MESCAL Carbon Assessment: Rewa Delta Mangrove Reference Levels & Emissions Due to Mangrove Conversion

November 2013

Prepared for:

Pacific Mangroves Initiative

IUCN Oceania Regional Office
5 Ma'afu St, Suva
Fiji Islands

Prepared by:

Chris Heider, Ecosystem Ecologist

Watershed Professionals Network LLC (WPN)
PO Box 1641, Philomath, Oregon 97370 USA
www.watershednet.com

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the Parliament of the Federal Republic of Germany

Acknowledgements

The following individuals contributed to this project. Contributions were made both in the field and in the project design and implementation. Their contributions are greatly appreciated.

Forestry Department Management Team

Samuela Lagataki, Conservator of Forests, Headquarters
Eliki Senivasa, Deputy Conservator of Forests (Services), Headquarters
Akosita Lewai, GIS Officer
Paula Kamikamica, Forest Officer
Viliame Tupua, Forester

Forestry Research Team & Nasinu Utilisation Division

Rafaele Raboiliku, Acting Principal, Siliviculture
Iowane Koroitamana, Forest Guard
Senitiki Navuso, Charge Hand
Sikeli Wainiqolo, Forester
Sainiana Naura, Forest Guard
Suchitra Dayal, Lab Technician

Forestry Field Monitoring Team (Permanent Sample Plots)

Ilimo Tulevu, Project Officer
Sukulu Cavu, Project Officer
Josefa Duikoro, Project Officer
Josaia Qaltaki, Cleaner
Joeli Ledua, Driver
Romuluse Rajale, Forester
Iliseniyasi Koroi, Forest Guard
Anare Nayacakalou, Temp. Forest Guard
Ilaisa Senikuraciri
Simeli Naulumatua

University of South Pacific - Institute of Applied Sciences (USP-IAS) Team

Marika Tuiwawa, USP Herbarium Curator
Hans Wendt, USP-IAS GIS Officer

IUCN Oceania Regional Office - Project Management Unit (PMU)

Milika Sobey, MESCAL Project Manager
Viliame Waqalevu, MESCAL Technical Officer
Neema Nand, MESCAL Fiji Country Coordinator
Epeli Nakautoga, MESCAL Support Officer

About MESCAL

Given the importance of mangrove ecosystems for local livelihoods and as natural insurance against climate change, IUCN has developed under its Pacific Center for Environmental Governance (PCEG), a Pacific Mangrove Initiative (PMI). The primary goal of the PMI is to increase resilience to climate change by assisting Pacific Island countries and territories (PICTs) implement sound evidence based policies, plans and practices and targeted capacity development in mangrove management. Under this initiative, IUCN has developed the Mangrove EcoSystems for Climate Change and Livelihood (MESCAL) project. MESCAL is a country-specific, country-driven, multi-dimesional partnership project set in Fiji, Samoa, Solomon Islands, Tonga and Vanuatu.

MECSAL is funded by the German government under the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The Ministry, which under a resolution of the German Bundestag has its principal office in Bonn.

Contents

List of Tables

List of Figures

Executive Summary

In 2013, the Pacific Mangrove Initiative launched a study as part of the Mangrove Ecosystems for Climate Change Adaptation & Livelihoods (MESCAL) project to assess the carbon stocks of primary mangrove forests, and to assess the emissions factors associated with converting mangroves from standing forests to agriculture or hard infrastructure (buildings, roads, etc.).

This report outlines the technical findings associated with this assessment and places mangroves in context with national greenhouse gas (GHG) inventories associated with fossil fuels emissions, and provides several recommendations to assign cost-benefit associated with mangrove conservation or avoided conversion.

The following highlights are presented in this report:

- Approximately 25% of the Rewa Delta is currently in mangrove forests (~8,600 ha)
- Mangroves contain approximately 1,700 tonnes of carbon dioxide equivalents per hectare (tCO_2e/ha), expressed in the units that are used for GHG reporting
- Converting a standing mangrove to be ready for agriculture or infrastructure will emit approximately 1,500 tonnes of carbon dioxide (tCO_2e) per hectare
- Only 500 ha of mangroves store as much carbon dioxide as Fiji emitted from burning fossil fuels in 2009
- Using conservative values for verified carbon credits, mangroves are valued between FJD $8,500 and $25,000 per hectare if conversion can be avoided
- To offset emissions from mangrove conversion, between 2 and 3 hectares of additional mangrove would need to be created, enhanced or *permanently* conserved to ensure that Fiji's national GHG inventory would continue to improve
- These strategies are in line with ongoing country-level strategies involving reducing emissions through avoiding deforestation and degradation (REDD+).

Purpose & Scope

This report serves as a section to the Mangrove Ecosystems for Climate Change Adaptation & Livelihoods (MESCAL) project led by IUCN-Oceania under the Pacific Mangrove Initiative. As part of the MESCAL project, there is a need to assess the importance of mangroves as carbon stocks, and to evaluate the potential impacts associated with mangrove conversion on greenhouse gas emissions. This report focuses efforts on a carbon assessment for the MESCAL-Fiji demonstration area, within the Rewa River Delta of Viti Levu, Fiji Islands.

Watershed Professionals Network (WPN) was contracted by IUCN to conduct a brief training with the Fiji Forestry Department in methodologies to sample mangrove environments for ecosystem carbon, and to develop Reference Levels (RL) of current ecosystem carbon stocks. The overarching goals included conducting in-field trainings to measure mangrove ecosystems, and to conduct inventories of mangroves that are in stages of early land cover conversion to determine (1) baseline total ecosystem carbon pools for intact mangroves, and (2) quantify emissions (reported as carbon dioxide equivalents, CO_2e) associated with land conversion from mangroves to pre-construction activities. Ultimately these factors will begin to form a baseline for national-level emissions and assist in quantifying the roles that mangroves play in a REDD+ strategy[1].

Objectives

Two major objectives were identified for this project. The first involves a baseline carbon assessment for the mangroves in the Rewa Delta Demonstration Area, which corresponds with other activities conducted as part of the MESCAL project. The second objective is to evaluate the relative *emissions* associated with mangrove conversion from standing forest to land suitable for agriculture or infrastructure development. These objectives are separate in that the first quantifies the *current condition* at a large landscape scale, while the second quantifies the *change* associated with active conversion. The perspective of this study is strictly focused on carbon stocks and emissions and does not quantify other ecosystem services associated with mangroves, such as fisheries nursery stock, water quality, sediment capture, coastal protection, biodiversity, and a host of other factors.

Objective #1: Baseline Carbon Assessment

The Rewa River Delta in Fiji's Central Division contains the largest mangrove ecosystem complex in the country. The Rewa Delta is proximal to the Capital of Suva, and the mangrove complex is experiencing very high pressures of land use and land conversion. Conversion from mangroves typically involves clearing the forest, importing topsoil to fill in and raise the surface elevation, and ultimate conversion to either agriculture or built infrastructure. Current rates of conversion in the Rewa Delta are not specifically known at the time of this report, though there are current efforts underway at University of South Pacific (Tuiwawa pers. comm.) to capture land use change with fine-scale mapping in the region.

[1] Reducing emissions through avoiding deforestation and degradation (REDD+)

Currently, there are many locations that are undergoing full conversion within and near the city limits, as well as areas experiencing some level of degradation via firewood harvesting in the surrounding village areas.

As part of the larger MESCAL project, a land cover map was developed that described the distribution of major vegetation types in the ~35,400 ha demonstration area (Figure 1). Approximately 8,886 ha were classified as mangrove types, representing approximately 25% of the demonstration area in the *current condition* (Table 1). It is not known if an historic analysis has been conducted regarding land cover *change* in these areas, and how much of that change occurred in mangrove types.

Table 1. Distribution of major vegetation types in the Rewa Delta Demonstration Area. Source: M. Tuiwawa.

Major Vegetation Type	Total Area (ha)	% of Total
Coastal strand vegetation	164	<1%
Freshwater wetland vegetation	278	1%
Lowland rain forest	2,779	8%
Mangrove forest and shrub	8,886	25%
Non Forest	8,841	25%
Water body	14,445	41%
Total Area	**35,393**	

Within the focus of mangrove forests, and in particular intact (undisturbed) forests, the IUCN-Fiji Forestry team discussed options to conduct field sampling to assess standing carbon stocks, given the overall goals of the project and available resources to conduct the assessment. Three major mangrove types were identified that best represented a "baseline" condition for intact mangroves in the Rewa Delta area--these included stands dominated by *Bruguiera gymnorrhiza*, *Rhizophora* spp., and a mix of the two major genera. Many additional species were found in these habitat types, though the dominance of the major species to affect the structure was the priority for determining broad carbon stocks and potential emissions from mangrove conversion[2]. Overall these three types represented a total of 18% of the demonstration area (6,453 ha) and represented 72% the mangrove types in the area (Table 2).

[2] For additional information about the region and species diversity, see Tuiwawa and Tuiwawa 2012.

Table 2. Distribution of mangrove types identified in the Demonstration Area. Area is expressed as percentage of the entire demonstration area (Table 1) and those of just mangrove types. Sampled types are indicated. Source: M. Tuiwawa.

Mangrove Type	Area (ha)	% of Total Area	% of Mangrove Types	Sampled?
***Bruguiera* forest**	1,978	6%	22%	**Yes**
***Rhizophora* forest**	968	3%	11%	**Yes**
Mixed mangrove forest	3,507	10%	39%	**Yes**
Back of mangrove	2,183	6%	25%	**No, use composite average**
***Acrostichum* swamp**	203	1%	2%	**No**
Salt marsh	41	<1%	<1%	**No**
Human habitation	5	<1%	<1%	**No**
Total Area	**8,886**			

Mangrove sites were selected on the basis of major type and replicated in different locations in the Rewa Delta to represent different geomorphic areas in the area (northern, central, lower delta areas).

Objective #2: Carbon Dioxide Emissions from Mangrove Conversion

Though the Rewa Delta is a large land area clearly undergoing some conversion to agriculture as well as degradation via firewood harvest, there is not a clear or completed historic analysis in identifying land cover change at specific locations in the mangrove ecosystems. Without this historic analysis and site specific activities, it was difficult to accurately quantify potential carbon dioxide equivalent (CO_2e) emissions associated with land cover change within the scope of this study. However, in areas near Suva, and just to the west of the Demonstration Area, several ongoing mangrove conversion projects have been initiated over the last several years that are readily accessed. In these areas, there is a unique opportunity to quantify these changes as the conversion process occurs.

The second objective of this study focused on three sites currently under conversion from mangroves to topsoil fill (and eventual building of infrastructure or potential agriculture lands). In these sites, there existed a combination of intact mangrove forest fragments, recently cut areas, and fully-converted land with topsoil fill. Sites were selected on the basis of opportunity to capture ongoing conversion of mangroves in a "rapid assessment" process. Objectives included comparing the intact fragments to the Rewa Delta baseline measures, and to obtain CO_2e emissions estimates for recently cut and fully-converted lands to better inform land managers as to the potential greenhouse gas outputs (and their potential value) associated with conversion.

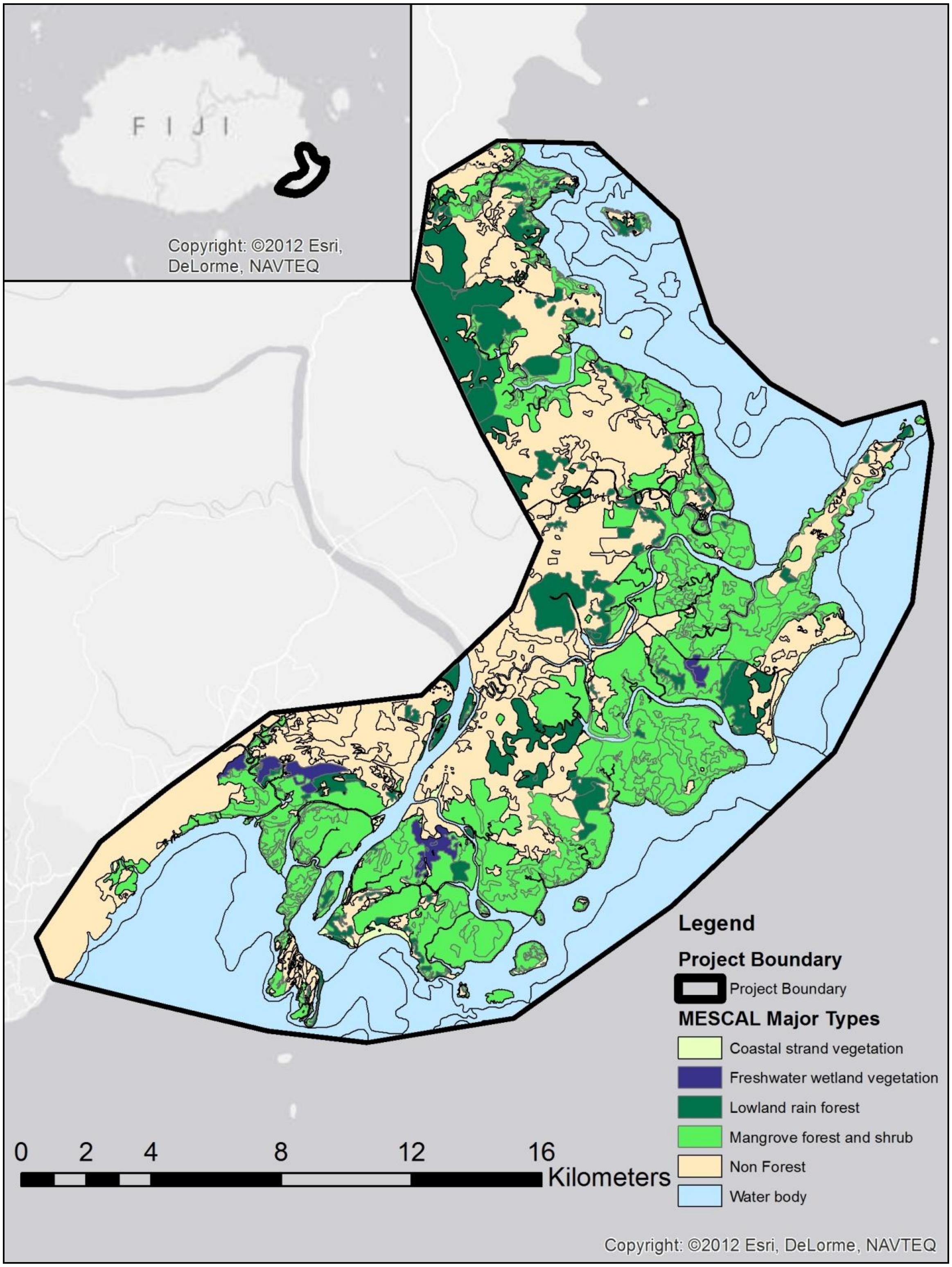

Figure 1. Map of the Rewa Delta Demonstration area in SE Viti Levu, Fiji. Major vegetation types have been mapped, indicating the locations of current mangroves in the region (Source: M. Tuiwawa).

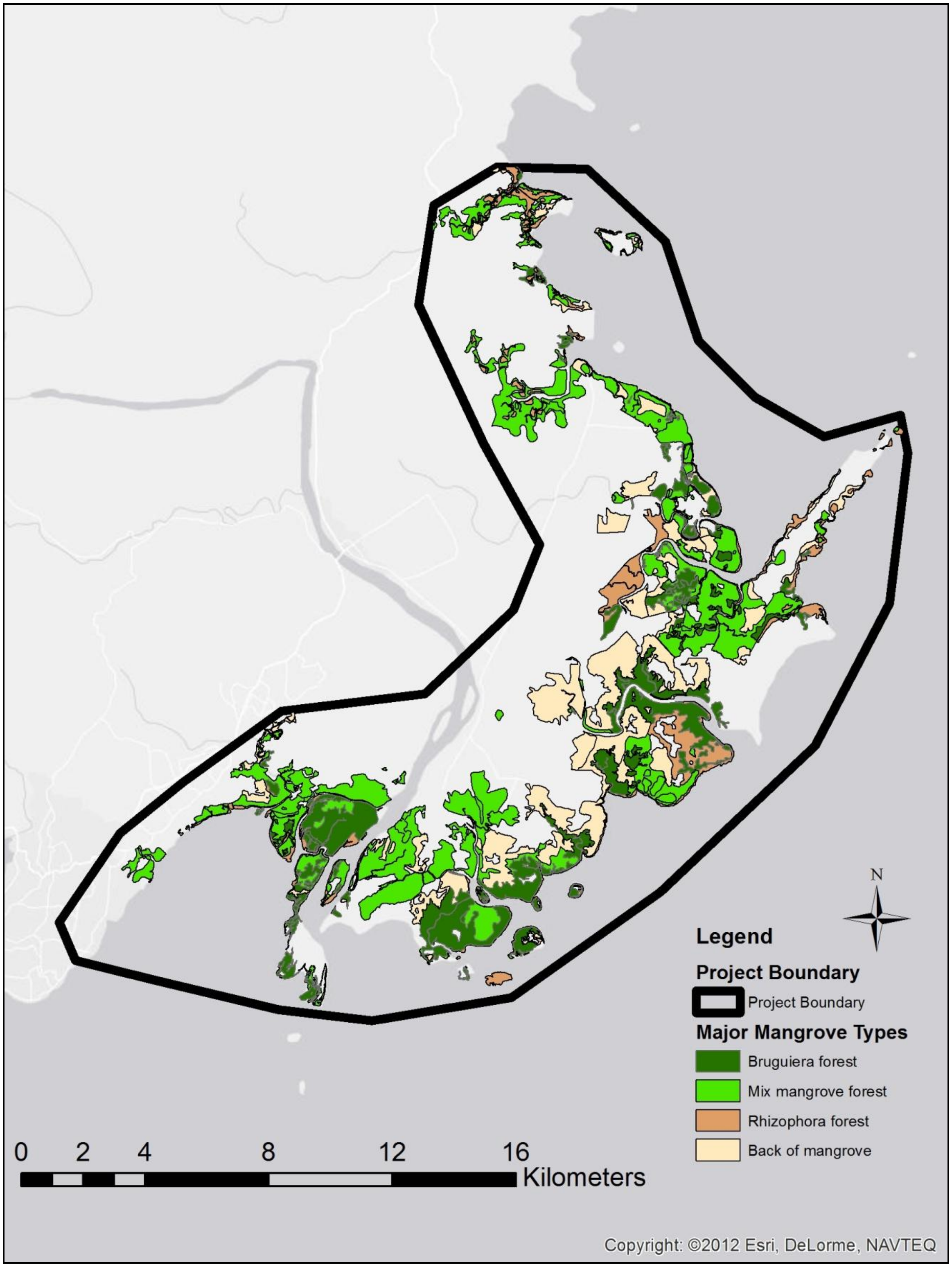

Figure 2. Detail of the four major mangrove types identified in the Rewa Delta. *Bruguiera*, *Rhizophora* and Mixed mangrove types were sampled as part of this study; Back of Mangrove areas were not sampled for carbon pools.

Methods

Total Ecosystem Pools

Total ecosystem pools include all elements of an ecosystem that store and sequester carbon from the atmosphere in the form of carbon dioxide. These pools include aboveground components (trees, shrubs, vines, ground cover vegetation, standing- and downed- dead wood), belowground roots, and carbon found in the soil organic matter horizon. To capture all of these pools, it is necessary to utilize methodologies that capture a statistically robust accounting for a particular site, and to stratify sites on the landscape to accurately sample the different vegetation types that are present in the study area.

For the purposes of this assessment, total ecosystem pools are consolidated and reported as total carbon pools, measured in metric tonnes per hectare (Mg/ha). Emissions levels are likewise reported in the standard of metric tonnes of carbon dioxide equivalents (tCO_2e), which is a conservative conversion from total ecosystem carbon as carbon dioxide and does not account for emissions generating from methane and other greenhouse gasses that have much higher global warming potentials (e.g. one molecule of methane is equivalent to 50 carbon dioxide molecules). As such, the estimates for emissions are conservative as they only apply to carbon dioxide sourced from carbon and not other gas species.

Field Sampling

The composition, structure and ecosystem carbon stocks were determined for 11 intact mangrove forests, of which two were fragments that were associated with ongoing conversion. Mangrove sites were situated throughout the demonstration area with emphasis to capture the three major mangrove types across a wide geographic and geomorphic gradient (see Table 2 on page 4). The objective was to conduct a baseline to determine the variability among types for future monitoring needs.

A total of 17 mangrove sites were measured as part of this assessment (Figure 3). Eleven mangroves were selected as part of determining the baseline condition (Reference Level, RL) of the current stocks within 3 *Rhizophora*, 4 *Mixed*, and 4 *Bruguiera* mangrove sites. Adjacent to two of these sites were differing degrees of land conversion, from recently cut to completely converted using land fill soil materials. A total of 6 additional sites were measured for belowground carbon only, as all of the vegetation was removed through the conversion process. In these sites, half of the number of sample plots (3) was used due to the size and consistency of the conversion sites.

Within each site, ecosystem C stocks (above and belowground) were measured following methodologies outlined by Kauffman and Donato (2012). For mangroves with trees ≥5 cm dbh[3], six 7 m radius plots were established 25 m apart along a 125 m transect established in a perpendicular direction from the marine ecotone. In the smaller statured (<5 cm dbh) mangroves characteristic of dwarf *Rhizophora* stands, 2 m radius plots were established in a similar manner every 10 m. At each plot, we collected the

[3] diameter at breast height, 1.3 m

data necessary to calculate total C stocks derived from standing tree biomass (live and dead), downed wood (dead wood on the forest floor), and soils at five depth profiles to the depths of the marine sands.

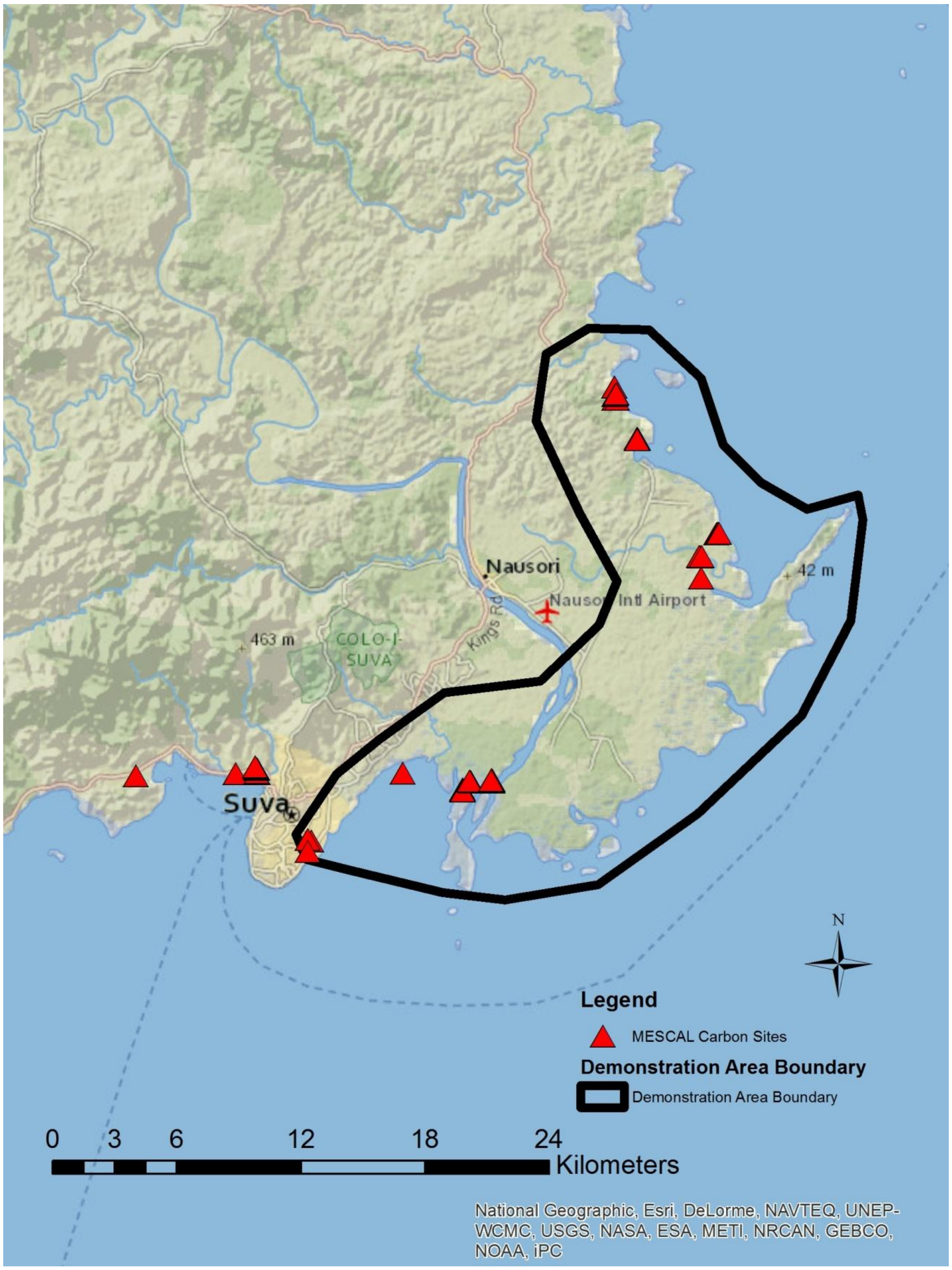

Figure 3. Site locations for the 17 sampled sites within the Rewa Delta Demonstration Area, as well as conversion sites just west of Suva.

Sampling & Calculations of Biomass & Carbon

Species-specific allometric equations were used to calculate tree biomass for each site, with preference for models developed in Micronesia (Kauffman and Donato 2012). Genus-level models were used following major growth form where species models were not available. Belowground root biomass for mangrove trees was calculated using the formula presented by Komiyama et al (2005). Tree carbon was calculated by multiplying by a factor of 0.48 for aboveground and 0.39 for belowground biomass (Kauffman and Donato 2012). Standing dead trees were likewise measured for biomass and carbon, assigned by decay class; dead trees were present but a rare fraction of the total ecosystem pool.

Downed wood was sampled using the planar intercept technique adapted for mangroves, and further adapted for capturing only larger pieces (≥7.5 cm diameter); this is a conservative technique as it does not account for small pieces, which contribute only a minor amount of biomass to the total ecosystem pool. Each downed wood transect involved four 12 m transects in each of the six plots. Methods for calculating biomass and carbon followed those outlined in Kauffman and Donato (2012).

In each plot, soil samples were collected using a specialized, 1 m peat auger with known volume. Samples were extracted from the core to represent 0-15, 15-30, 30-50, 50-100 and >100 cm depths (where available). A soil depth probe was inserted into the soil to measure the depth to the marine sands to identify the organic horizon of the mangrove system. Core samples of each depth were dried and weighed to calculate bulk density, and shipped to the Oregon State University Central Analytical Laboratory (Corvallis, Oregon, USA) for analysis. Carbon concentrations were determined using the dry combustion method (induction furnace) with a Leco CNS-2000 Macro Analyzer. Bulk density and carbon concentrations were combined with plot-specific soil depths to determine the total C stocks.

Total ecosystem pools for each plot were summarized and averaged for each site. Sites were likewise averaged according to major vegetation type. Results were reported in total ecosystem C (Mg/ha) and as tonnes carbon dioxide equivalents (tCO_2e).

Results

Reference Level Conditions: Rewa Delta

The reference level conditions (RL) that were established for the Rewa Delta Demonstration Area ranged from 368 to 513 Mg/ha C (1,351 to 1,884 tCO_2e per ha), with a composite average of 464 ± 38.1 Mg/ha (1,703 ± 139.8 tCO_2e per ha) (Table 3). Given the small number of sample sites and the general good agreement among all mangrove types sampled, a conservative estimate for the Rewa Delta reference level conditions would use the Composite Average (n=11) values (Table 3 and Figure 4). This captured the broadest range in geomorphic conditions as well as species assemblages found in the Rewa Delta Demonstration Area.

Table 3. The reference level for ecosystem carbon measured for the major mangrove types sampled, and a composite average of all sampled types.

Mangrove Type	Number of Stands	Total C + SE (Mg/ha)		Total CO_2e ± SE (Mg/ha)	
Bruguiera	4	486.9	70.5	1,787.0	258.6
Mixed	4	513.3	47.1	1,883.8	172.9
Rhizophora	3	368.1	75.2	1,351.1	276.1
Composite Average	**11**	**464.1**	**38.1**	**1,703.3**	**139.8**

At the landscape scale, assuming the map described in Figure 2 accurately represents the land area for major mangrove types, and that the "Back of Mangrove" classification is considered to be equivalent in carbon stocks as the composite average of the other three measured systems, then the total ecosystem carbon pools for the mangrove types on the Rewa Delta are approximately 15 million tCO_2e (range: 13.5 - 16.8 million tCO_2e) as standing stocks (Table 4).

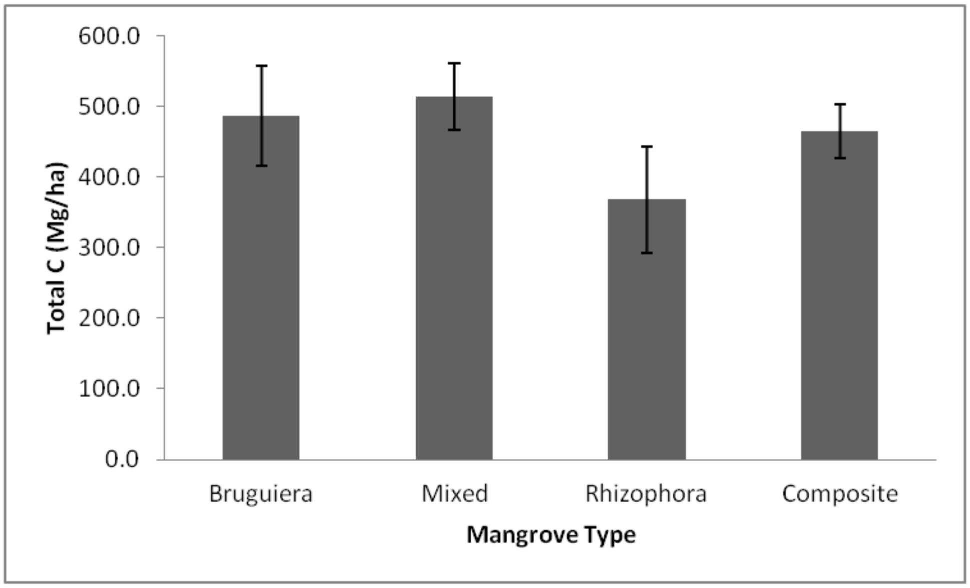

Figure 4. The total ecosystem C pools for the major mangrove types, and a composite average. Data illustrate those presented in Table 3.

Table 4. Total ecosystem stocks for the three measured mangrove types and an assumed composite value for the unmeasured back of mangrove system. Values are in Mg/ha (t) of CO_2e, with standard errors expressed as the low and high estimated ranges.

Mangrove Type	Area (ha)	Avg. Pools (tCO2e/ ha)	Total (tCO_2e)	Low Estimate (tCO_2e)	High Estimate (tCO_2e)
Bruguiera	1,978	1,787	3,534,712	3,023,153	4,046,271
Mixed	3,507	1,884	6,607,040	6,000,460	7,213,620
Rhizophora	968	1,351	1,308,434	1,041,041	1,575,826
Back of mangrove	2,183	1,703	3,717,635	3,412,541	4,022,728
Total Area	**8,636**		**15,167,821**	**13,477,196**	**16,858,446**

The carbon stocks presented here are similar to the mangrove stocks reported elsewhere in the Pacific and S. Asia, though slightly lower in socks due to generally shallower soils. Coastal fringe mangroves in Yap, Micronesia reported total ecosystem carbon to be 1,066 MgC/ha (3,912 tCO_2e/ha); *Rhizophora*-dominated stands in Palau reported 723 MgC/ha (2,653 tCO_2e/ha). Mangroves in the Ganges River delta of Bangladesh reported similar values to the Rewa Delta, with 566 MgC/ha (2,074 tCO_2e/ha) (Kauffman and Donato 2012) (Figure 5).

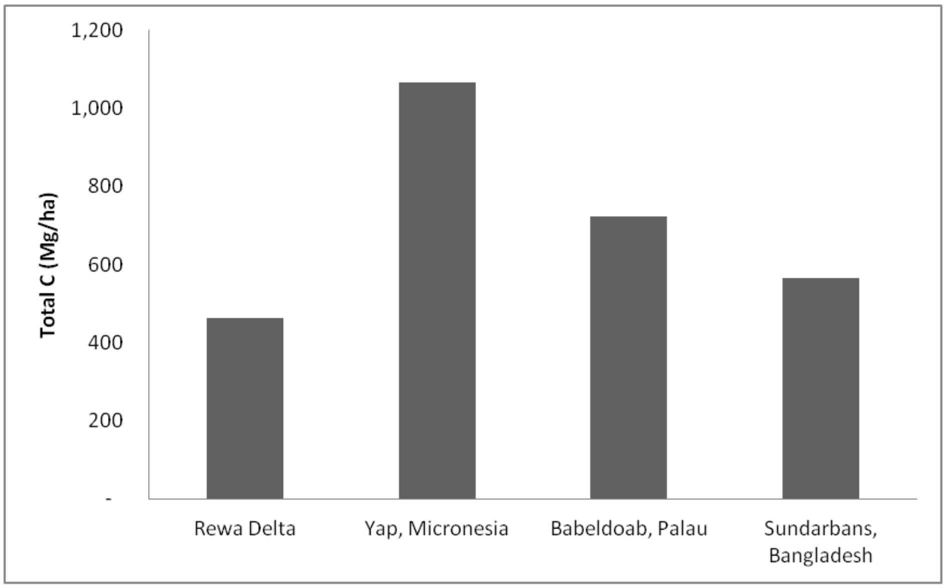

Figure 5. Comparative carbon stocks for other mangroves in the Pacific and S. Asia. Source: Kauffman and Donato (2012).

Emissions from Mangrove Conversion

Using the baseline (reference) conditions described above on a per hectare basis, emissions from mangrove conversion was estimated as the difference between intact forest stands and converted stands, where the mangrove trees were cut and cleared, and the soils were fallow for a variable period of time (days to years), and then covered with imported fill dirt. It is assumed that the soil profile below contains carbon for a period of time, with a constant level of degradation of the soil carbon pools over a period of time that would minimize the soil stocks. Only the soils in the top profiles would be the "interactive" soils with any vegetation from agriculture, and should full conversion occur to replace with hard-surface infrastructure, then complete degradation would be assumed. As such, these estimates assume full conversion has taken place *without* the addition of agricultural plants or hard infrastructure in place--only "fully prepared" land.

Given these assumptions, there is significant change in standing stocks between the baseline and fully converted areas, ranging from 1,703 ± 139.8 tCO_2e for the baseline stocks (range 1,564 to 1,843) to 185 ± 46.4 tCO_2e in the fully converted areas (range 139-232) (Table 5 and Figure 6). The relatively high standard error of the fully converted areas (SE of 25%) suggests high degrees of variability in the remainder carbon pools, although the only represent ~10% of the baseline stocks. Cut areas generally had virtually no aboveground biomass, yet contained soil carbon with only some minor "collapse" since removal of the vegetation. These cut areas were likely not older than a year old, with some mangroves undergoing active cutting while sampling occurred.

Table 5. Standing stocks at different stages of conversion. The baseline numbers refer to the composite average/ reference levels for all mangroves sampled in the Rewa Delta area.

Stage of Conversion	Number of Sites	Standing Stock ± SE (tCO_2e)		Low Estimate	High Estimate
Baseline	11	1,703	139.8	1,564	1,843
Cut	3	1,369	32.9	1,336	1,402
Converted	3	185	46.4	139	232

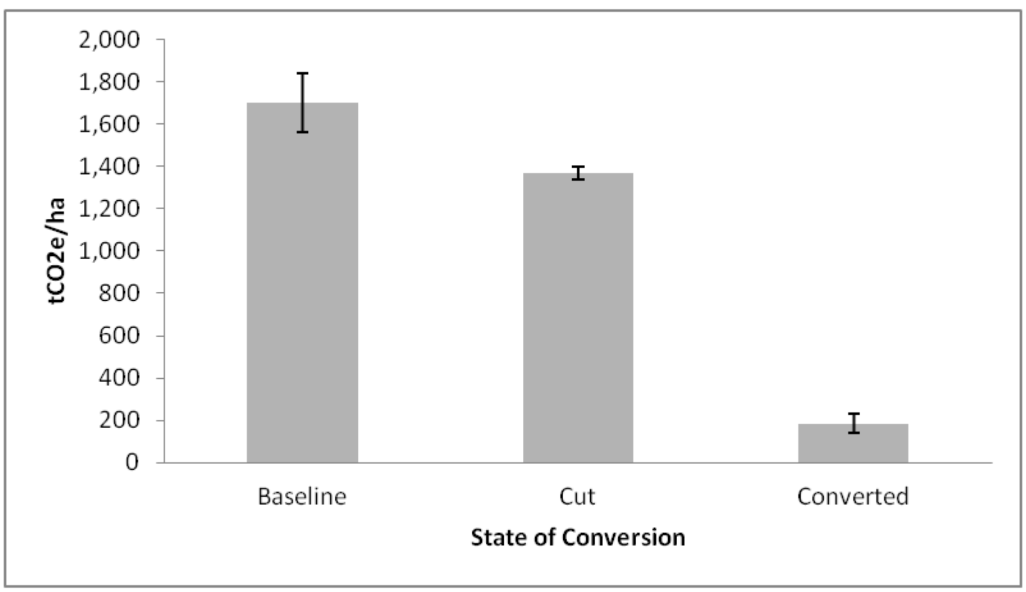

Figure 6. Graphic representation of the total standing stocks reported in Table 5, expressed as Mg/ha (t) of CO_2e per hectare in the three converted sites. Baseline data from these sites was also incorporated with the Reference Levels from the other mangrove sites in the Rewa Delta to give broad comparisons.

Emissions were calculated as the difference in carbon stocks from the baseline/ reference condition. It is assumed through this calculation that the difference in carbon equates directly to carbon dioxide emissions, and not other greenhouse gas species (such as methane), which have higher global warming potentials and hence would increase the estimates of CO_2e. As such, this is a conservative approach to estimating emissions.

Average emissions values averaged 334 (range 227 - 441) tCO_2e following mangrove deforestation, and 1,518 (range 1,425 - 1,611) tCO_2e in the fully converted sites (Table 6 and Figure 7).

Table 6. The emissions estimates and ranges associated with intact mangroves (high and low ranges presented here), following cutting, and after full conversion to filled lands. Emissions are calculated as the difference in standing stocks before and after a given event.

State of Conversion	Average Emissions Estimate (tCo2e/ ha)	Low Estimate (tCo2e/ ha)	High Estimate (tCo2e/ ha)
Baseline	0	-140	140
Cut	334	227	441
Converted	1,518	1,425	1,611

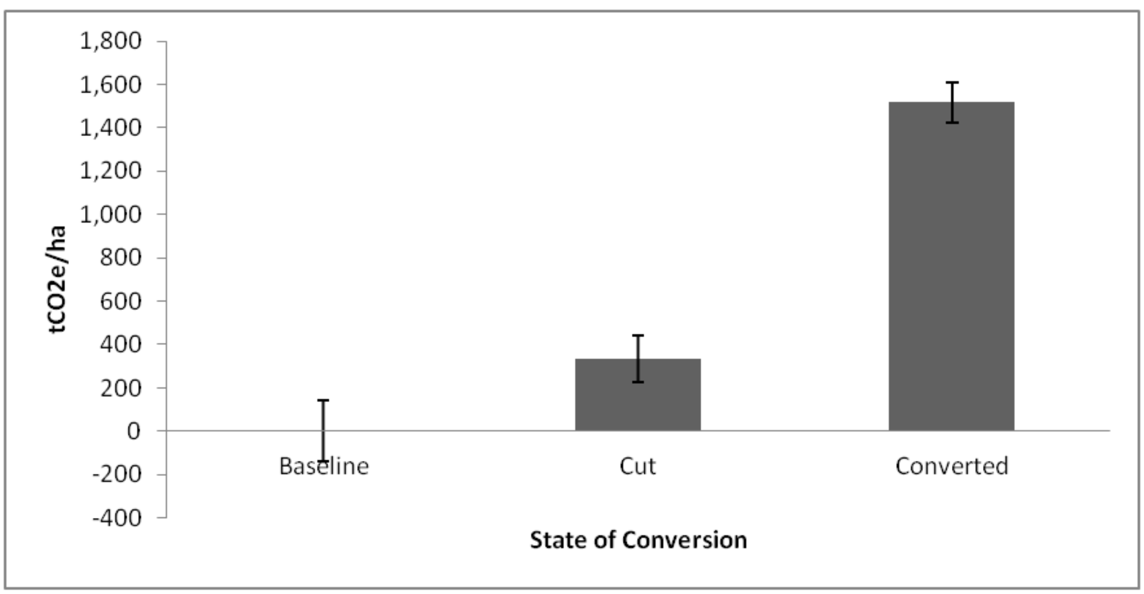

Figure 7. The average, low and high estimates for emissions in tCO_2e per hectare for the baseline condition (with high-low estimates), recently cut, and fully converted lands. Graphically represented from Table 5.

Management Implications

Mangroves in Context of Country-Level GHG Emissions

For 2009, the World Bank[4] recorded the CO_2e emissions reported by the Country of Fiji to be 846 ktCO_2e for the country level emissions attributed to the burning of fossil fuels and the manufacture of cement. These emissions represent a 3-year steady decline averaging ~170 kt per year since reporting a highs of 1,371 and 1,364 ktCO_2e in 2005 and 2006. Although these emissions are only attributed to fossil fuels and not to forest conversion, there is an opportunity to consider mangrove conservation in context of offsetting country-level emissions due to fossil fuels. Given the rate of decline over recent years in fossil fuels emissions, the conversion and loss of approximately 113 ha of mangroves would effectively negate all efforts in reducing fossil fuel emissions for the country[5]. Conversely, avoiding the conversion of 113 ha of mangroves would *double* the current rate of decline in fossil fuel emissions. Further, the entire fossil fuel emissions for 2009 would be offset with conservation and enhancement of only 500 ha of intact mangroves[6].

Data provided by the Department of Forestry indicated that permits issued between 2008 and 2012 yielded a harvest of 705.6 m^3 of mangrove fuel wood in the Suva-Nausori corridor in the Rewa Delta area. While the exact land area of harvest is not known, using a conservative wood density average for the dominant species of 0.87 g/cm^3 (Kauffman and Donato 2012), the wood harvest would equate to approximately 1,154 tCO_2e in wood mass alone (approximately 0.68 ha equivalents). This value does not account for losses in mangrove productivity or potential emissions from soil losses. Wood harvest strategies that selectively harvest (i.e. not patch cuts) and that are monitored to ensure a 1-to-1 relationship in permitting and wood yield may prove to be a sustainable solution to maintain a viable conservation strategy (i.e. manage both harvest and no-harvest areas) under REDD+ where both conversion and degradation are avoided while providing net benefits to a community.

Clearly more specific information regarding the national forest inventory database that is tracking land use/land cover change will need to be obtained to better understand the context of the mangrove estimates reported in this report. However, there is considerable concern with conversion of mangroves--if only on an *emissions level* and not considering other ecosystem service factors that mangroves provide (food, biodiversity, coastal protection, etc).

---

[4] http://www.quandl.com/WORLDBANK-World-Bank/FJI_EN_ATM_CO2E_KT-Fiji-CO2-emissions-kt

[5] Assumes the emissions from conversion at 1,518 tCO_2e per ha, Table 6

[6] Assumes reference level of 1,703 tCO_2e per ha, Table 3

Potential Value of Emissions Associated with Avoiding Mangrove Conversion

Estimates for applying lower tier IPCC emissions factors can range from 50-80% of the total emissions reported. This allows countries (or participants) to provide a conservative estimate in the crediting process, and to allow for sample error and unexpected losses of ecosystem carbon as the result of non-sanctioned or force majeure activities. Assuming these ranges (as well as 100% of the credit for reference), we may also assume a range of potential values for verified carbon units (VCU) credited under the Verified Carbon Standard (VCS) assuming an "avoided conversion" scenario. Under these VCU's, a range of low (USD$3, FJD$5.55[7]), medium (USD$6, FJD11.11), and high (USD$9, FJD$16.65) value scenarios are considered here as conservative values to be applied to better inform management of the potential "value" of conversion activities to primary mangrove forests. Table 7 displays a range of assumptions under the two major conversion scenarios measured in this document.

Table 7. Value scenarios, expressed in FJD on a per hectare basis for potential values of verified carbon credits associated with mangrove conversion.

			VCU Value per ha (in Fiji Dollars)		
			Low Estimate	Med Estimate	High Estimate
Activity	% Claimed as Credit	Adjusted Emissions (tCO_2e/ ha)	$5.55	$11.11	$16.65
Cutting/ Extensive Firewood Harvest	100%	334	$1,855	$3,711	$5,566
	80%	267	$1,484	$2,969	$4,453
	50%	167	$928	$1,855	$2,783
Full Conversion to Agriculture or Infrastructure	100%	1,518	$8,425	$16,849	$25,274
	80%	1,214	$6,740	$13,479	$20,219
	50%	759	$4,212	$8,425	$12,637

Conservative estimates for assigning value for a "cost-benefit" analyis would range between $4,212 and $6,740 per ha to be converted, though this assumes only 50% - 80% of the potential carbon as a verified credit, and does not fully account for the loss in greenhouse gasses. Full accountability for emissions should consider the 100% claimed as credit under the low, medium, or high value scenarios (e.g. $8,425 - 25,274 per ha).

[7] Assuming current market value of FJD$1.85 for USD$1.

Using "Multipliers" as Potential Mitigation Mechanisms

Coupled with the potential value of avoiding emissions, and the potentially very high emissions factors associated with conversion of mangroves to other uses, there is opportunity to consider mitigation practices that will offset both greenhouse gas emissions and the losses of mangrove habitats due to conversion, while achieving an overall balance in maintaining functioning mangrove ecosystems within the Rewa Delta and surrounding areas.

For example, values obtained from land use permits could be applied to a trust to conserve, enhance and restore mangroves in a site nearby but not within the area currently being converted. Given the emissions factors of 334 and 1,518 tCO_2e per ha associated with cutting and conversion (see Table 6), there may be opportunity to offset the degraded land and also offset the CO_2e lost to the conversion. Depending on the conservation or offset objective, it is possible to set targets for protecting or increasing mangrove habitat and monitoring the success based on CO_2e stocks.

The concept of "multipliers" is a simplified way to view these emissions on a per hectare basis and provide guidance for potential offset mechanisms to conserve, improve, enhance or restore the mangrove systems in Fiji. In general, multipliers allow for land management to dictate how future objectives can be met through mandatory activities associated with land use. For purposes of consideration, the following scenarios are considered:

- **Low Multiplier.** This requires that the same amount of emissions due to an activity are offset elsewhere. This is equal to the emission factor for the activity and can be done via conservation, restoration, or other enhancement activity. For pure conservation, the equivalent land area would be 0.2 and 0.9 ha for cutting and conversion, respectively (i.e. replace the 334 or 1,518 tCO_2e).

- **Medium Multiplier.** Similar to the low multiplier, this requires not only offset of the damage done, but also requires the establishment of a carbon reserve equal to the full hectare under conversion. The concept behind this strategy is to ensure that fragment size is maintained nearby and that there is a net positive to the mangrove size as well replacement of carbon reserves.

- **High Multiplier.** This strategy involves restoring or offsetting double the emissions values from damage done, as well as establish a reserve equal to each full hectare under conversion. This concept enforces the fact that as low as 50% of a carbon credit can be accounted for under lower tier IPCC emissions factors, *and* further increases mangrove fragment size to ensure higher benefit. This strategy would be most in line with REDD+ and objectives to reduce deforestation and degradation.

A matrix for each of these multiplier strategies is presented in Table 8. Values presented in tCO_2e are targets for offset via direct conservation, or dispersed across lands via enhancement or restoration through time. Values are also presented on a per hectare equivalence.

Table 8. Offset multiplier scenarios, presented on a per hectare basis, where the two major land activities are considered for offsetting emissions by increasing standing stock via conservation or enhancement. Low, medium and high estimates are considered. Values represent the target tCO_2e and per hectare equivalents required for the offset.

			Offset Multiplier Strategies (on a per hectare basis)					
Activity	Baseline	Emissions	Low Multiplier: Offset Damage Only		Med Multiplier: Offset Damage + Original		High Multiplier: Double Offset Damage + Original	
	tCO2e	tCO2e	tCO2e	ha	tCO2e	ha	tCO2e	ha
Cutting/ Extensive Firewood Harvest	1,703	334	334	0.2	2,037	1.2	2,371	1.4
Full Conversion to Agriculture or Infrastructure	1,703	1,518	1,518	0.9	3,221	1.9	4,739	2.8

Summary & Recommendations

The mangroves of the Rewa Delta represent significant carbon storage for Fiji. Given the high threats to infrastructural development and conversion to agriculture, the following summarize the important highlights and recommendations:

- **Mangroves currently cover approximately 25% of the Rewa Delta.** It is not known what the current deforestation or scale of degradation (firewood harvest) is occurring within the region. An historical analysis and current evaluation of threat is recommended to better ascertain the use and conversion of mangroves, with respect to maintaining habitat and carbon stocks.

- **Sample size is adequate for an initial assessment.** A total of 11 sites were measured across geomorphic features and across a wide geographic range. There is considerable variability in the mangrove structures within the Rewa Delta, and further refinement of these estimates is required to improve tiers in emissions levels, including sampling elsewhere in the Country.

- **Improved capacity within Fiji Forestry.** There is good capacity to conduct the field surveys required by Fiji Forestry. Practice with the methodology is recommended, and intensified additional training in data analysis and data chain of custody is required prior to future sampling. Training should also involve MRV (measurement, reporting & verification) as part of the REDD+ process and the National Forest Monitoring System (NFMS).

- **Verify and refine mapping efforts & link to land managers.** Further refinement of vegetation mapping is a necessity when considering land use changes and evaluating emissions associated with change. This requires a centralized and annual update effort, as well as coordination with the NFMS and land management decision makers to ensure up-to-date information is shared and appropriately considered in decisions.

- **Reference Level for Mangroves.** It is appropriate to consider 464 ± 38 Mg/ha carbon and 1,703 ± 140 tCO_2e as baseline carbon stocks for mangroves. More measurements are required in other mangrove and coastal community types to better refine this value at the country scale.

- **Emissions Factors for Mangrove Conversion.** Using the reference levels, estimates of 334 for cutting and 1,518 tCO_2e are "first approximations" for mangrove conversion in the Rewa Delta and surrounding area. These values can be used in a variety of ways to offset or apply "value" to mangrove conversion.

- **Context of the Country Greenhouse Gas Inventory.** Currently available data sources indicate emissions in 2009 were 846 $ktCO_2e$ for the country, accounting only for fossil fuels emissions. Only 500 ha of mangroves store the equivalent of all of fossil fuels emissions in Fiji in 2009.

- **Consider emissions in future planning.** Planning officials can consider emissions factors as ways to mitigate damage associated with mangrove conversion, and use as benchmarks for success by ensuring emissions are returned to mangrove forests though restoration and enhancement, as well as through avoiding conversion. This is a particularly powerful tool when contemplating a REDD+ strategy.

References

Kauffman, J.B. and D.C. Donato. 2012. Protocols for the measurement, monitoring, and 4 reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. 5 Center for International Forest Research. 40p.

Komiyama, A., S. Poungparn, and S. Kato. 2005. Common allometric equations for estimating 16 the tree weight of mangroves. Journal of Tropical Ecology. 21:471-477.

Tuiwawa and Tuiwawa 2012. MESCAL Report: Vegetation and Flora of the Rewa River Mangroves, Tailevu and Rewa Provinces, Viti Levu, Fiji Islands. IAS-USP and IUCN-Oceania internal report.

Tuiwawa, M. GIS maps associated with the Rewa Delta bioassessment component of the MESCAL project. Personal Communication.