PARTITIONING OF SYSTEM TOTAL CARBON POOL OF KALA OYA MANGROVE ECOSYSTEM IN SRI LANKA

[1]K.A.R.S.PERERA, [2]M.D.AMARASINGHE

[1]Deartment of Botany, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka.
[2]Deartment of Botany, University of Kelaniya, Sri Lanka

Abstract- Mangrove communities are normally characterized efficient in carbon sink compared to other terrestrial plant communities. Due to the surprisingly lacking of data on total carbon storage in whole mangrove ecosystems, study was objected to account the total organic carbon (TOC) content in a largest mangrove ecosystem, Kala Oya in Sri Lanka. Above and below ground mangrove biomass was determined with allometric method and converted to TOC. TOC in soils were determined with standard chemical procedures. TOC in plant to be 204.74 t ha^{-1}, comprised 171.73 t ha^{-1} from above ground and 33.01 t ha^{-1} form below ground components. TOC in soil was recorded to be 376.26 t $ha^{-1.}$ Total calculated TOC in whole ecosystem to be 581.00 t ha^{-1} and the total estimated amount of TOC in Kala Oya mangrove (1200 ha) ecosystem to be $697.2x10^3$ t.

Key words- Mangrove, total organic carbon, vegetation structure, soil,

I. INTRODUCTION

Mangroves are associated with tropical coastal environments and they are comprised with woody halophytes that are well adapted to intertidal conditions. Mangroves are characterized as an important sites of carbon sequestration (Fujimoto, 2004; Donato et al., 2011; Perera et al., 2012) Rapid rate of primary production and slow rates of sediment carbon decomposition in this anaerobic soil environment justify their preservation as important sites of carbon sequestration (Alongi et al., 2001). Despite the multi-functional nature of mangrove ecosystems, they have received attention only in the recent past especially due to increased recognition of their role in global carbon cycle based on improved estimates of mangrove carbon stocks (Kauffman et al. 2011; Donato et al., 2012). Although number of studies on processes, services, traditional uses and diversity of mangroves in local and international level have so far been reported, very few of reliable estimates are available on carbon retention capacity of mangroves including above and below ground estimates with mangrove soils. Study was conducted with objective of fil the gap on knowledge of total carbon retention capacity of mangrove ecosystems in Sri Lanka.

II. MATERIALS AND METHOD

Study area and sites

Kala Oya estuary is located on the north western coast of Sri Lanka, (8^0 17' N; 79^0 50'E) which is the longest with the biggest river basin and supports the largest and least disturbed mangroves in Sri Lanka, which extends over 1200 ha (Kanakaratne et al., 1983). Relatively a dry climate prevails in the area, where annual rainfall is 1000 -1200 mm and mean atmospheric temperature is 29-33 ^{0}C.

In order to gather data on mangrove vegetation structure and Total organic carbon (TOC) content, five (5), 10 m wide belt transects were laid randomly selected places in the mangrove forest. Each transect occurred perpendicular to the shoreline, up to varying lengths inland, depending on the width of the mangrove area and divided in to 10m x 10m sampling plots (100 m^2). Total of five (5) transects, (length 400-500 m) comprised of 21 sampling plots were occurred to collecting the data.

Vegetation Structure

Standard methods were adopted to quantify the major structural parameters of the mangroves, as described by Cintron & Novelli, (1984), Kathiresan and Khan, (2010). Data on mangrove structural properties i.e. species richness, tree diameter at breast height (dbh) and tree height of the stands were gathered from each study plot (100 m^2) in the belt transects. Plants with less than 2.5 cm were excluded.

Complexity index (CI), indicates the diversity and abundance of flora within the forest community and it is calculated using data on the number of species, stand density, basal area and height (Holdridge et al., 1971; Kathiresan and Khan 2010; Perera et al., 2013; Perera & Amarasinghe 2016).

CI = Number of species x stand density x stand basal area x stand height x 10^{-5}

Biomass and total organic carbon (TOC) content in mangrove vegetation

Above ground and below ground biomass of mangrove species encountered in the sub-plots was determined by allometric equations derived for individual species. The allometric equations of $\log_e(AGB)= 6.247+2.64 \log_e(dbh)$ and $\log_e(AGB)= 5.551+2.153\log_e(dbh)$ were used to calculate the above ground biomass of Rhizophora mucronata and

Avicennia marina respectively (Amarasinghe and Balasubramaniam, 1992). The above and below ground biomass of Bruguiera gymnorrhiza was calculated using AGB= 0.289 $(dbh)^{2.327}$ and BGB= 0.100 $(dbh)^{2.364}$ respectively (Perera et al., 2012). The allometric equation, AGB= 0.114 $(dbh)^{2.523}$, was used to calculate the above ground biomass (AGB) of Lumnitzera racemosa while below ground biomass (BGB) was computed with BGB= 0.118 $(dbh)^{2.063}$ (Perera et al., 2012).

The biomass of other species encountered in the sample plots were calculated using common equations, i.e. AGB= 0.251 ρ $dbh^{2.46}$ and BGB= 0.199 ρ 0.899 $dbh^{2.46}$ (ρ – density of wood) (Komiyama et al., 2005).

Standing stock of biomass values were then converted to the TOC values with the percentage TOC content in biomass of each plant component of mangrove species, reported by Perera and Amarasinghe, (2016).

Total organic carbon (TOC) content in mangrove soil

Soil samples were collected with a split core sampler/auger 77801 (2” x12’), from a minimum of five randomly selected sites in each sampling plot (100 m^2). At each auger site, samples were collected from three (3) depths i.e., 0 – 15cm, 16 – 30cm and 31 – 45cm.Composite soil samples were prepared for each depth. Soil samples were air-dried and followed by oven dried subsequently at 60^0C to constant weight.

III. CHEMICAL ANALYSIS

Biomass and Total organic carbon (TOC) stock retained in mangrove vegetation

Above and below ground biomass values of the area recorded 322.52 and 64.80 t ha^{-1} respectively and total biomass to be 387.32 t ha^{-1} (Table 2). Published records of mangrove biomass in last two decades, revealed extensively ranged. The highest above ground biomass, 460 t ha^{-1} was recorded in Malaysia with R.apiculata dominated forest (Putz and Chan, 1986) and the lowest, 40.7 t ha^{-1} was reported at Indonesia with same species (Kusumana et al., 1992; Komiyama et al., 2008). Cintron and Novelli, (1984), explained many factors strongly influence the occurrence and growth of mangroves and these include geographical latitude, wave action, rainfall, freshwater runoff, erosion/sedimentation rates, aridity, salinity, nutrient inputs and soil quality.

Total amount of TOC, 204.74 t ha^{-1} was retained in the above and below ground components of mangrove vegetation. Among eight (8) constituent mangrove species occurred in the area, more than 70% of TOC retention capacity subsist only on three

Total organic carbon content (TOC) in mangrove soil samples were measured using the standard wet oxidation technique which involves the rapid dichromate oxidation of organic matter (Walkley-Black, 1934; Anderson and Ingram, 1998; Schumacher, 2002). $K_2Cr_2O_7$ Solution was used to oxidize the organic carbon in acid medium. The amount of oxidized carbon in the sample was measured by determining the amount of chromic ions produced during oxidation. Colorimetric method was used to determine the chromic ion concentration. Absorbance was recorded sample solutions by using UV-visible spectrophotometer (Spectro UV-VIS Double Beam UVD-3000) at 600 nm absorbance.

Standard methods were adopted to determine the bulk density of soils in three depths (0 – 15cm, 16 – 30cm and 31 – 45cm) at the Kala Oya mangrove area as described by Anderson and Ingram, 1998.

IV. RESULTS AND DISCUSSION

Mangrove species compotation and vegetation structure

Relatively high species diversity was revealed in the mangrove ecosystems at Kala Oya, evident that nearly thirty present of the true mangrove species that have been recorded from Sri Lanka occurs in the 2100 m^2 (21 study plots) at Kala Oya estuary. As in many other mangroves ecosystems in the dry zone coastal regions in Sri Lanka, Rhizophora mucronata recorded the most dominant. In addition to that Avicennia marina, Excoecaria agallocha and Lumnitzera racemosa are the major constituent species. (Table 1). Similar observations were recorded by Amarasinghe and Balasubramaniam, (1992), de Silva, and de Silva, (1989) and Perera et al (2013).

species ie. L.racemosa, R. mucromata and E.agollocha (Table 2). Recorded TOC content in mangrove plants at Kala Oya, revealed relatively high with the reported TOC values at Batticaloa (149.7 t ha^{-1}) and Uppar (135.2 t ha^{-1}) lagoon mangroves (Perera and Amarasinghe, 2014).

A positive correlation ($p<0.001$) was revealed between total organic carbon (TOC) content in biomass of mangrove vegetation and complexity index (CI). This relationship (TOC = 2.2652 CI + 126.1) elucidate the impact of TOC retention capacity on the vegetation structure of mangroves (Fig 1).

Total organic carbon (TOC) stock retained in mangrove soil

Top soil layer (0 -15 cm) recoded higher values for percentage of TOC content (9.574) and bulk density (1.217), followed by depth 2 (16-30 cm) and depth (31-45 cm). Total amount of TOC stock remained in up to the depth of 45 cm in mangrove soil was recoded, 376.26 t ha^{-1} (Table 3). Similar results were recorded at mangrove forests at Ecuador (Del Vecchia, et al., 2013) and Palau and Yap (Kauffman, et al., 2011).

Table 2: Species vise distribution of biomass and Total organic carbon (TOC) at Kala Oya estuarine mangroves

Mangrove species	Biomass (t ha^{-1})		Total organic carbon (t ha^{-1})	
	Above ground	Below ground	Above ground	Below ground
R.mucronata	67.55	14.12	38.03	7.72
E.agallocha	75.08	14.96	35.81	6.93
A.marina	41.67	8.77	21.84	4.49
L.racemosa	90.84	17.33	50.69	8.87
B.cylindrical	36.19	7.18	19.22	3.70
C.tagal	6.89	1.55	3.80	0.83
B.gymnorrhiza	4.23	0.87	2.32	0.46
A.corniculatum	0.07	0.02	0.03	0.01
Total	322.52	64.80	171.73	33.01

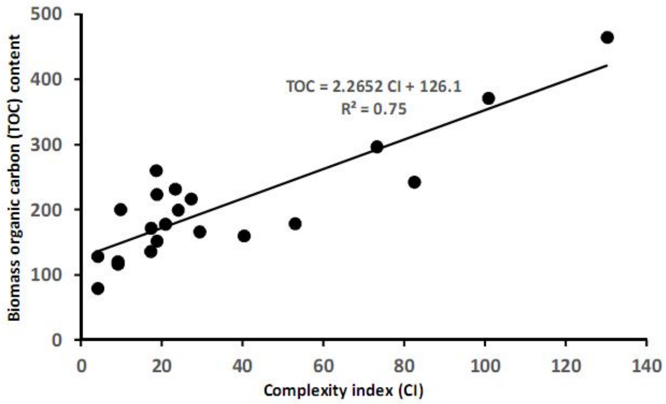

Fig 1: Relationship between total organic carbon (TOC) and complexity index (CI)

Table 3: Distribution of TOC in different depths of soils at Kala Oya estuarine mangroves

	Depth 1 (0-15 cm)	Depth 2 (16-30 cm)	Depth 3 (31-45 cm)
% TOC	$9.574 \pm 3.5\text{x}10^{-3}$	5.775 ± 0.02	$5.441 \pm 4.25 \times 10^{-3}$
Bulk density	1.217 ± 0.03	1.210 ± 0.02	$1.194 \pm 4.25 \times 10^{-3}$
TOC density	0.116 ± 0.01	$0.069 \pm 3 \times 10^{-3}$	$0.064 \pm 2.5 \times 10^{-3}$
TOC weight (t/ha)	174.91 ± 16.50	104.35 ± 4.66	97.00 ± 6.07

Table 4: Calculated Total organic carbon (TOC) content in mangrove ecosystem at Kala Oya

Total organic carbon (TOC) content (t ha^{-1})	
Above ground biomass of mangrove trees	171.73
Below ground biomass of mangrove trees	33.01
Mangrove soil	376.26
Total	581.00

Soil TOC values recorded at Kala Oya, relatively high with reported values for other tropical forest types in the world, ie, tropical forests, 122.73 t ha^{-1}; Deserts and semi deserts, 41.98 t ha^{-1}; tropical savannas and grasslands, 117.33 t ha^{-1} and also crop lands,80.00 t ha^{-1}(Bouillon, et al 2008).

Calculated the total TOC stock retained in mangrove ecosystem at Kala Oya to be 581 t ha^{-1} (Table 4). Total mangrove extend of the area was estimated 1200 ha (Kanakarathe, 1985) and therefore TOC stock retained in the mangrove area to be $697.2\text{x}10^3$ t. Total recorded values for ecosystem TOC (581 t ha^{-1}), is relatively high with other tropical ecosystems, ie, tropical forests, 243.18 t ha^{-1}; Deserts and semi deserts, 43.74 t ha^{-1}; tropical savannas and grasslands, 146.66 t ha^{-1} (Bouillon, et al 2008).

Deforestation currently generates nearly 20% of anthropogenic carbon emissions globally (van der Werf et al., 2009). To reduce this impact, identification and carbon valuation mechanisms essential to encourage the conservation at local to national scales needs.

REFERENCES

[1]. 1 Alongi, D. M., Wattayakorn, G., Pfitzner, J., Tirendi, F., Zagorskis, I., Brunskill, G. J., Davidson, A. and Clough, B. F. (2001). Organic carbon accumulation and metabolic pathways in sediments of mangrove forests in southern Thailand, Marine Geology, 179: 85–103.

[2]. 2 Amarasinghe, M.D. and Balasubramaniam, S. (1992b). Structural properties of two types of mangrove stands on the northern western coast of Sri Lanka. Hydrobiologia. 247:17-27.

[3]. 3 Anderson,J.M. and Ingram, J.S.I. (1998) (eds.), Tropical soil biology and fertility, A Handbook of methods, CAB publishing, UK.

[4]. 4 Bouillon, S., Borges, A.V., Castan˜eda-Moya, E., Diele, K., Dittmar, T., Duke, N.C., Kristensen, E., Lee, S.Y., Marchand, C., Middelburg, J.J., Rivera-Monroy, V. H., Smith, T.J. and Twilley, R.R. (2008). Mangrove production and carbon sinks: A revision of global budget estimates, Global Biogeochemical Cycles, 22: 1-12.

[5]. 5 Cintron, G. and Schaeffer-Novelli, S. Y. (1984). Methods for studying mangrove structure, In: Snedaker, S. C. & Snadaker, J. (eds.), The mangrove ecosystem: research methods, UNESCO, Paris, 91-113.

[6]. 6 de Silva, M., and de Silva, P.K. (1989).Status, diversity and conservation of the mangrove forests of Sri Lanka, Journal of South Asian natural History 3:(1), 79-102.

[7]. 7 Donato, D.C., Kauffman, J.B., Mackenzie, R.A., Ainsworth, A. and Pfleeger, A.Z. (2012). Whole-island carbon stocks in the tropical Pacific: Implications for mangrove conservation and upland restoration, Journal of Environmental Management, 97: 89-96.

[8]. 8 Donato, D., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M. and Kannien, M. (2011). Mangroves among the most carbon-rich forests in the tropics, Nature Geoscience, 4: 293-297.

[9]. 9 Fujimoto, K. (2004). Below-ground carbon sequestration of mangrove forests in the Asia-Pacific region. In: Vannucci, M. (ed.) Mangrove management and conservation. United Nations University Press, Tokyo, 138–146.

[10]. 10 Holdrige, L. R., Grenco, W. C., Hathey, W. H., Liang, T. and Tosi, J. (1971). Forest environment in tropical life zone: A pilot study, Pregaman Press, New York.

[11]. 11 Kanakaratne, M.D., Perera, W.K.T. and Fernando, B.U.S. (1883). An attempt at determining the mangrove coverage in Puttalam lagoon, Dutch bay and Portugal bay, Sri Lanka using remote sensing techniques, Proc. 4th Asian Conf. Remote Sensing, Colombo: Sri Lanka, 15-19.

[12]. 12 Kathiresan, K. and Khan,S.A. (2010). International Training Course on Costal biodiversity in Mangroves: Course manual, Annamalie University (CAS in Marine Biology, Parangipettai), India. 744 pp.

[13]. 13 Kauffman, J.B., Heider, C., Cole, C.T., Dwyer, K. and Donato, D.C. (2011). Ecosystem carbon stocks of Micronesian mangrove forests, Wetlands, 31: 343-352.

[14]. 14 Komiyama, A., Poungparn, S. and Kata, S. (2005) Common allometric equations for estimating the tree weight of mangroves, Journal of Tropical Ecology 21: 471-477.

[15]. 15 Komiyama, A., Ong, J.E. and Poungparn,S. (2008) Allometry, biomass and productivity of mangrove forests: A review, Aquatic Botany 89: 128-137.

[16]. 16 Kusmana, C., Sabiham, S., Abe, K. and Watanabe, H. (1992). An estimation of above ground tree biomass of a mangrove forest in east Sumatra, Indonesia, Tropics ,1: 243–257.

[17]. 17 Perera, K. A. R. S., Sumanadasa W. A. and Amarasinghe M. D. (2012b). Carbon retention capacity of two mangrove species, Bruguiera gymnorrhiza (L.) Lamk. and Lumnitzera racemosa Willd. in Negombo estuary, Sri Lanka. Journal of the Faculty of Graduate Studies, 2012, University of Kelaniya, Sri Lanka, 1: 56-70 pp.

[18]. 18 Perera, K. A. R. S, Amarasinghe, M. D. and Somaratna, S (2013). Vegetation Structure and Species Distribution of Mangroves along a Soil Salinity Gradient in a Micro Tidal Estuary on the North-western Coast of Sri Lanka, American Journal of Marine Science 1(1): 7-15.

[19]. 19 Perera, K. A. R. S, and Amarasinghe, M. D. (2014). Distribution pattern of total organic carbon in soils of micro tidal mangrove ecosystem in west coast of Sri Lanka, International Journal of Science and Knowledge, 3(1): 27-33.

[20]. 20 Perera, K.A.R.S., M.D. Amarasinghe and W.A. Sumanadasa (2012). Contribution of plant species to carbon sequestration function of mangrove ecosystems in Sri Lanka, Proceeding of the International Conference: Meeting on Mangrove ecology, functioning and Management (MMM3), Vrije Universiteit Brussel (VUB), the Université Libre de Bruxelles and University of Ruhuna, July 2012 Sri Lanka, 137p.

[21]. 21 Perera, K. A. R. S, and Amarasinghe, M. D. (2016). Atmospheric carbon removal capacity of a mangrove ecosystem in a micro-tidal basin estuary in Sri Lanka, 22 Schumacher, B.A. (2002). Methods for determination of total organic carbon (TOC) in soils and sediments, NCEA-C-1282 EMASC-001, Ecological risk assessment support center, Office of Research and Development US. Environmental Protection Agency.

[22]. 23 van der Werf, G.R., Morton, D.C., DeFries, R.S., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J., Randerson, J.T., (2009). CO2 emissions from forest loss. Nature Geoscience 2: 737-738

[23]. 23 Walkley, A. and I. A. Black, I. A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method, Soil Science, 37: 29-37.

★★★