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Soil Carbon Stock in Cambodian Monsoon Forests

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Abstract

We studied the relationships among the soil C stock in tropical monsoon forests, the type of forest, and the environmental factors in the lower Mekong basin in Cambodia. We analyzed nine soil profiles in evergreen and deciduous forests growing over sedimentary rock and basalt. Evergreen forest soils tended to have a larger C stock than deciduous forest soils within geological formations. In evergreen and deciduous forest soils, carbon stocks were 56.9 ± 30.0 (mean ± SD) and 34.9 ± 23.5 Mg C ha^{-1}, respectively, in the 0- to 30-cm depth range, and 108.7 ± 53.0 and 53.2 ± 30.4 Mg C ha^{-1}, respectively, in the 0- to 100-cm depth range. Soil C stock was highly positively correlated with soil water content in the dry season, which is likely affected by the openness of the forest canopy and by soil clay content.

Discipline: Forestry and forest products
Additional key words: deciduous forests, evergreen forests, REDD

Introduction

Tropical monsoon forests that cover wide areas of the Indochina peninsula are key regions for the Reducing Emissions from Deforestation and Forest Degradation (REDD) project in Southeast Asia. Countrywide data from five major carbon (C) pools in the forest ecosystem (forest aboveground and belowground biomass, deadwood, litter, and soil) are required for technical support of the REDD scheme[7]. However, the monsoon forest C inventory, particularly for soil, is presently inadequate for this purpose[2].

In the REDD scheme, soil C inventories are to be developed for all categories of forest, soil, and geological configuration for estimating carbon stocks at national levels. Existing vegetation maps provide useful information on forest categories and their distributions, but forest classification systems differ among Southeast Asian countries[1]. In addition, the extent of deforestation and forest degradation changes from day to day in tropical monsoon regions through logging, agricultural land development, and forest fires; human and research resources required for comprehensive forest surveys are limited in Southeast Asia. To build a C-monitoring system for wide use across the region, common systems of forest classification and forest-soil C inventory compilation are needed.

In the lowlands of tropical monsoon Asia, a mosaic-like distribution of the two forest types, i.e., evergreen and deciduous, occur under similar climatic conditions[17]. The categorization of tropical monsoon forests into evergreen and deciduous forests likely reflects their intrinsic ecological functions, and this classification has been adopted by some Southeast Asian countries[5] (e.g., Thailand, Cambodia, and Laos) and by global biome research

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undertakings[9,13,25]. This categorization is consistent with current procedures in forest hydrology[16], root ecology[11], and satellite ecology[6]. Hence, the measurement of soil C stock in evergreen and deciduous forest types will contribute significantly to soil C inventory programs and to interdisciplinary interpretations of forest ecology in tropical monsoon regions.

Studies of soil C stock by Southeast Asian forest type began first in Thailand. Tsutsumi et al.[22,23] conducted large-scale soil surveys across forest types within the country and provided 39 soil profile data sets. Tsutsumi et al.[22] demonstrated that differences in soil C stock between forest types are unclear due to large variations within types; nevertheless, he observed a small soil C stock in dry dipterocarp forests, which are a typical deciduous forest in Thailand.

The REDD-scheme soil C inventory[7] requires data from soil depths of 0–30 and 0–100 cm. Toriyama et al.[18,20] studied the physico-chemical characteristics of 11 Cambodian soil profiles >100 cm deep in relation to forest type and geological formation (Tertiary and Quaternary sedimentary rocks). However, Cambodian forest soil C stocks on major basalt rock formations have yet to be surveyed.

Hence, we determined the soil C stock in tropical monsoon forests, focusing on evergreen and deciduous stands, and investigated the effects of environmental factors on the carbon stock. We also aimed at improving the soil C inventory methodology in Cambodia.

Materials and methods

Our study area spanned a range of geological formations in the lower Mekong basin in Cambodia (Fig. 1). We used six soil profiles on Quaternary sedimentary rocks[18], four on Tertiary sedimentary rocks[20], and eight over basalt. The soil profiles were analyzed by forest type (evergreen vs. deciduous) and by the forest conditions in the plots (Table 1)[17]. The basal areas per unit area of woodland were determined as indicators of forest biomass.

1. Quaternary and Tertiary sedimentary rock series

Soil profiles were constructed for the Quaternary sedimentary rock area region in Kampong Thom province[18]. The predominant soil type was Acrisol[18]. The formations were made up of extensive Quaternary sedimentary rock[24]. The mean annual temperature in the province

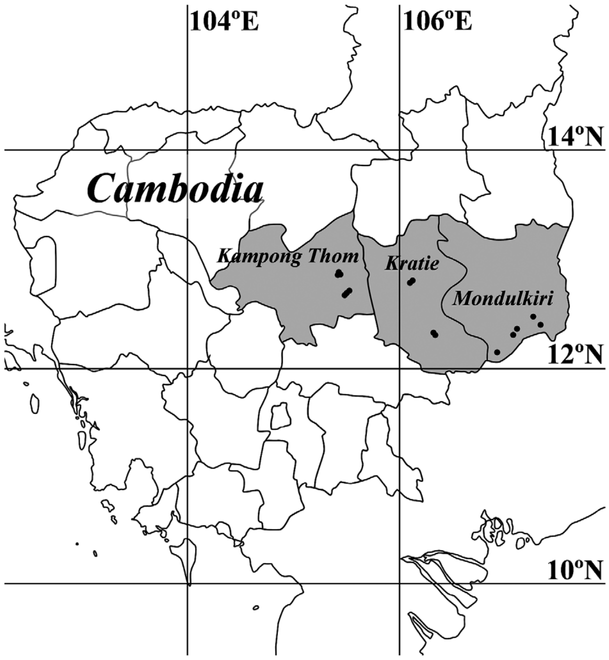

Fig. 1. Location of the study site
The dots in the map denote the location of soil profiles.

Table 1. Forest parameters in study plots

	Sedimentary rocks		Basalt	
	EFS	DFS	EFS	DFS
Stem basal area ($cm^2 m^{-2}$)	24.8 ± 11.2	9.1 ± 2.7	34.1 ± 7.8	17.9 ± 3.3
n	3[a]	5[a]	5	3
Dominant species	*Dipterocarpus costatus*	*D. obtusifolius*	*Irvingia malayana*	*Terminalia tomentosa*
	Anisoptera costata	*D. tuberculatus*	*Peltophorum dasyrrhachis*	*D. tuberculatus*
		Shorea siamensis	*Schima wallichii*	*S. siamensis*
		S. obtusa		*S. obtusa*

Modified from Tani et al.[17].
[a]: Not all plots of evergreen and deciduous-type forests were included in the forest surveys.
EFS: evergreen forest soil.
DFS: deciduous forest soil.

was 27°C. The annual rainfall was 1085–1857 mm (1994–2004)[15], with a pronounced dry season lasting from November to February. The elevation ranged from 60 to 110 m a.s.l., and the landscape relief was slightly undulating. We compiled soil data for four soil profiles in dry evergreen forest and two in dry deciduous forest.

Soil samples over Tertiary sedimentary rock were taken in Kratie province[20]. The predominant soil type was Plinthosol[20]. The formations of the Kratie area were mainly Tertiary and partly Quaternary sedimentary rocks[24]. The mean annual temperature of the province was 27°C. The annual rainfall was 1341–2530 mm (1994–2004)[15], with a dry season from December to March. The elevation of the study site was 40–70 m a.s.l., and the topography was terrace plain. Soil data were compiled from four profiles in dry deciduous forest.

2. Basalt series

Basalt areas in Kampong Thom and Mondulkiri provinces were sampled. The predominant soil type was Ferralsol[4]. The geological formation was basalt, shown as Triassic intermediate to mafic volcanic rock on the geological map[24]. The mean annual temperature of the province was 20°C in the high-elevation areas. The annual rainfall was 2250 mm[17]. Field surveys in Kampong Thom and Mondulkiri were conducted in February 2006 and May 2004, respectively. The elevation of the Mondulkiri study site was 100–900 m a.s.l., and the topography was flat terrace. After a preliminary survey, soil pits were dug, as in previous surveys[18,20]. Five soil profiles were developed for evergreen forests and three for deciduous forests. Soil pits extended down 100 cm, except for one pit (in deciduous forest) that had a continuous rock layer at a depth of 90 cm.

3. Sampling and soil analysis

Soil sampling was conducted during the middle to late dry season (from February to May). Disturbed soil samples for the total carbon content (total C) analysis of basalt sites were collected uniformly from each horizon using plastic bags; undisturbed soil samples for bulk density (BD) calculation were collected from the mid depth of each horizon using three 100-mL (19.6 cm^2 in area × 5.1 cm in depth) steel cylinders. The total C was measured by the dry combustion method (JM1000, J-Science Lab Corp.). The field water content was determined from cylinder samples, and the root content in the cylinders was measured by wet sieving (>2 mm). CN values were calculated for topsoil only because there were no data for subsoils from some of the sedimentary rock sites[18].

4. Calculation of soil carbon stock and statistical analysis

The soil C stock at 0- to 10-cm, 0- to 30-cm, 0- to 50-cm, 0- to 70-cm, and 0- to 100-cm depth ranges were calculated following classical procedures[3]. The soil C stock (Mg C ha^{-1}) in each soil horizon was calculated by multiplying the total C by BD and the thickness of the horizon. When horizons crossed a given depth, the profile was divided into two horizons whose thicknesses were measured above/below the crossing depth. The soil C density in each soil layer was calculated by dividing the C stock in each soil layer by the thickness of the soil layer.

We compared the means of groups pairwise (i.e., evergreen vs. deciduous, sedimentary rock vs. basalt) using the Wilcoxon rank sum test. Spearman's rank correlation coefficient was used for correlation analyses. Nonparametric tests were adopted because the sample sizes of soil groups were insufficient for parametric tests. All statistical analysis was conducted using R ver. 2.11 software.

Results

In general, the total C, BD, and soil C stock differed between sedimentary rock (n = 10) and basalt (n = 8) formations. Hence, we compared evergreen and deciduous forest soils (EFS and DFS, respectively) by geological group. The mean soil C stocks of EFS (n = 9) and DFS (n = 9) were also calculated for the 0- to 30-cm and 0- to 100-cm depth ranges, respectively.

1. Total C and BD

EFS tended to have a higher total C than DFS in both the sedimentary rocks and basalt groups, although the difference was not significant. The total C was generally higher in basalt than in sedimentary rock formations (Fig. 2). Significant differences in the mean total C were found between sedimentary rock and basalt formations within each soil layer [0–10 cm ($p < 0.001$), 10–30 cm ($p < 0.01$), and 30–50 ($p < 0.05$) cm].

BD was not clearly different between forest types within geological formations (Fig. 3). The vertical change in BD within the 10- to 100-cm depth range was smaller in EFS than in DFS. The mean BD was higher in the sedimentary rock formation than in the basalt formation in the 0- to 50-cm ($p < 0.001$) and 70- to 100-cm ($p < 0.01$) depth ranges.

2. Soil C density and cumulative soil C stock

The EFS C density in the sedimentary rock group was higher than the DFS C density on sedimentary rocks (significant at the 10- to 30-cm and 70- to 100-cm depth ranges, Table 2). The C density of EFS in the basalt group also tended to be higher than the DFS C density on basalt (significant in the 70- to 100-cm depth range (Table 2).

The difference in the cumulative soil C stock between forest types within geological groups increased with the soil profile depth. EFS tended to have a larger C stock than DFS within geological formations, although the difference was not significant (Table 2). The ratio of mean EFS C stock to DFS C stock (EFS/DFS) increased with a depth from 1.3 (0–10 cm) to 2.0 (0–100 cm) in the sedimentary rock group, and from 1.1 (0–10 cm) to 1.7 (0–100 cm) in the basalt group.

The mean C stocks of EFS and DFS were 56.9 ± 30.0 and 34.9 ± 23.5 Mg C ha^{-1}, respectively, for the 0- to 30-cm depth range (not significantly different), and 108.7 ± 53.0 and 53.2 ± 30.4 Mg C ha^{-1}, respectively, for the 0- to 100-cm depth range (significantly different, $p < 0.05$).

3. CN ratio in topsoil, root content, and field water content

DFS (18.7 ± 1.2) had a higher mean CN ratio than did EFS (13.5 ± 2.6; $p< 0.05$) in the basalt group; no significant difference was found within the sedimentary rock group between EFS (25.9 ± 2.2) and DFS (22.3 ± 10.0).

DFS tended to have higher root content in the 0- to

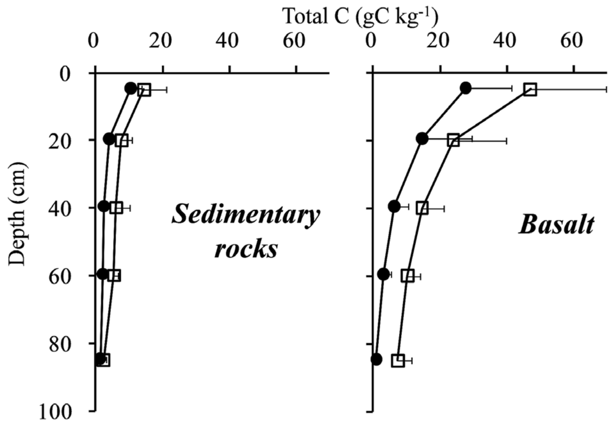

Fig. 2. Change in total C with depth
Error bar = SD.
The original soil profile data are categorized by soil layer at corresponding depths.
—□— : EFS, —●— : DFS.

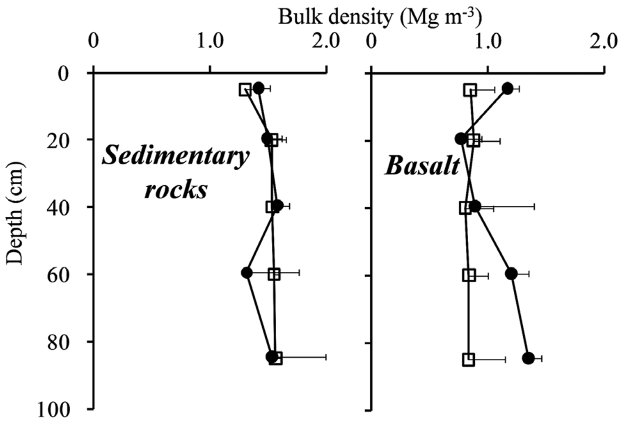

Fig. 3. Change in bulk density with depth
Error bar = SD.
The original soil profile data are categorized by soil layer at corresponding depths.
—□— : EFS, —●— : DFS.

Table 2. Soil C density and cumulative soil C stock in evergreen (EFS) and deciduous (DFS) Cambodian forest soils

	Depth (cm)	Sedimentary rocks				Basalt			
		EFS	DFS	All	p*	EFS	DFS	All	p*
Soil C density (Mg C ha^{-1}cm^{-1})	0−10	1.66 ± 0.65	1.27 ± 0.43	1.43 ± 0.53	0.48	3.56 ± 1.30	3.18 ± 1.39	3.42 ± 1.25	0.79
	10−30	1.13 ± 0.47	0.54 ± 0.20	0.78 ± 0.43	0.04	1.77 ± 1.07	1.29 ± 0.80	1.59 ± 0.95	0.79
	30−50	0.89 ± 0.55	0.35 ± 0.20	0.57 ± 0.45	0.11	1.13 ± 0.63	0.53 ± 0.32	0.91 ± 0.59	0.39
	50−70	0.60 ± 0.30	0.23 ± 0.14	0.38 ± 0.28	0.05	0.87 ± 0.43	0.37 ± 0.29	0.68 ± 0.44	0.25
	70−100	0.40 ± 0.13	0.17 ± 0.07	0.26 ± 0.15	0.02	0.67 ± 0.29	0.11 ± 0.02	0.46 ± 0.36	0.04
Cumulative soil C stock (Mg C ha^{-1})	0−10	16.6 ± 6.5	12.7 ± 4.3	14.3 ± 5.3	0.48	35.6 ± 13.0	31.8 ± 13.9	34.2 ± 12.5	0.79
	0−30	39.2 ± 15.3	23.6 ± 7.9	29.8 ± 13.3	0.11	71.1 ± 32.6	57.7 ± 29.8	66.0 ± 30.2	0.79
	0−50	56.9 ± 26.3	30.6 ± 11.9	41.1 ± 22.2	0.17	93.7 ± 43.0	68.3 ± 36.1	84.2 ± 40.0	0.57
	0−70	68.9 ± 32.2	35.2 ± 13.5	48.7 ± 27.4	0.17	111.0 ± 49.6	75.7 ± 40.4	97.8 ± 47.0	0.57
	0−100	80.8 ± 35.3	40.2 ± 14.1	56.5 ± 31.1	0.07	131.0 ± 57.3	79.0 ± 41.1	111.5 ± 55.5	0.25
n		4	6	10		5	3	8	

Mean ± SD.
p-values are derived from Wilcoxon tests for significant differences between EFS and DFS by soil-depth range.

10-cm depth range and lower content in the 10- to 100-cm depth range than did EFS in both the sedimentary rock and basalt groups, although the trend was not significant except for the 50- to 70-cm depth range within the sedimentary rock group ($p < 0.05$; Table 3).

EFS had generally higher field water content than did DFS in both the sedimentary rock and basalt groups (Table 3). The difference between EFS and DFS was significant in the upper soil layers (0–30 cm, $p < 0.05$) in the sedimentary rock group. EFS had significantly higher field water content than did DFS in the lower soil layers (70–100 cm, $p < 0.05$) in the basalt group.

4. Relationships between soil and forest parameters

Spearman's rank correlation coefficients for relationships between properties of topsoil and basal area ($cm^2\ m^{-2}$) are presented in Table 4. The soil C stock was highly correlated with field water content and basal area, but not with CN value or root content.

Discussion

Below, we compare soil C stock in Cambodian tropical monsoon forests with soil C stock in forests in Thailand and in humid tropical regions. Subsequently, we consider environmental factors that affect soil C stock in tropical monsoon forests and offer recommendations for the development of forest soil C inventories.

We re-arranged a dataset from Thailand[21] for comparison with our study (Table 5). We analyzed 27 Thai soil profiles from lowland monsoon forest, six from evergreen forest (dry evergreen forest), and 21 from decidu-

Table 3. Root content and field water content in Cambodian evergreen and deciduous forest soils

	Depth (cm)	Sedimentary rocks				Basalt			
		EFS	DFS	All	p*	EFS	DFS	All	p*
Root content ($kg\ m^{-3}$)	0−10	3.47 ± 0.91	5.07 ± 1.98	4.47 ± 1.78	0.25	4.25 ± 3.23	5.70 ± 3.25	4.79 ± 3.09	0.79
	10−30	1.40 ± 0.90	3.16 ± 3.00	2.50 ± 2.49	0.57	3.02 ± 3.22	1.10 ± 0.91	2.30 ± 2.67	0.39
	30−50	4.57 ± 2.04	1.38 ± 1.48	2.58 ± 2.27	0.07	1.68 ± 2.87	0.06 ± 0.09	1.07 ± 2.32	0.14
	50−70	2.15 ± 1.35	0.42 ± 0.43	1.06 ± 1.19	0.04	1.29 ± 1.71	0.18 ± 0.15	0.88 ± 1.42	0.79
	70−100	0.72 ± 0.72	0.17 ± 0.15	0.38 ± 0.49	0.14	0.60 ± 1.09	0.13 ± 0.11	0.42 ± 0.86	0.57
Field water content (cm^3cm^{-3})	0−10	0.194 ± 0.037	0.079 ± 0.041	0.122 ± 0.070	0.04	0.354 ± 0.063	0.249 ± 0.088	0.315 ± 0.086	0.13
	10−30	0.200 ± 0.039	0.116 ± 0.013	0.147 ± 0.050	0.04	0.373 ± 0.065	0.265 ± 0.071	0.333 ± 0.084	0.14
	30−50	0.195 ± 0.032	0.151 ± 0.013	0.168 ± 0.030	0.14	0.362 ± 0.066	0.296 ± 0.058	0.337 ± 0.068	0.39
	50−70	0.197 ± 0.026	0.164 ± 0.013	0.176 ± 0.024	0.10	0.345 ± 0.069	0.274 ± 0.062	0.319 ± 0.072	0.25
	70−100	0.200 ± 0.025	0.202 ± 0.015	0.201 ± 0.018	1.00	0.334 ± 0.061	0.161 ± 0.031	0.269 ± 0.102	0.04
n		3	5	8		5	3	8	

Mean ± SD.
p-values are derived from Wilcoxon tests for significant differences between EFS and DFS by soil-depth range.

Table 4. Spearman's rank correlation coefficients among soil and forest parameters

	TC_{top}	BD_{top}	CN_{top}	$Root_{10}$	$Water_{10}$	BA
SCS_{10}	0.95***	-0.74***	-0.49	-0.19	0.77***	0.46*
TC_{top}		-0.90***	-0.59	-0.10	0.78***	0.55*
BD_{top}			0.57	0.10	-0.80***	-0.71**
CN_{top}				0.07	-0.38	-0.44
$Root_{10}$					-0.35	-0.42
$Water_{10}$						0.80***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
TC_{top}, BD_{top} and CN_{top} : Total carbon, bulk density and CN value of topsoil, respectively.
SCS_{10}, $Root_{10}$, $Water_{10}$: soil carbon stock, root content, and field water content of soil in the 0−10-cm depth respectively, respectively.
BA: Basal area of forest plot.

ous forest (11 in deciduous dipterocarp forest and 10 in mixed deciduous forest). These profiles were distributed between sandstone and conglomerate (*n* = 23) and limestone (*n* = 4).

1. Soil C stock in tropical monsoon forests

Our Cambodian estimates of soil C stock are close to those from Thai sites with similar geological features. Our mean soil C stock estimates (0- to -30-cm depth range) for EFS and DFS in the sedimentary rock group were similar to the mean values for the Thai evergreen and deciduous forests on sandstone and conglomerate (36.4 ± 9.6 and 24.0 ± 9.8 Mg C ha^{-1}, respectively) (Table 5). However, Cambodian estimates for EFS and DFS in the basalt group (no data are available for Thai basalt) exceeded all estimates from Thailand, except those from deciduous forests on limestone (Table 2, Table 5). We therefore propose that soil C stocks are similar within forest and geological groups across the tropical monsoon region of the Indochina peninsula.

The soil C stock of Cambodian evergreen forests in our study area was larger than in the primary forests of the Southeast Asian humid tropics, even though there is a global trend for increasing soil C stock with increasing precipitation[13]. The estimated soil C stocks for the 0- to 30-cm depth range were 26.8 Mg C ha^{-1} in Southern Thailand[22] and 29.9 Mg C ha^{-1} in East Kalimantan[28]. Within the 0- to 100-cm depth range, estimates were 55.0 Mg C ha^{-1} in East Kalimantan[28] and 70.0 Mg C ha^{-1} in peninsular Malaysia[27]. The studies mentioned above did not report C stocks in the 0- to 100-cm depth range of Andosols and Andisols[12,26], although these are the largest stocks (>200 Mg C ha^{-1}) in the humid tropics. In brief, the soil C stock in Cambodian monsoon evergreen forests exceeded that of Southeast Asian humid tropics (with the exception of the Andosols group).

For the REDD scheme, soil C stock should be discussed as a component of the forest ecosystem C pool. Kiyono et al.[14] estimated the four C pools (tree and understory biomass, litter, and deadwood) for evergreen and deciduous forests in Cambodia as 223.6±35.7 (*n* = 5) and 144.4±45.6 (*n* = 6) MgC ha^{-1}, respectively. Using the mean values of Kiyono et al.[14] and the soil C stock of this study (0–30 cm depth), the forest ecosystem C stock was estimated as 280.5 (20.3 % in soil C) and 179.3 (19.5 %) Mg C ha^{-1} for evergreen and deciduous forests, respectively, and the soil C was the second largest C pool in the forest ecosystem, following tree biomass C.

2. Factors affecting soil carbon stock in tropical monsoon forests

At our Cambodian sites, soil water content in the dry season was highly correlated with soil C stock. Combined Cambodian and Thai soil data (0- to 30-cm depth range) also showed a high correlation between soil C stock and soil water stock (Fig. 4) regardless of differences in sampling periods. Tsutsumi et al.[22] indicated that differences in field water content between study sites were caused by differences in precipitation.

Variations in soil moisture conditions that we measured under similar Cambodian climatic conditions may be attributable to two key factors: openness of the forest

Table 5. Site description for a Thai soil dataset

		Sandstone and conglomerate				Limestone		
		DEF	MDF	DDF	All	DEF	MDF	All
Basal area ($cm^2 m^{-2}$)		43.2	33.4 ± 6.4	19.6 ± 2.4	29.4 ± 9.8	–	–	–
n		1	4	3	8			
A_0 horizon (Mg ha^{-1})		3.99 ± 0.26	3.48 ± 1.52	1.36 ± 0.44	2.65 ± 1.51	2.06	1.21 ± 0.64	1.49 ± 0.67
n		3	6	7	16	1	2	3
Soil C stock (Mg C ha^{-1})								
Depth (cm)	0−10	19.8 ± 4.8	14.9 ± 4.0	13.0 ± 4.9	14.9 ± 5.0	19.4 ± 1.4	31.4 ± 1.6	25.4 ± 7.0
	0−30	36.4 ± 9.6	27.6 ± 9.8	21.5 ± 9.4	26.2 ± 10.7	34.3 ± 7.5	74.1 ± 3.3	54.2 ± 23.5
	0−50	47.0 ± 16.1	35.8 ± 15.6	26.3 ± 12.9	33.2 ± 15.8	42.4 ± 13.3	99.0 ± 6.4	70.7 ± 33.8
	0−70	55.7 ± 23.7	42.0 ± 17.8	28.5 ± 13.6	37.9 ± 19.2	48.0 ± 21.1	109.9 ± 18.8	78.9 ± 39.3
n		4	8	11	23	2	2	4

Modified from Tsutsumi et al.[21, 22, 23].
Mean ± SD.
DDF: deciduous dipterocarp forest, MDF: mixed deciduous forest, DEF: dry evergreen forest.

canopy and clay content of the soil. Deciduous forests have a more open canopy than evergreen forests[10,21], and the greater loss of soil moisture in deciduous forests is likely caused by high rates of evaporation from the forest floor[8]. Litter decomposition in deciduous forests may be suppressed to a greater extent (during prolonged dry periods) than in evergreen forests, and remained litter is frequently burned in annual forest fires[22]. A series of processes related to the openness of deciduous canopies likely depresses both soil water content and the mechanism by which C is supplied to the soil.

In mid or late dry season in tropical monsoon regions, the proportion of water absorbed on the surface of clay particles may exceed that of capillary water (i.e., matric potential is <-100 MPa, taking into account both field water content and soil water retention curves)[19]. Increases in the surface area of clay particles (a major site of C sequestration) may increase soil C stock[12,28]. Accordingly, differences in field water content between forest types in the dry season may reflect differences in soil clay content. Under similar climatic conditions in Kampong Thom province, Cambodia, clayey soil (such as Ferralsols) is derived from basalt, and relatively sandy soil (such as Acrisols) derives from sedimentary rocks[4]. The higher field water content of soils in the basalt group (Table 3) might also result from differences in clay content between the two geological formations. In short, variation in soil water conditions in the dry season indirectly indicates the environmental conditions that promote/inhibit accumulation of soil organic C in tropical monsoon regions.

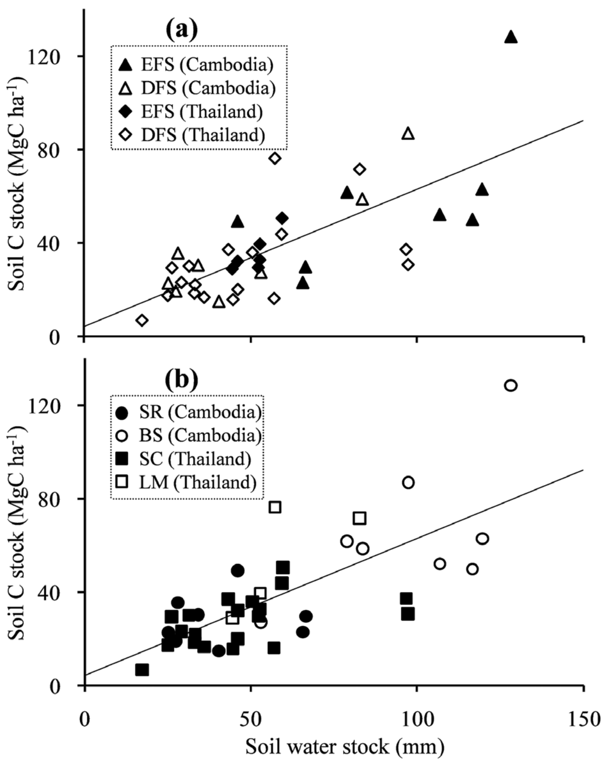

Fig. 4. Relationship between soil water content and soil C stock (0- to 30-cm depth range)

(a): For different forest types, (b): For different geological groups.
In 0- to-30-cm in depth.
Y: 0.585X + 4.38, r^2: 0.52.
EFS: evergreen forest soil, DFS: deciduous forest soil, SR: sedimentary rocks, BS: basalt, SC: sandstone and conglomerate, LM: limestone.

Conclusion

We estimated the soil C stocks in evergreen and deciduous forests in the tropical monsoon regions of Cambodia. The mean C stocks of the evergreen and deciduous forest soils were 56.9 ± 30.0 and 34.9 ± 23.5 Mg C ha^{-1}, respectively, in the 0- to 30-cm depth range, and 108.7 ± 53.0 and 53.2 ± 30.4 Mg C ha^{-1}, respectively, in the 0- to 100-cm depth range. The soil C stocks were comparable to those of similar forests and geological formations in Thailand, and higher than those in Southeast Asian humid tropics (except in Andosols). Soil C stock was highly correlated with soil water content in the dry season, which in turn is thought to be related to forest canopy openness and soil clay content, which is likely an indicator of conditions for the accumulation of soil organic C in tropical monsoon regions.

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