Abu Dhabi, Madagascar and Mozambique:

1. What is your role in the intervention site?
2. How long has the project been in existence?
3. Are there other partners or organizations that are playing an important role?
4. What are the habitats at the specific intervention site?
5. Is it a representative area in the country? If so, in what way, if not, why not?
6. What is the current health of the ecosystem?
7. What are the threats and sources of degradation? (i.e. humans, on site/off site, or external factors such as pollution and climate change)
8. What is the time scale and intensity? Is the site unique in the area?
9. What are the interests and priorities in blue carbon? For example, receiving credit for emissions reductions? Getting paid for carbon credits? Are there other reasons? What are the short and long term interests? To what degree do factors in the country affect those choices?
10. Who owns/controls the property rights of the specific blue carbon ecosystem(s) in question?
11. Follow-up: What is the form of ownership (e.g. private property, public trust, common property, etc.) Are the beneficiaries different than the owners?
12. Are plans in place to protect existing habitat or restore/create new habitat?
13. Follow-up: What policies and actions have/can you put in place to ensure permanence of the habitat?

Specific carbon market related questions if relevant, based on earlier responses:

14. Can additionality be demonstrated? In what way would this be demonstrated? (use of baseline year, or "business-as-usual")
15. Do you plan to pursue validation and verification from outside entities? What kind?
16. Have you chosen a methodology to measure, report and account for the emissions reductions associated with protecting or restoring the BC resource?
17. Do you have the capacity "in-country" for ongoing measurement, monitoring, maintenance and reporting of carbon emissions and sequestration?
18. Do you know what other types of ecosystem service co-benefits are being generated through the intervention site? Do you have specific ideas or goals regarding these co-benefits?

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