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Ecological Value of Soil Organic Matter at Tropical Evergreen *Aglaia-Streblus* Forest of Meru Betiri National Park, East Java, Indonesia

Hari Sulistiyowati[1], Sugeng Winarso[2], Damasa Macandog[3], Rachel Sotto[3],
Nestor Baguinon[3], Inocencio Buot Jr.[3]

[1]Biology Department, MIPA Faculty, The University of Jember, Indonesia
[2]Agriculture Faculty, The University of Jember, Indonesia
[3]Plant Biology Division, Institute of Biological Sciences, College of Arts and Sciences, The University of The Philippines Los Banos (UPLB), Philipinne.

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ABSTRACT

As part of carbon pools, forest soil stores soil organic matter (SOM) that contains many elements including organic C, N, P, and K. These elements contribute nutrients for biogeochemical cycles within the ecosystem. This study was done to determine the ecological value of forest soil organic matter at tropical evergreen *Aglaia-Streblus* forest of Meru Betiri National Park (MBNP), East Java, Indonesia. The data were sampled along gradient topography in Pringtali tropical forest of TMBNP. Direct measurements of soil moisture, temperature, and pH were taken in the field. The soil samples were extracted from 6 points of soil solum using soil auger, and then oven-dried to get value of dry-weight. The elements content of organic C, N, P, and K were analyzed and estimated at the laboratory. The ecoval of SOM was appraised using developed ecological valuation tool. The result showed that SOM contributed higher ecoval of organic C (66.03 Mg ha^{-1}) than other elements. Compared to P and K elements, N had the highest stock of element content. However, comparing to other two tropical forest ecosystems of Asia the ecoval of SOM elements in TMBNP was relatively low because of its natural geomorphological features.The ecoval of SOM elements in TMBNP was relatively low because of its natural geomorphological features. The ecovals contributed about 2.440,64 - 6.955,50 USD or 31.271.923,73 - 89.120.837,23 IDR per hectare of ecological value (d) to the ecosystem. This value was mainly contributed by organic C stock in the TMBNP forest SOM. It means the forest SOM had higher element content of organic C than N, P, and K elements. This d value is an indicator for TMBNP to protect the SOM elements meaning protecting their resources to sustain the biogeochemical cycles in the forest ecosystem. All the management and policy correlated to this protected area should consider this valuable information for their plan and actions.

Keywords: Biogeochemical, ecological valuation, ecological value, ecoval, SOM

ABSTRAK

Bahan organic tanah (BOT) khususnya di kawasan hutan tropis selain mengandung C-organik juga mengandung elemen-elemen an-organik seperti N, P, dan K yang dibutuhkan oleh tumbuhan. Elemen-elemen ini memiliki nilai dan peran penting dalam siklus biogeokimia dalam ekosistem hutan. Penelitian ini dilakukan untuk menghitung nilai ekologi BOT di hutan hijau sepanjang tahun *Aglaia-Streblus*, Taman Nasional Meru Betiri (TNMB) Jawa Timur, Indonesia. Sampling data dilakukan sepanjang gradien topografi kawasan hutan ini. Pengukuran kelembaban tanah, suhu, dan pH diambil secara langsung dari kawasan sebanyak tiga ulangan. Solum tanah diukur pada 6 titik dengan menggunakan auger, sekaligus sampling tanah untuk analisis laboratorium C, N, P, dan K. Nilai ekologi (*ecoval*) BOT ini dinilai dengan menggunakan formula valuasi ekologi yang telah dikembangkan. Hasil penelitian menunjukkan bahwa kandungan elemen C organik (66,03 Mg.ha^{-1}) lebih tinggi daripada elemen lainnya. Elemen N memiliki stok yang lebih tinggi dibandingkan elemen P dan K. Namun demikian dibandingkan dengan dua ekosistem hutan tropis Asia lainnya, nilai ekologi elemen BOT kawasan TNMB masih relatif rendah hal ini lebih dipengaruhi oleh karakter geomorfologi tanahnya. Valuasi ekologiBOT di kawasan ini menunjukkan bahwa nilai ekologi BOT berkontribusi sebesar ±2.440,64-6.955,50 USD atau 31.271.923,73-89.120.837,23 IDR per hektar. Kontribusi terbesar nilai BOT ini adalah oleh nilai ekologi elemen C organik yang tersimpan. Nilai *ecoval* ini merupakan indikator bagi TNMB untuk melakukan proteksi terhadap elemen BOT yang berarti juga perlunya melakukan konservasi terhadap sumber-sumber

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pensuplai BOT agar siklus biogeokimia dalam ekosistem hutan ini secara berkelanjutan. Semua manajemen dan kebijakan yang berkaitan dengan kawasan lindung harus mempertimbangkan informasi penting nilai ekologi tersebut dalam perencanaan dan aktivitasnya.

Kata Kunci: Biogeokimia, BOT, nilai ekologi, *ecoval* dan valuasi ekologi

INTRODUCTION

As habitat of any living organisms at the forest ecosystem, soils not only provide organic matter or nutrients but are also protection for plant roots, insects, vermes, or others that live within forest soils. Forest soils play important roles in the formation of vegetation composition and structure within forest ecosystem (Lasky *et al.* 2014). They also support integrated ecological processes resulting in plants-soils feedback especially for carbon cycles (Schimel, 1995; Jabaggy and Jackson, 2000; Mi-Youn *et al.* 2009). Therefore most scientists proposed soils as supporting services within forest ecosystem (MEA 2005; Costanza *et al.* 1997; Carrasco *et al.* 2014; Costanza *et al.* 2014; Strassburg *et al.* 2014). Biogeochemical processes within forest ecosystem initiate the soils in stocking more carbon held in the form of organic matter than living organism (Eswaran *et al.*1993). The soil organic matter which includes all the dead organic compounds in soil, in all states of decay, ranging from plant and animal residues, to cells soil microorganisms, and to subtances that are so well-incoporated within soil mass is one of largest carbon sinks.

The ecological value of carbon stocks within the soils is influenced by the total organic matters inputs, controlled vegetation structure, and productivity at the forest ecosystem. However, climate factors such as temperature and moisture also play important roles in organic matter decomposition within forest soils initiated by the microbial community actions (Xiao *et al.* 1998; Raich and Tufekcioglu 2000). Mineralization of SOM through soil respiration activities of microbes or decomposers contributesto the rising concentration of CO_2 in the atmosphere (Raich and Tufekcioglu 1992; Trumbore *et al.* 1996; Schlesinger and Andrews 2000); therefore, they are one of the carbon pools controling carbon balance in the forest ecosystem.

As suggested by Philips *et al.* (1998) and Smith (2004), both vegetation and soils are viable pools of atmospheric carbon. It means that these pools play important roles in global warming mitigation. Therefore, it is interesting to get information on how much worth is carbon stocks of soils as a product of the ecological process within tropical forest ecosystem. This is quite difficult to answer because so far, soils are already understood as supporting services. Knowing the ecological value of carbon stocks in the soils will enhance our attention to monitor, control, or protect them for forest investment or carbon trading through conservation management and policy. This study was done to determine ecological value

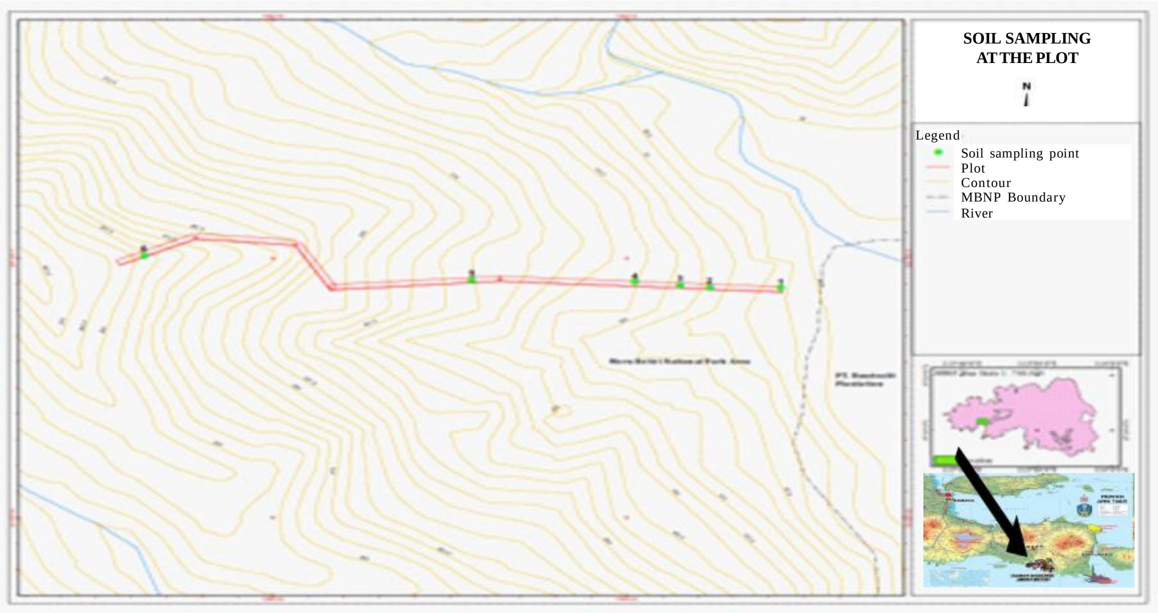

Figure 1. The soil sampling design within 100 ×10m^2, green points represent 6 soil pits at study site (digitized map of location was provided by TMBNP).

of forest soil organic matter (SOM) at tropical evergreen Aglaia-Streblus forest of Meru Betiri National Park, East Java, Indonesia.

MATERIALS AND METHODS

Study Area

The soil samples were taken from within the study area of Pringtali tropical forest of TMBNP (east Java) at 8,46887° LS - 113,70388° BT dan 8,46799° LS - 113,71300° BT. The location is a humid tropical forest with annual precipitation of about 2.544 - 3.478 mm yr^{-1}, and slopes are 30-98°. The six coring pits were selected based on the dominant plant species cover and tracked using handy GPS Garmin C60 within the 100 × 10 m^2 plot as seen at Figure 1.

The first coring was taken under *Schizostachyum zollingeri* and *Sterblus spinosus*, the second was *Caryota mitis* and *Grewia koordersiana*, the third was *Ficus hispida* and *Pterospermum javanicum*, the fourth was *Cleistanthus sumatranus* and *Pterospermum acerifolium*, the fifth was *Panicum repens* and *Leea indica*, and the sixth was *Trema orientalis* and *Syzygium polyanthum*. The variety of soil samples from these different canopy covers can give a good total average ecovals of soil organic matter and its elements content.

Soil Sampling

Direct measurements of soil moisture, temperature, and pH were taken in the field (Figure 2A). Using soil borer/auger, the soil solum was digged and each soil pit was extracted for sample analysis. Three coring The length of the extracted core was measured for soil depth increment estimation and then 100 g soil sample representative of top- and sub-soils of the solum was taken (Figure 2B, C, and D). The soil samples were then air-dried, homogenized and sieved to pass a 2 mm mesh sieve for further analysis (Akbar *et al.* 2010). The soil samples were dried for 2 hours in a conventional oven at 105 °C for dry weight estimation (Skjemstad and Baldock 2008).

Estimation of C, N, P and K Content within SOM

Soil organic matter (SOM) was analyzed using the most common soil test for carbon wet oxidation method BOT of Walkley and Black (1934). Furthermore, N-total was analyzed using Kjeldahl method (Yeomans and Bremner 1988), P in the form of P_2O_5 was analyzed using Olsen or Bray-1 (McDowell and Sharpley 2001), and finally K in the form of K_2O was analyzed using ammonium pH 7 extract and then measured using AAS (Atomic Absorption Spectrometry). All the analyses were performed in duplicate at the Laboratory of Soil Science, Agricultural Faculty of Jember University, Jember, East Java, Indonesia. The bulk density was determined based on the dry mass of total soil material of each depth increment. The estimated elements of SOM which were Organic C, N, P, and K consentrations were used to calculate their total weights in Mg per ha metric unit.

Results were presented as means and standard deviation unless indicated differently. The organic C, N, P, and K stocks for fixed soil volumes of solum (top and sub soils) were calculated based on bulk density, solum thickness, and element concentration (Schrumpf *et al.* 2011). The equivalent soil masses per area werecarried out based on cumulative fine earth masses per area of the soil layers of each soil core in tonne per ha (Ellert and Bettany 1995). These organic C, N, P, and K elements estimation can be seen in formulas as follows:

$$\text{Organic C weight Mg ha}^{-1} = \%\ \text{Organic C x soil weight Mg ha}^{-1}$$
$$\text{N-total weight Mg ha}^{-1} = \%\ \text{N-total x soil weight Mg ha}^{-1}$$
$$P_2O_5\ \text{weight Mg ha}^{-1} = P_2O_5\ \text{ppm x soil weight Mg ha}^{-1}/10{,}000$$
$$K_2O\ \text{weight Mg ha}^{-1} = (K^+\ \text{me100 g}^{1}\ \text{x soil weight Mg ha}^{-1})/(2*100)$$

The standing litterfalls at the O horizon layer which are not incorporated within the soil solum was

Figure 2. (A.) Direct measurements of soil temperature, moisture, and pH; (B.) Soil coring at the site; (C.) extracted soil sample from the pit;(D.) SS is soil solum; r is regolith.

already discussed in ecoval necromass carbon pool estimation, therefore this study was done to examine the organic C, N, P, and K stocks concentrations within the solum which are the decomposed or weathered solid soil mass as a reference. The plant roots, rhizomes or tubers as below ground biomass were not included in the sampling and discussion in this forest soil carbon pool.

SOM Elements (C, N, P, K) Appraisal

Cost based approach which is cost of measures taken to maintain or replace forest goods and services in valuation methods that have been discussed in many studies (Turner *et al.* 2003; Chee 2004; Pak *et al.* 2010; Kiran and Malhi 2011; Diamini 2012) was used to appraise SOM elements in this study. This approach actually refers to the use of the national standard price of N, P, and K fertilizer in the market.

As supporting services, forest soils are not yet valued in ecological economic. In ecological valuation perspective, there is a need to appraise SOM considering that it contains available elements. For this purpose, this developed equation focused on Organic C and N, P, and K nutrients stored in incorporated soil. Cost based approach and simple arithmetic model were used to appraise SOM elements based on the base value of fertilizer trade price to determine its ecological value (ecoval) as follows

$$\text{I€ (USD)} = \{bS*E\} + \{bF*3.667W\}$$
$$= \{(bSN*N)+(bSP*P)+(bSK*K)\}+\{(c+o)*3.667W)\}$$

Where d is ecoval in USD, S is ecological structure value, Fis ecological function value in USD, *b*S is ecological base value of S in USD referring to basic replacement NPK fertilizer price, E is the elements (N, P, K or others) content of SOM which is the weight of N, P, K or others in Mg, *b*F is ecological base value of F in USD, c is carbon credit, o is ecological resource offset, 3.667 is conversion of C to carbon dioxide, W is dry weight of organic C in Mg.

The ecological base value of structure refers to base value of structure in USD currency of N, P, and K elements of SOM taken from NPK price stated in the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 130/Permentan/SR.130/11/2014 (MOAGRI 2014). The rated price in this regulation is in IDR converted into USD. The composition of 16-16-16 NPK (16%N, 16% P_2O_5, 16% K_2O)fertilizer as much as 0.18-0.51 USD per kg was used as comparable price market (currency 1 USD=12,813 IDR per 23th February 2015). Based on the percentage (16%) composition and its chemical weight (N is 2.24; P of P_2O_5 is 0.437, K of K_2O is 0.829), the prices of elemental N, P, and K can be calculated at about 0.024 – 0.067 USD per kg, 0.013–0.036 USD per kg, and 0.024–0.067 USD per kg, respectively.

The ecological base value of function can be charged by carbon credit (c) based on carbon content pricing and/ or resource offset based on transaction cost in USD. The standard price of carbon credit which is in the range of 7-20 USD Mg CO_2 prices was taken from the Consolidation Report: Reducing Emissions from Deforestation and Forest Degradation in Indonesiapublished by FORDA Indonesia (MOFOR 2008). Therefore 3.667 was used to convert carbon content into CO_2

Figure 3. The variation of soil solum depths (red line double arrow).

Table 1. Analyzed variables of soil solum and textures at the top- and sub-soil of MBNP forest ecosystem.

Parameters	Solum (20-80 cm)	
	Top Soil (10-20 cm) (Mean±SD)	SubSoil (10-60 cm) (Mean±SD)
Solum depth	15±4.47	33.33±22.73
Sandy (%)	39.27±10.87	43.2±15.38
Silt (%)	33.51±11.02	30.18±8.06
Clay (%)	27.22±6.96	26.62±8.39
Texture	CL	CL

to calculate the *b*F. The ecological resource offset (o) was taken from the standard commonly used to ratify transaction cost of forest carbon offset which is in the range of 4-15 USD Mg CO_2 prices (Wertz-Kanounnikoff 2008).

RESULTS AND DISCUSSION

The Physical Character of Forest Soil

Forest soil horizon layers of TMBNP are not well-developed therefore the soil type was categorized as entisol or alluvial. The soil solummeasured at the study site varied in depth ranges of 20-80 cm that consisted of top-soil at the range of 10-20 cm and sub-soil at the range of 10-60 cm (Figure 3 and Table 1). The surface contours were undulating to straight line with degree of slopes varied from 30-90^o (Figure 4).

Soil textures at two layers of solum were analyzed as clay loam (CL) at both the top and sub soils as reported in Table 1. Mean pH ranged from 5.8 to 6.5. The forest soils during the sampling werere latively moist to wet, therefore the mean soil humidities were relatively high within the range of 72 to 100% and the mean soil temperatures of the study site varied from 24.2 to 28.0 ^oC.

The bulk density of soil was 1.1 g cm^{-3} determined based on the dry mass of total soil material of each depth increment. Using this value, the total average weight of soil solum at MBNP can be calculated at about 5316.67 Mg ha^{-1}which

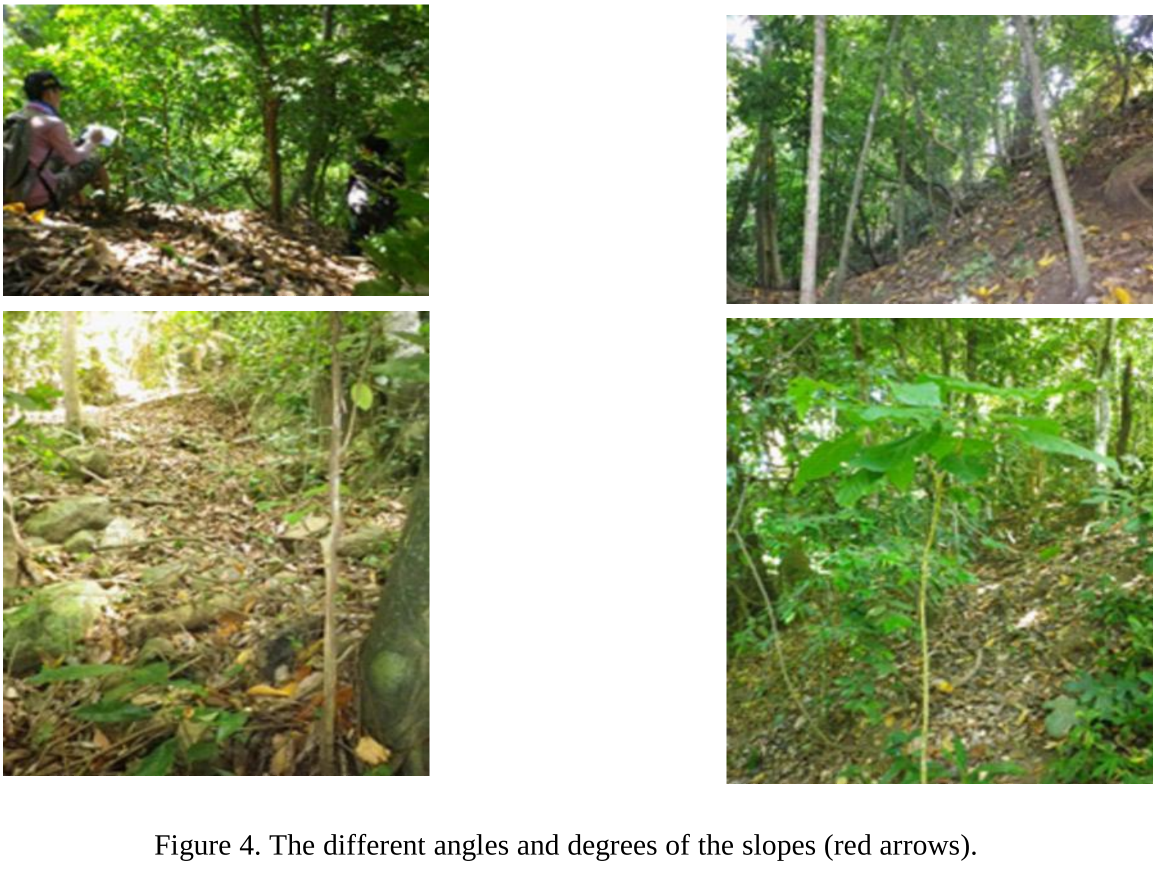

Figure 4. The different angles and degrees of the slopes (red arrows).

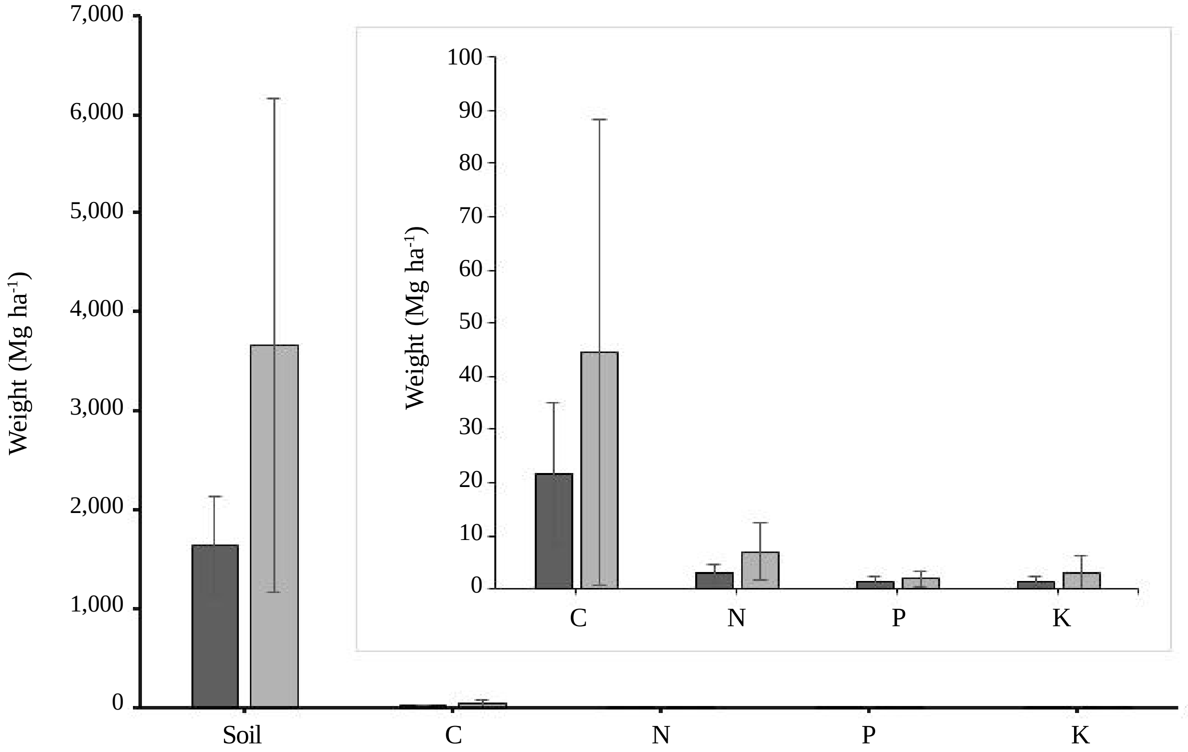

Figure 5. Analyzed variables of SOM elements content at the top- and sub-soil of MBNP forest ecosystem.

was accumulated by 1650 Mg ha^{-1} at the top-soil and 3666.67 Mg ha^{-1} at the sub-soil (Table 1).

The Dynamics of SOM

Based on soil analysis, the solum contained about 2.51% of organic C which was accumulated from organic C in total which 1.34% was contributed from the top-soil and 1.17% was contributed from the sub-soil (Figure 5). These little values might be influenced by active soil respiration by living organisms within the forest soil that release organic C in the form of CO_2 to the atmosphere. As a consequence, the total C-weight 64.03 Mg ha^{-1} within the solum and within both of top- (21.63 Mg ha^{-1}) and sub-soil (44.40 Mg ha^{-1}) were low too. The total organic C was almost close to the one found (65.8 Mg ha^{-1}) in fluvisol soils (similar to alluvial based on FAO soil taxonomy) of Miombo Woodland Ecosystem, Tanzania (Shelukindo *et al.* 2014a and 2014b). However it was low compared

Table 2. Total ecoval of SOM (d_{SOM}) within TMBNP.

Parameter Equation		Top Soil		Sub Soil		Total Forest Soils	
	Elements	Min	Max	Min	Max	Min	Max
bS(USD)	N	196,31	556,21	445,47	1.262,18	641,78	1.818,39
	P	6,98	19,78	10,56	29,93	17,54	49,71
	K	26,22	74,28	60,24	170,67	86,45	244,95
	∑	229,51	650,27	516,27	1.462,77	745,78	2.113,04
bF(USD)	c	555,31	1.586,59	1.139,55	3.255,87	1.694,86	4.842,46
	o	317,32	1.189,94	651,17	2.441,90	968,49	3.631,84
	∑	872,62	2.776,53	1.790,73	5.697,77	2.663,35	8.474,30
I€$_{SOM}$ without o (USD)	bS + bF	784,81	2.236,86	1.655,83	4.718,64	2.440,64	6.955,50
I€$_{SOM}$ with o (USD)	bS + bF	1.102,13	3.426,80	2.307,00	7.160,54	3.409,13	10.587,34

Note: *b*S is ecological base value of structure, *b*F ecological base value of function, c is carbon credit of organic C content, o is ecological resource offset, d_{SOM} is ecological value of SOM, min is minimum price/cost charged, max is minimum price/cost charged.

to tropical soils which was about 130–160 Mg ha^{-1} (Jabbagy and Jackson 2000).

In the estimations of elements content in the form of N, P (P_2O_5), and K (K_2O) within soil solum soil depth (top- or sub-soils), soil volume (1.1 gr cm^{-3}), and soil weight were used (Table 1). The SOM content analysis show that total average of N weight within sub-soil was higher than that of N weight within top-soil (Figure 5). The variable data of N weight was high both top and sub soil. The total weight of N at the study site was 10.13 Mg ha^{-1} deposited by 3.10 Mg ha^{-1} and 7.03 Mg ha^{-1} of the top- and sub-soils, respectively. Comparing both N and P, P in the form of P_2O_5, the lowest in weight was within soil solum. The high range of standard deviation of the sampled data indicated that the mean data genuinely varied based on the elevation of the area, or it could be due to one or more outliers as a single outlying value will shift the mean and substantially increase the standard deviation.

Appraisal of SOM Ecoval

Total of 79.77 Mg ha^{-1} soil organic matter of all elements content accounted about 2.440,64 - 6.955,50 USD per ha or 31.271.923,73 - 89.120.837,23 IDR per ha of ecoval determination without charging the o value. This value of 62-68% was highly accumulated by the *b*F value of organic C content within SOM (Table 2).

On the other hand, the *b*S value was relatively low which was about 745,78 - 2.113,04 USD per ha. Among the elements of SOM, the *b*S of N element contributed the highest monetary value while the bS of P nutrient contributed the lowest monetary value (Table 2).

As seen in Table 2, additional charge of o value (968,49-3.631,84 USD per ha) as replacement cost for losing the SOM per ha increased the ecological value to become 3.409,13 - 10.587,34 USD per ha or 43.681.203,65 - 135.655.636,95 IDR per ha. This value took into account compensation of reducing CO2 emission and restored SOM resources for long periods of time in the future. This additional compensation penalty will be an ecological resource offset cost of one hectare forest soils destruction.

DISCUSSION

Structure of Forest Soil

The soil alluvial order of TMBNP forest ecosystem was representative of recent deposit soils or young or newly developed soils which can be shown by the undeveloped soil horizons found within the soil profile Dudal and Soepraptohardjo (1957) soil taxonomy or entisol order based on USDA soil taxonomy. Based on many studies, the alluvial or entisol soils are dynamic because of erosion and deposition processes (Mc Auliffe 1994; Iqbal *et al.* 2005; Paoli *et al.* 2006). It is supported by the variability of its solum depth.

The depths of soil solum varied from 20 cm to 80 cm or 48.33 cm in average of total depth. The average soil layers exhibited little or no evidence of horizon development. The vertical structure showed less variation of horizon layers. The forest soils were enriched with litterfall accumulation. However they lack enough alteration of parent materials to form other horizons because of frequent erosion processes. The dynamic nature of the forest ecosystem of TMBNP may also directly limit soil development (MOFOR 2007). High precipitation particularly in the tropical rainforest of MBNP can initiate runoff and transport the surface layer from the upslope location to the bases of slopes.

These processes may interrupt pedogenesis and inhibit the formation of horizon layers as suggested by Peterson (1981). Additionally, the topographic area of the study site is dominated with very steep slopes where soil materials are easilyremoved so fast that time is insufficient for significant horizon development. The degree inclination of slopes in the MBNP forest is mostly >50^{o} and also initiates the run off surface layers at the study site, therefore the natural fertility of the depositions or sediments are low (Edelman and Van Der Voorde 1963).

Furthermore, the clay loam texture of this study site indicates medium textured soils that moderately loose aggregates and compaction. As results these soils also had moderate drainage and water holding capacity because of having mid proportion of clay, silts and sandy percentage (Osman 2013; Moeys 2014). The soil texture of TMBNP is a mixture of sand, silt, and clay which give agritty feel, yet fairly sticky and slightly plastic. The proportion of sands within the texture may provide good aeration because of their air spaces, so it is good for soil aeration. This soil texture was inherited from the parent materials and it originated through weathering and pedogenic processes, including recrystallization, eluviation, and illuviation (Osman 2013).

Ecoval of SOM

The total organic C of TMBNP forest soils at 66.03 Mg ha^{-1} was low compared with other tropical forests at 106 Mg C ha^{-1} (in 100cm depth) as reported by Don *et al.* (2011) and 64 Mg C ha^{-1} (in 30 cm depth) reported by Hoffmann *et al.* (2014). This value is close to C-stock found in 30 cm depth secondary forest soils of Andes which was about 66.5 Mg ha^{-1} (Sierra *et al.* 2012). On the other hand, among other elements found in forest SOM of TMBNP the N value was high. However, this value was lower than the value found in the forest of the Serra do Mar, Brazil which was 200–300 Mg ha^{-1}, and 14 to 20 Mg ha^{-1} based on the elevation (Vieira *et al.* 2011).

It can be seen from Table 2 that it is not only organic C content that was low but also other elements: N, P and K within SOM. This limited Organic C, N, P, and K elements within the solum cannot only be influenced by removing standing litterfall and woody debris from the calculation and analysis but can also be caused by high decomposition processes below soil surfaces of soil microbes (Ramirez *et al*. 2009; Rumpel and Kögel-Knabner 2011; Schmidt *et al*. 2011).

The microbes' respiration releases soil organic-C to the atmosphere as CO_2. The soil decomposition process provides soil organisms with carbon compounds to burn for cell energy and for building their cells and tissues. Decomposition also makes important nutrients such as nitrogen, phosphorus, and sulfur available to soil organisms and plants (Matson and Vitousek 1987; Walbridge *et al.* 1991; Qualls and Haines 1991; Riley and Vitosek 1995, Tang *et al.* 2012).

The low of P held in organic form is characteristic of highly weathered tropical soils that may be bound by secondary soil minerals, precipitated, or leached in organic or inorganic forms which is commonly called as sorption process (immobilize P) (Chadwick *et al.* 1999; Hobble and Vitousek 2000; Leader *et al.* 2008; Fink *et al.* 2016). Slowly, the processes may reduce available P into immobile state and total available. The high value of N held in the SOM of TMBNP, on the other hand, may be caused by high rate of nitrogen fixation through physical or biological processes (Zhu *et al.* 2015).

This long term interconnectivity between plant and soil system or nutrient cycles within forest ecosystem influences plant's ability to obtain these critical nutrients as internal factor. Furthermore, the changes of precipitation and temperature in tropical forest as external system can also interfere with the accumulation of available nutrients in forest soils (Raich *et al.* 2002; Harris *et al.* 2008; Li 2013). Hence, theseexternal environmental factors also influence nutrient dynamics among different compartments of an ecosystem (Tomlinson 2003; Kaspari *et al.* 2008; Violanteand Caporale 2015). Consequently, the soil fertility of this tropical forest site is low compared to grasslands or subtropical forest ecosystem (Costanza *et al.* 1997; Nadeau and Sullivan 2015).

Appraising Ecoval of SOM

The ecoval of SOM found in the Meru Betiri National Park was worth about 2.440,64 - 6.955,50 USD or 31.271.923,73 - 89.120.837,23 IDR per hectare (Table 2). This ecological worth value was derived based on the replacement price of NPK 16-16-16 fertilizer and carbon credit which are commonly applied in Indonesia trade. The high value of organic C compared with other elements of SOM was connected with the high of carbon stored in the forest soils of the study site. The ecological structure values of N, P, and K elements contributed about 745,78- 2.113,04 USD per ha to the forest ecosystem.

The ecoval of N element had the highest ecological structure value among other elements of SOM, while the P element had the lowest value. The difference of these values was mainly driven by their difference in stock within the soil solum. Their ecological structure values were related to how much nutrients resource availability in the forest of TMBNP. Lack of these elements will influence the forest soil fertility (Johnson *et al.* 2009; Rumpel and Kögel-Knabner 2011, Zhu *et al.* 2015). Lowsoil fertility will give impact on the growth of plant species as starting point of geochemical cycles once the plants drop their dead materials to the forest soils.

This valuable resource of SOM in tropical forest of TMBNP was worth about 3,007.72 – 9,450.02 USD. Comparable of ecovalrefers to sustainable biogeochemical cycles within TMBNP. This valuable information can be used as consideration in making policies or management conservation to protect the SOM elements as nutrient sources of forest vegetation.

Ecoval appraisal result also showed that the economic valuation method can be integrated in the ecological valuation approach as stated by many studies (de Groot *et al.* 2012; Morse-Jones *et al.* 2010; Numes and Nijkamp 2010; Costanza *et al.* 2011, Hermann *et al.* 2011, Sulistiyowati and Buot 2013) that social, economic, and ecological components should be included to asses and account ecosystem services.

Many believe that forest soils can not be accurately measured because as supporting ecosystem services the available elements of SOM will be directly absorbed by plant species to support ecological processes and functions. Most economic valuation on ecosystem services studies put their monetary value in terms of soil erosion and soil formation (Costanza *et al.* 1997 and 2014; Selassie and Belay 2013), soil protection (Wu *et al.* 2010), soil stabilization and soil fertility maintenance (Nahuelhual *et al.* 2007), or soil natural capital *per se* (Robinson *et al.* 2009; Dominati *et al.* 2010).

The market based, cost and benefit analysis and many other valuation techniques are commonly used to derive the monetary value of the soils as supporting services. However, some studies also used replacement cost of fertilizer prices commonly put in the market (Nahuelhual *et al.* 2007; Kiran and Malhi 2011) for soil loss estimation not for forest soil contribution as approached in ecological valuation.

The ecological value of forest soil organic matter was not done to trade its resource, but rather to get information on how much valuable the forest SOM in TMBNP is. Policy makers and management in all levels can use this information to generate actions to prevent any anthropogenic destruction that may destroy the SOM elements availability. Protecting the forest ecosystem of TMBNP will protect the forest soils and at the same time sustain the biogeochemical cycles in this ecosystem. This natural resource has to be protected from losing its contribution to the system as life support system where human is part of. Implementation of this appraisal method in ecological valuation may encourage people to be more concerned on the functioning of natural ecosystem.

CONCLUSIONS

The result showed that the ecological value of SOM in tropical forest of TMBNP was worth about 3.409,13 - 10.587,34 USD per ha. Comparable of ecovalrefers to sustainable biogeochemical cycles within TMBNP. The SOM contributed higher ecoval of organic C (66.03 Mg ha^{-1}) than other elements. Compared to P and K elements, N had the highest stock of element content. However among other ecosystem, the ecoval of SOM elements in TMBNP was relatively low because of its natural geomorphological features.

The ecological value is derived the integration of cost based approach with ecological values of Organic C, N, P, and K elements content of SOM. This ecological valuation tool enabled to give monetary value on the immeasurable value of SOM elements which was once said impossible to be measured. This worth of SOM as carbon pools can be used as information to gauge how valuable our forest soils are in terms of natural heritage. Therefore, we have to be concerned on the contribution of SOM as carbon pools that directly or indirectly support all living organisms including our lives as part of the system.

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