MANGROVE BIOMASS AND CARBON ESTIMATIONS

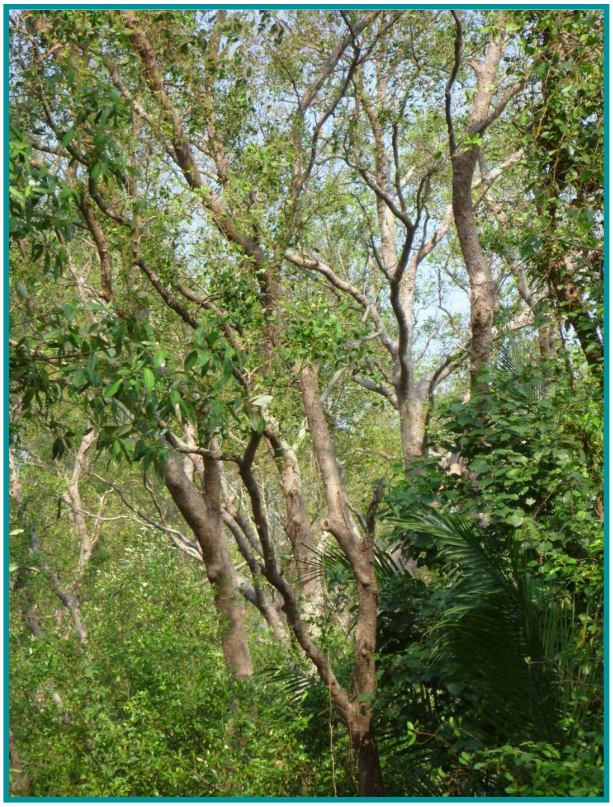
A case study in Kien Giang Province

INTRODUCTION

This case study presents the first estimate of regional-level mangrove biomass and associated CO_2 storage held within the mangrove forests of Kien Giang Province. Biomass and carbon estimations from plot based vegetation studies were extrapolated to district and province values using satellite vegetation classification and mapping.

FORESTS, BIOMASS AND CARBON

Trees and shrubs make the bulk of above ground biomass in a forest, with the total biomass of a stand varying markedly depending on the climate and soil and, in the case of mangrove vegetation, the frequency and duration of tidal inundation.



The age of the forest and its constituent trees is also a factor. In relatively young forests the carbon store builds over time as the trees and forest grow.

It is the size of the trees and their density that is the principal determinant of stand biomass. The wood density of the tree further affects the carbon content of the plants and hence that of the stand of vegetation.

The relationship between the size of trees and their biomass is not linear – meaning that as the diameter and height of the tree increases its biomass increases in a disproportionally greater way.

A typical mangrove tree may increase in dry biomass by greater than 5 times with every doubling of its trunk diameter of which about half is carbon. This means that a forest of thin

trees, even if tightly packed, may have only a fraction of the biomass of a forest of wider spaced large trees.

All carbon in biomass derives ultimately from atmospheric carbon dioxide (CO_2) via plant growth. Removal of forest cover and the burning or rotting of cut biomass returns carbon to the atmosphere in the form of CO_2, or sometimes methane (CH_4) in the case of rotting. Hence forests are a standing store of sequestered atmospheric carbon, despite some turnover over on a daily basis.

Some of the turnover (productivity) breaks down to return to the atmosphere, but other fractions enter food chains or are stored in the soil. Soil carbon can be stable for long periods.

Sedimentary environments like mangrove ecosystems can facilitate the burial of biomass and sometimes form peat due to restricted breakdown of biomass in the wet soils. It follows that the degradation and disturbance of naturally-functioning wetlands can be a major cause of increased carbon emissions as soil carbon oxidises to the atmosphere.

METHODS

Visits were made to Kien Giang province in July-August 2009 and January 2010.

The methodology was largely devised for this task (details in Wilson 2010).

Many observations on the nature and condition of the mangrove vegetation were made, along with the collection of plot-based data using a rapid field assessment methodology.

Estimates of above ground biomass (AGB) were made using published allometric equations (Komiyama et al. (2008) and one for Vietnam provided by Dr V. N. Nam.

Conversion from biomass to carbon was achieved through dividing biomass by the carbon fraction of 50% (Gifford 2000), apart from with *Rhizophora apiculata,* where 49% was used based on equations provided by Dr V. N. Nam.

To convert standing carbon content to atospheric CO_2 equivalent, standing content was multiplied by 3.67.

VEGETATION DESCRIPTION

There were 22 tree and shrub species taller than 1.3 m within the plots, plus four common species of understorey plant (two *Acrostichum* and two *Acanthus* species). This represents the majority of Kien Giang's recorded mangrove diversity.

Table 1. Average vegetation characteristics from the sample plots.

Characteristic	Range	Overall Average
Average height of the trees	2.1 m - 11.2 m	**6.2 m.**
Height of the tallest trees	5m - 16.9 m,	**10.1 m.**
Height of the tallest 'stratum'	2.4 m - 12.5 m,	**9.1 m.**
Canopy cover	58% (heavily cut) - 83%.	**71%**
Tree diameter	2.3 cm - 14.2 cm,	**6.4 cm.**
The basal area per hectare	3.8 m^2 / ha - 54.7 m^2 / ha	**22.5 m^2 / ha**
Above ground biomass (AGB)	1.4 – 424 t/ ha	**123.8 t/ ha**
Root weight	2.6 – 128 t/ ha	**33.9 t/ ha**
Total carbon content	6.4 – 248.5 t/ ha	**78.8 t/ ha**
Total CO2 equivalent	**23.4 – 912 t/ ha**	**289 t/ ha**

ESTIMATATION OF BIOMASS AND CO2 STORAGE

Plot locations were identified as either *mangrove type 1* or *mangrove type 2* based on geographic location within landuse maps developed from remote sensing. Average biomass and total atmospheric CO_2 eqivalent storage per ha was calculated for each vegetation unit.

To estimate total atmospheric CO_2 equivalent stored within mangrove forest, mangrove area (ha) was multiplied by average total atmospheric CO_2 equivalent per ha for both *mangrove type 1* and *mangrove type 2* vegetation classes.

As available satellite mapping is currently limited to ~70% of the coast of Kien Giang Province, total forest biomass and carbon storage figures were generated for both the known (mapped) area, and the estimated total mangrove area of Kien Giang. This estimation of 3500 ha is based on an extrapolation of the known area of mangrove from the mapped districts.

The average forest biomass for the forty plots for both above and below ground biomass is 157 t / ha. The average dry weight of total mangrove biomass (above and below ground) in *mangrove type 1* forest is 147 t / ha, which is lower than total dry weight of *mangrove type 2* vegetation which is 190 t / ha.

Total atmospheric CO_2 eqivalent stored in one hectare of mangrove forest (both *mangrove type 1* and *mangrove type 2)*, was estimated based on all 40 plots where above and below ground biomass was calcuated as 282. t / ha. This converts to an average atmospheric CO_2 eqivalent stored in one ha of mangrove forest in *mangrove type 1* forest of 264 tonnes. *Mangrove type 2* forest stored a higher amount of CO_2 with an average of 340 t / ha.

ESTIMATED CARBON STORAGE

Given the current estimate of mangrove area of 3500 ha in Kien Giang province, carbon storage in mangrove forests of Kien Giang is 269000 tonnes, representing around 987000 tonnes of atmospheric CO^2.Based on both plot based data and vegetation mapping,

The estimated total carbon content of each district for both *mangrove type 1 (M1), mangrove type 2 (M2)* and total mangrove forest (*M1 + M2)* in the mapped area of Kien Giang province (currently representing ~70% of the province) is shown in Table 2.

Table 2: Total estimated carbon content held in mangrove type 1, mangrove type 2 and total mangrove forests in each mapped region of Kien Giang.

	Mangrove Type 1 *(M1)*		Mangrove Type 2 *(M2)*		*M1 + M2*	
Region	**ha**	**Carbon content (tonne)**	**ha**	**Carbon content (tonne)**	**ha**	**Total Carbon content (tonne)**
Hon Dat	406	29000	387	362000	793	64800
Rach Gia	89	6400	104	9700	193	15800
Chau Thanh	27	1900	32	3000	60	4900
An Bien	263	18900	255	23800	518	42300
An Minh	424	30400	549	51400	973	79500
Regions total	1210	**86,600**	1328	**450,000**	2537	**207,300**

Based on the carbon content of mangrove forest (Table 2), the total atmospheric carbon equivalent held in mapped mangrove forests of Kien Giang is estimated as 743,800 tonnes. Total atmospheric carbon equivalent for the estimated complete area of mangrove forest in Kien Giang is 987,000 tonnes.

SYNTHESIS OF RESULTS

The higher mangrove biomass values in Kien Giang compare reasonably well with published values (Saenger 2002; Komiyama et al. 2008; Alongi 2009). Some biomass values, however, are low, although this may be in keeping with the vegetation type. Some *Avicennia alba* stands have low biomass because of their young frontal position. Overall, biomass is moderate.

Above ground biomass (AGB) figures of more than 600 t / ha have been recorded in mangrove forests, but they are generally between 150 and 350 t / h in well developed tropical mangroves (Alongi 2009). The average AGB for the plots in this study is 123.8 t / ha, in comparison to a average of 247 t / ha in the literature compiled by Alongi (2009).

Many published studies concentrate on tall forest and sampling of the range of vegetation in KG including young forest, some significantly cut forest and scrubby vegetation may have reduced the average somewhat relative to the published figure.

1. **There is significant standing mangrove biomass in Kien Giang province, and hence carbon storage where the vegetation remains.**
2. **For a given species, the size of trees contributes most to high biomass, although spacing of trees (density) is also a factor.**
3. **Wood density is a factor in biomass and carbon storage, with heavier timbered species being better stores for a similar size.**

Older forest has higher biomass and greater diversity.

Allowing trees to grow to maximal size is the best way to maximise biomass.

DISCUSSION AND IMPLICATIONS OF THE BIOMASS AND CARBON SURVEY

It is obvious that human influences on mangrove forest quality (such as cutting) substantialy impact the carbon storage potential of the forest. **To enhance the level of biomass, and subseqent carbon storage within mangrove forests in Kien Giang, efforts to protect the forest will be worthwhile.**

Cutting mature trees can substantially impact the biomass and carbon storage potential of the forest.

Protection and restoration of the forest is important for climate change mitigation strategies and will confer considerable economic benefits to Kien Giang.

We estimated current total forest biomass in Kien Giangs mangrove forests (based on extrapoloation of mangrove area mapping to be 549114 tonnes.

This corresponds to 269089 tonne of carbon storage. If, through protection, restoration and rehabilitation, mangrove forest biomass were to reach levels in line with primary forest biomass of nearby Thailand, total forest biomass could increase to as much as 1999900 tonne (given a total biomass level of 571.4 t / ha). **This in an increase of 1450785 tonne, which is more than 3.5 times the level of mangrove forest biomass we see today, with no increase in the area of mangrove in Kien Giang.**

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