FLORISTIC DIVERSITY, FOREST STRUCTURE AND ABOVEGROUND BIOMASS OF MANGROVE FOREST IN KANYIN CHAUNG COASTAL AREA, DAWEI DISTRICT, TANINTHARYI REGION, MYANMAR*

San Mon Thu[1] and Thi Thi Moe[2]

Abstract

This research conducted in the mangrove forests of Kanyin Chaung coastal area, Thayet Chaung Township, Dawei District, Tanintharyi region. To study the floristic diversity, forest structure and aboveground biomass of mangrove forest of Kanyin Chaung coastal area, twelve sample plots (20m x 20m) were established and observed during 2018. The diversity index of Kanyin Chaung coastal area was H=3.49, D= 0.90 and E= 0.92 (i.e Shannon-Wieners index (H), Simpsons index (D) and Shannon-Wieners index (E). Ecological successful species with the highest Importance Value Index were *Rhizophora mucronata* (44.02 %), *Xylocarpus moluccensis* (36.53 %) and *Avicennia marina* (31.45 %) in Kanyin Chaung coastal area. Forest density and basal area were 539 stem ha^{-1} and 14.11 m^2 ha^{-1} in the study area. The total mean aboveground biomass and carbon stocks of the study area were estimated 111.19 ton ha^{-1} and 53.37 C ton ha^{-1}. Aboveground biomass was significantly correlated with study stand ($p<0.01$) of the study area.

Keywords: Diversity, Forest Structure, Biomass, Mangrove forest

Introduction

In Myanmar, Latitude 20˚ N and 10˚ N Longitude 94˚ E and 98˚ E, from East to West 936 km and from North to South 2051 km, Coastal length 2300 km in Rakhine, Ayeyarwady delta and Tanintharyi with forest covering 52%. Tanintharyi Region lies at the southern end of Myanmar. The Region has common borders with Thailand on the east and south-east, Mon State on the north, and Andaman Sea on the west. The area of the Region is 16,735 square miles. Out of about 1,000 islands along Myanmar's coastline over 800 are in Tanintharyi coast. Myanmar hosts 32 species of mangrove trees of which *Rhizophora*, *Sonnertia*, *Aviccennia*, *Bruguiera* and *Xylocarpus* spp. are dominant (FAO, 2010).

Mangroves are salt-tolerant trees and shrubs that fringe intertidal areas of tropical and sub–tropical coastlines. They are keystone coastal ecosystems that are of economic, ecological and environmental importance to millions of people in the tropics. Mangroves provide important habitats and feeding grounds for a range of benthic and pelagic marine animals and bird species (Saenger, 2002; FAO, 2007a; FAO, 2007b), providing commercial fisheries resources and nursery grounds for coastal fisheries (Costanza *et al.*, 1997). As much as 75% of commercial fish species in the tropics spend part of their life cycle in mangroves environment (Mumby *et al.*, 2008). Mangroves are also important in climate regulation, nutrient cycling, habitat provisioning, shoreline protection and the provision of building materials and fuel wood. The value of mangrove goods and services worldwide has been estimated at US $ 1.6 billion each year (FAO, 2007b).

Forest structural characteristics such as canopy height, tree density, and biomass accumulation may be influenced primarily by climatic factors such as rainfall and by nutrient input (Golley *et al*., 1975; Smith 1992 and 2001). The architecture of a mangrove forest structure

[1] Dr, Assistant Lecturer, Department of Botany, University of Yangon
[2] Lecturer, Department of Botany, Dawei University
[*] Best Paper Award Winning Paper in Botany (2019)

is influenced by the magnitudes and periodicities of such forcing functions as tides, nutrients, hydroperiod, and stressors such as hurricanes, drought, salt accumulation, and frost. These in turn determine the basal area of the stem, the height, overall density and the species diversity of the forest stand (Lugo and Snedaker, 1974).

In the content of global warming, carbon absorption by mangrove forest ecosystem receives considerable attention now. Allomatery is a powerful tool for estimating tree weight from independent variable such as trunk diameter and height that are quantifiable in the field (Komiyama *et al.*, 2005). Mangrove forests are characterized by high productivity, high biomass and litter production (Alongi 2009; Boto & Bunt 1981; Mann 1982; Odum & Heald 1972).

Residents search for crab and prawns in the Kanyin Chaung mangrove forest. As long as they don't cause damage to the forest, they are allowed to extract its natural resources to generate income. The objective of the present study is to determine species diversity, forest structure and biomass accumulation of tree trunk weight in mangrove forest the study area in order to support sustainable mangrove forest management.

Methodology

Description of study area

This study area was carried out in the natural mangrove forest situated in the coast of Khanyin Chaung village, Thayet Chaung Township, Dawei District. It lies 98˚ 25' 45.87" E longitude and 13˚ 31' 35.92" N latitudes. Khanyin Chaung coastal mangrove area is 207.6 ha and protected since 1970. The Kanyin Chaung mangrove forest is bordered on one side by a 6.4 kilometer beach with beautiful *Casuarina* trees lining the shore. It was "unique" mangrove forest for establishing a community-based tourism project. The location map of the study area is as shown in figure 1.

The climate condition of the study area is warm and wet tropical climate for 2008-2018. The highest amount of rainfall is observed during August while April is the driest. The mean annual precipitation (MAP) is 5408 mm while the mean annual temperature (MAT) is 27°C.

Figure 1 Location and land-cover map of Kanyin Chaung Coastal Area

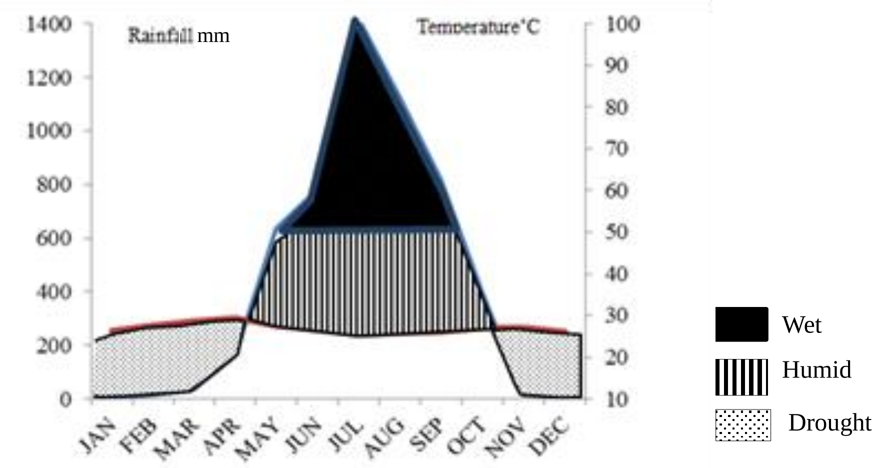

Figure 2 Climatic diagram of the study area (2008-2018)

Data collection

Each twelve plots of size 20 x 20 m were established through a nondestructive quadrat sampling technique to determine the species diversity, forest structure and aboveground biomass in the study area. The plots were laid depending on vegetation characteristic and landscape. Inside each plot, all trees with at least 5 cm girth breast height (GBH) were identified and measured the truck diameters (cm) and total height (m). We measured the truck diameter at 15 cm above the highest prop root for *Rhizophora* species, whereas the rest were measured at GBH (130 cm).

Data analysis

Forest inventory data were processed using standard analysis procedures as described by Cintron and Novelli (1984) to derive forest stand characteristics: stand frequency distribution, density (stems ha^{-1}), basal area (m^2 ha^{-1}), relative density, relative frequency, and relative dominance. Ecological importance values index (IVI) of each species was determined by summing the respective relative density, relative frequency and relative dominance. Importance value index measures relative dominance of species by criteria of how often it occurred, number of species, and area it occupies in a community. The species that attained the highest IVI was considered the principal species:

$$\text{Relative density} = \frac{100ni}{\sum_{i=1}^{m} ni}$$

$$\text{Relative frequency} = \frac{100Fi}{\sum_{i=1}^{m} Fi}$$

$$\text{Relative dominance} = \frac{100\ Bai}{Ba}$$

Species diversity is a measure of both species richness and evenness of a community. Species diversity varies greatly from one community to another. The diversity indices are better measures of the species diversity of a forest than the species density and mixture ratio and more information than species counts alone (Weident, 2000). Species diversity is often expressed by the Shannon-Wiener index (H), Evenness (E) and Simpson's index (D) (Magurran, 1988).

Floristic diversity index, determined in this study using the Shannon-Wiener's Index (Shannon & Weaver, 1963), indicates a quantitative description of mangrove habitat in terms of species distribution and evenness. This species diversity index was used in several studies (Gevaña & Pampolina, 2009; Sharma *et al.*, 2010; Lumbres *et al.*, 2012) and was calculated using the following form:

$$H = -\sum P_i \ln P_i$$

Where, H is Shannon-Wiener diversity index, S is the number of species, and P_i is proportion of total sample belonging to the i^{th} species.

Shannon-Wiener diversity index places more weight on the rare species while Simpson's diversity index emphases on the common species (Weidelt, 2000).

Simpson's Index (D)

$$D = 1 - \sum_{i=1}^{s} (P_i)^2$$

Where, D is Simpson's diversity index, S is the number of species, and P_i is proportion of species i^{th} in the community.

Evenness (*E*)

Species evenness is the relative abundance of individuals within a species in an area. Evenness is how evenly organisms are among species. Evenness gives an impression of the species distribution in a stand. The value E is regard as a suitable dimension for recording the second diversity component evenness. E is between 0 and 1. The value 1 represents all species as equally abundant. The value of E gradually goes down to 0 when the number of species decreases. Increasing evenness values mean a rise in diversity. Evenness was calculated by Shannon-Wiener function (1963), as follow:

$$E = \frac{H}{H_{max}} \qquad H_{max} = log_2 S$$

Where, E is the Shannon's evenness (evenness measure, range 0 - 1), H is the Shannon Wiener diversity index, H_{max} is the species diversity under conditions of maximal equitability, and S is the number of total species found in the sample plot.

Aboveground biomass and carbon stocks

Estimation of above-ground biomass (AGB) in live trees used commom allometric equations for trunk weight of mangroves was developed by (Komiyama *et al*. 2005):

$$W_s = a\,\rho\,(D^2\,H)^b$$

Where D is Diameter at breast height, H is Height, ρ is wood density of trunk and a and b are constant (a=0.0696, b=0.931)

Statistical Analysis

All statistical analysis for comparing the value of aboveground biomass and environmental factors were performed by SPSS version 16.0. Mean values was subjected to Pearson's correlations analysis at significant level of 0.01 and 0.05 to find the differences aboveground biomass, stem density, salinity, PH, soil fertility and soil texture between forest stands.

Results

Species Diversity

The diversity index of Kanyin Chaung coastal area was H=3.49, D= 0.90, E= 0.92 (i.e Shannon-Wieners index (H), Simpsons index (D) and Shannon-Wieners index (E) (Table 1). Species richness of the study area was 14.00 respectively. As a result of Shannon Wiener evenness (0.92) was evenly distributed among the species (Table 1).

Among the species recorded in the mangrove stand, *Rhizophora mucronata* was found dominating the mangrove forest with an IVI of 44.02 %; 11.01 % of relative density occurred in the study area (Table 2 and Figure 3). It was followed by *Xylocarpus moluccensis* (36.53 %) and *Avicennia marina* (31.45 %). All species with the highest importance values belonged to the family Rhizophoraceae.

Table 1 Species diversity in Kanyin Chaung coastal area

Description	Kanyin Chaung coastal area
Species richness	14.00
Shannon-Wiener index (H)	3.49
Simpson index (D)	0.90
Evenness (E)	0.92

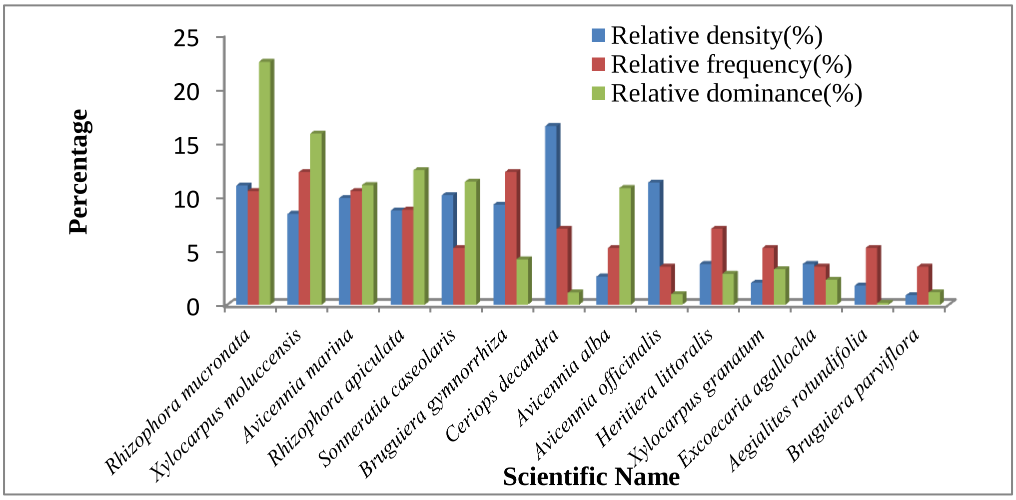

Figure 3 Relative density, frequency and dominance in Kanyin Chaung coastal area

Table 2 Ranking of importance value index in Kanyin Chaung coastal area

No.	Scientific name	RD(%)	RF(%)	RDm(%)	IVI(%)
1	*Rhizophora mucronata*	11.01	10.53	22.48	44.02
2	*Xylocarpus moluccensis*	8.41	12.28	15.84	36.53
3	*Avicennia marina*	9.86	10.53	11.07	31.45
4	*Rhizophora apiculata*	8.70	8.77	12.45	29.91
5	*Sonneratia caseolaris*	10.14	5.26	11.38	26.78
6	*Bruguiera gymnorrhiza*	9.28	12.28	4.21	25.77
7	*Ceriops decandra*	16.52	7.02	1.11	24.65
8	*Avicennia alba*	2.61	5.26	10.80	18.68
9	*Avicennia officinalis*	11.30	3.51	0.96	15.78
10	*Heritiera littoralis*	3.77	7.02	2.87	13.66
11	*Xylocarpus granatum*	2.03	5.26	3.26	10.55
12	*Excoecaria agallocha*	3.77	3.51	2.28	9.56
13	*Aegialites rotundifolia*	1.74	5.26	0.15	7.15
14	*Bruguiera parviflora*	0.87	3.51	1.13	5.51
	Total	**100**	**100**	**100**	**300**

Forest Structure

Horizontal and vertical structure

The GBH of mangrove species ranging from 5 cm to > 100 cm, total height vary from < 3 m to > 12 m. Tree density and basal area of the highest GBH classes of >100 cm in Kanyin Chaung area was 50 stem ha^{-1} and 7.42 m^2 ha^{-1} (Table 3 and Figure 4). The total basal area of mangrove species per hectare in Kanyin Chaung area was 14.11 m^2 ha^{-1} (Table 3). *Sonneratia caseolaris*, *Xylocarpus moluccensis* and *Rhizophora apiculata* registered the largest girth while *Avicennia alba*, *Rhizophora apiculata* and *Xylocarpus moluccensis* were the tallest. The average density of mangrove in the study area was 539 stem ha^{-1} (Table 3).

Population density of total individual mangrove species by the height classes of the Kanyin Chaung area was 37.10% (Table 4). While the height classes of >12 m in Kanyin Chaung area was 11.01% (Table 4). Stratification or vertical structure of the community determines the different growth forms. This stratification is determined by the species diversity and age structure of a site, and affects the tree growth due to competition for light and other resources.

Table 3 Forest structure of the study area showing basal area and stem numbers per hectare in different girth classes

GBH classes	Density (stem ha^{-1})	BA/ha (m^2 ha^{-1})
5 - 19.9 cm	227	0.34
20 - 39.9 cm	125	0.91
40 - 59.9 cm	45	0.93
60 - 79.9 cm	55	2.17
80-99.9 cm	38	2.34
> 100 cm	50	7.42
Total	**539**	**14.11**

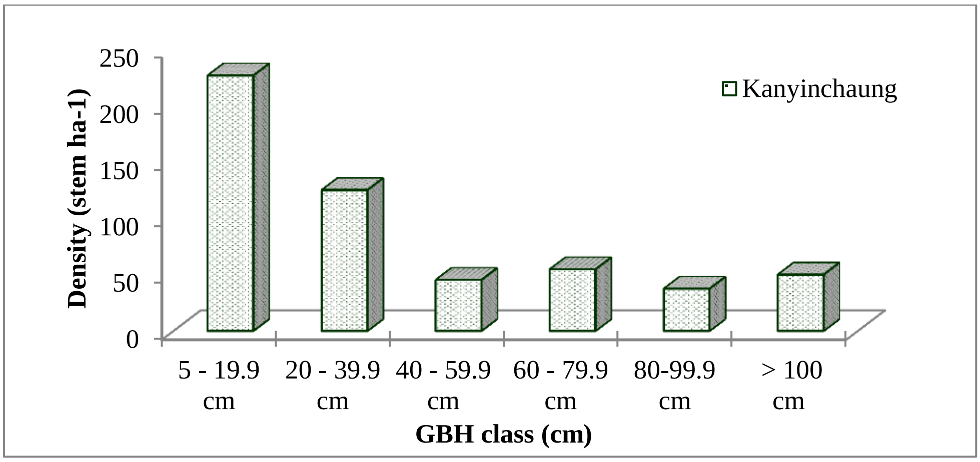

Figure 4 Stand structure of Kanyin Chaung coastal area

Table 4 Population density of mangrove species across height classes interval in Kanyin Chaung coastal area

Height Classes	No. of species	No. of Individual	% of total individual
< 3m	10	74	21.45
3 - 6m	13	128	37.10
6 - 9 m	11	66	19.13
9 - 12 m	10	39	11.30
>12 m	8	38	11.01
Total	52	345	100

Aboveground biomass and carbon stock of tree- trunk weight

On the study area**,** the Kanyin Chaung mangrove forest has a total mean biomass and carbon stock of 111.19 ton ha^{-1} and 53.37 C ton ha^{-1}. The total biomass C-stock 373.59 C ton ha^{-1} varied from 134.14 C ton ha^{-1} to 13.84 C ton ha^{-1} of each stand (Table 5 and Figure 5). Among the established sample plots, the highest huge quantities of biomass and stored carbon of

Rhizophora mucronata stand (279.45 ton ha^{-1}) and (134.14 C ton ha^{-1}) was estimated with large tree girth and high species wood density.

The results of Pearson's correlation between aboveground biomass and the environmental factors of the study area are shown in Table 6. According to the Pearson's correlation, significant negative correlations were found between study stand and total nitrogen ($p<0.05$), between study stand and soil texture (Clay) ($p<0.05$). The significant positive correlations were found between stem density and salinity ($p<0.05$), between stem density and available phosphorus ($p<0.01$). Aboveground biomass was significantly correlated with study stand ($p<0.01$) of the study area.

Table 5 Aboveground biomass and carbon stocks of each stand

Stand Name	Biomass (ton ha^{-1})	Carbon Stock (ton C ha^{-1})
Rhizophora mucronata	279.45	134.14
Xylocarpus moluccensis	129.46	62.14
Avicennia marina	127.29	61.10
Avicennia alba	98.73	47.39
Sonneratia caseolaris	83.36	40.01
Xylocarpus granatum	31.20	14.98
Bruguiera gymnorrhiza	28.83	13.84

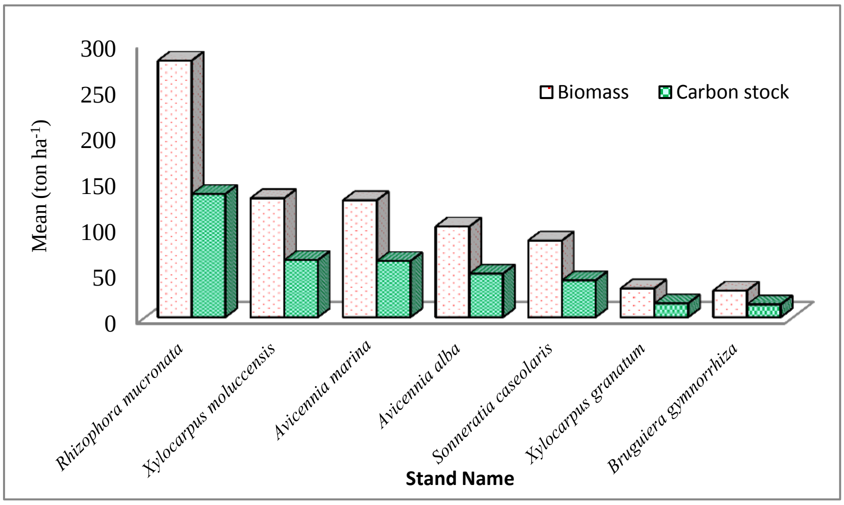

Figure 5 Aboveground biomass and carbon stocks of each stand

Table 6 Pearson's correlations between aboveground biomass and environmental factors of the study area

Variables	Study stand	Salinity	PH	N	P	K	Sand	Silt	Clay
Study stand	1	-0.621	-0.457	**-.811***	-0.541	**.830***	0.653	0.439	**-.823***
ABG Biomass (ton ha^{-1})	**.904****	0.596	0.333	0.646	0.63	-0.295	-0.547	-0.395	0.675
Stem density (n ha^{-1})	-0.408	**.794***	-0.431	0.023	**.958****	0.153	0.17	-0.362	0.071

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.
Note: pH = Soil pH, N = Total nitrogen, P = Available phosphorus, K = Potassium

Discussion and Conclusion

The species richness diversity index of Kanyin Chaung area was relatively higher than the Pantin-In area, Long-Lone Township (Thanda Soe, 2016) analysed by the method of Shannon-Wieners index (H), Simpsons index (D) and Shannon-Wieners index (E). Kirui *et al*., (2012) reported that changes in species richness in mangrove forest were likely to reduce resilience of mangrove ecosystem and make it vulnerable to natural and anthropogenic activities. Weidelt (2000) suggested that species diversity indices are better measure of the species diversity of a mangrove forest and more information than species counts alone.

Fourteen mangrove species were found in the study area with *Rhizophora mucronata*, *Xylocarpus moluccensis* and *Bruguiera gymnorrhiza* having high relative frequency compared to other species. Hamad *et al*., 2014 reported that high frequency of these species might be attributed to their high regeneration capacity despite their high use preference for building pole and fire wood. Mangrove species dominance value index indicated *Rhizophora mucronata* cover large area in the study site (Table 2). This might be attributed to the fact that most of *Rhizophora mucronata* species large in size, an indication that the species is less preferred for cutting as compared to the species of the family Rhizophoraceae and therefore has opportunities to grow into large tree.

The basal area of the highest GBH classes in Kanyin Chaung area (14.11 m^2 ha^{-1}) was higher than Pantin-In, Long-Lone area (Thanda Soe, 20016) (5.78 m^2 ha^{-1}). According to Bundotich *et al*., (2009), the observed basal area was standard of a healthy forest. The highest height classes of >12 m in Kanyin Chaung area (11.01%) was higher than the Long-Lone area (0.38 %) (Thanda Soe, 2016). Stratification or vertical structure of the community determines the different growth forms. This stratification is determined by the species diversity and age structure of a site, and affects the composition of the understory as well as tree growth due to competition for light, climatic factors and other resources.

The total mean aboveground biomass for the study area (111.19 ton ha^{-1}) within 50 years was compared to those reported the total aboveground biomass for Long-Lone Township (89.62 ton ha^{-1}) (Thanda Soe, 2016) and estuarine along the Bay of Bengal, India (60.0 ton ha^{-1}, Kathiresan *et al.*, 2013) which was lower than the study area. Moreover, the above-ground mean carbon stocks estimated in Southern China (50.0 ton C ha^{-1}, Chen *et al.*, 2012) was lower compared to that of the present study area due to Kanyin Chaung mangrove forest are easily accessible from forest age, stem density and trunk diameter with relatively less effort required to harvest the products such as firewood and poles etc. These results agreed with the size range of trunk diameters and stem density in this present study was the sample diameter range of Komiyama *et al.,* (2005). According to Pearson's correlation, aboveground biomass was strongly significant between stands ($p < 0.01$). Stem density was significantly correlated with salinity ($p < 0.05$) as well as soil fertility ($P < 0.01$).

This study aimed at investigating the diversity, structure and aboveground biomass accumulation rates in Kanyin Chaung mangrove forest and the environmental factors. A high diversity index was observed in the study area attributed to the dominance of species, those belonging to the family Rhizophoraceae and Avicenniaceae. Nonetheless, because of the large tree girth and high density of species observed in this forest, it has the potential to sequester and store large amount of atmospheric carbon. Climatic factors, particularly rainfall, are important determinants of species richness, stand structure, and biomass of tree trunk weight in mangrove forests. It will be valuable for the restoration, conservation and management of natural mangrove forest resources. The restoration of natural mangrove forest is beneficial for balance of natural environment and local peoples' requirement. Mangroves ecosystem may be developed as sources of high value commercial products and fishery resources and as sites for an ecotourism industry.

Recommendation

This study presented findings that demonstrate the forest structure and biomass densities are key elements to view of carbon market and carbon trading as significant climate change mitigation opportunity, it is recommended that (a) assessment and monitoring should be done to assess mangrove cover changes overtime and predicts extents of human impacts on mangrove forest, (b) permanent plots should be established for MRV system of mangrove forest carbon stocks and (c) collaborative management should be done by harmonizing rules and regulations across stakeholders.

Acknowledgement

I would like to express our sincere thanks to Professor Dr Myint Aung, Department of Botany, University of Yangon for their invaluable advice and encouragement. I would like to mention to One Map Myanmar for helping land cover map.

References

Alongi, D. M. (2009). **The Energetics of Mangrove Forests.** Springer, Dordrecht.

Boto, K. G. & J. S. Bunt. (1981). **Tidal export of particulate organic matter from a northern Australian mangrove system**. *Estuarine Coastal and Shelf Science* **13:** 247-255.

Bundotich ,G., M. Karachi, E. Fondo and J.G. Kairo. (2009). **Structural inventory of mangrove forest in Ngomeni, in Advances in Coastal Ecology**: People Processes and Ecosystem in Kenya, J. Hoorweg and N. Muthiga, Eds., pp. 111-121, African studies centre, Leiden, Netherlands.

Chen, L., X. Zeng, N.F.Y. Tam, W. Lu, Z. Luo, X. Du and J. Wang. (2012). **Comparing carbon sequestration and stand structure of monoculture and mixed mangrove plantations of *Sonneratia caseolaris* and *S. apetala* in Southern China.** *For. Ecol. Manage.*, 284: 222-229.

Cintron, G and Y. S. Novelli. (1984). "**Methods for studying mangrove structure,"** in The Mangrove Ecosystem: Research Methods, S. C. Snedaker and J. G. Snedaker, Eds., pp. 91–113, UNESCO, Paris, France.

Costanza R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., M. van den Belt. (1997). T**he value of the world's ecosystem services and natural capital.** *Nature* **387**:253-260.

FAO, (2007a). **State of the world's forests**. Food and Agriculture Organization of the United Nations, Rome. 237.

FAO, (2007b). **The World's Mangroves 1980-2005**. Forestry Paper 153, FAO, Rome. ix + 77 pp.

FAO. (2010). **Global Forest Resources Assessment 2010 Main Report** (FRA 2010); Food and Agriculture Organizations of the United Nations: Rome, Italy, 2010.

Gevaña, D.T. and N.M. Pampolina. (2009). **Plant diversity and carbon storage of a Rhizopora stand in Verde Passage, San Juan, Batangas, Philippines**. *J. Environ. Sci. Manage.*, 12: 1-10.

Golley, F. B., J. T. McGinnis, R. G. Clements, G. I. Child, and M. I. Duever. (1975). **Mineral cycling in a tropical moist forest ecosystem**. University of Georgia Press, Athens.

Hamad, H. M., I. S. Mchenga, and M. I. Hamisi. (2014). **“Status of exploitation and regeneration of mangrove forests in Pemba Island, Tanzania,”** *Global Journal of Bio-Science and Biotechnology*, vol. 3, no. 1, pp. 12–18.

Kathiresan, K., R. Anburaj, V. Gomathi and K. Saravanakumar. (2013). **Carbon sequestration potential of *Rhizophora mucronata* and *Avicennia marina* as influenced by age, season, growth and sediment characteristics in southeast coast of India.** *J. Coast Conserv.*, DOI 10.1007/s11852-013-0236-5.

Kirui, B. Y. K., J. G. Kairo, M. W. Skov, M. Mencuccini, and M. Huxham. (2012). **Effects of species richness, identity and environmental variables on growth in planted mangroves in Kenya.** *Marine Ecology Progress Series*, vol. 465, pp. 1–10.

Komiyama, A., S. Poungparn and S. Kato. (2005). **Common allometric equations for estimating the tree weight of mangroves**. Journal of Tropical Ecology 21: 471-477. 2005 Cambridge University Press.

Lumbres, R.I.C., J.A. Palaganas, S.C. Micosa, K.A. Laruan, E.D. Besic, C.W. Yun and Y.J. Lee. 2012. **Floral diversity assessment in Alno communal mixed forest in Benguet, Philippines**. *Landsc. Ecol. Eng.*, DOI 10.1007/s11355- 012-0204-5.

Lugo, A. E., S. C., Snedaker. (1974). **The ecology of mangroves.** *Annual Review of Ecology and Systematics* **5** 39-64.

Magurran, A. E. (1988). **Ecological diversity and its measurement**. Chapman and Hall, London. 179 pp.

Mann, K. H. (1982). **Ecology of Coastal Waters:** *A Systems Approach*. University of California Press, Berkley, USA.

Mumby P. J., Broad K., Brumbaugh D. R., Dahlgren C. P., Harborne A. R., Hastings A., Holmes K. E., Kappel C. V., Micheli F., Sanchirico J. N., (2008). **Coral reef habitats as surrogates of species, ecological functions, and ecosystem services**. *Conservation Biology* **22**:941-951.

Odum, W. E. & E. J. Heald. (1972). **Trophic analysis of an estuarine mangrove community.** *Bulletin of Marine Science* **22:** 671-738.

Saenger, P. (2002). **Mangrove Ecology, Silviculture and Conservation.** Kluwer Academic Publishers, Dordecht, The Netherlands.

Shannon, C. E, and Wiener, W. (1963). **The Mathematical Theory of Communication**, University of Illinois Press, Urbana, USA.

Sharma, C.M., N.P. Baduni, S. Gairola, S.K. Ghildiyal and S. Suyal. (2010). **Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India.** *For. Ecol. Manage.*, 260: 2170-2179.

Smith, T. J. (1992). Forest structure. Pp. 101-136. In A. I. Robertson and D. M. Alongi (eds.), **Tropical Mangrove Ecosystems.** American Geophysical Union, Washington, D.C.

Smith, R.L and T.M Smith (2001). **Ecology and Field Biology**.6th edition. Addison Wesley Longman, San Francisco.

Thanda Soe. (2016). **Phytosociological Study of Mangrove Vegetation in Laung-Lone Township**, **Tanintharyi Region.** PhD Thesis, University of Yangon.

Weidelt, H.J. (2000). **Lectures Notes on Tropical Silviculture I and II.** Institude of Silviculture, Sec.II, Tropical Silvicultue, Gottingen University, Germany (Unplished).