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Ecological value of soil organic matter (mandala customary forests with awiq-awiq management)

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Abstract. The current ecological value has become a global trend that can be used as a reference in conservation. Soil is one of the parameters of the ecological value that stores organic matter (SOM) consists of organic elements C, N, P, and K contributing to the biogeochemical cycle. The purpose of this study is to determine the ecological value of soil organic matter in Mandala customary forests that is managed by using awiq-awiq. Data on soil organic matter content was carried out in the customary forests of Mandala, Bayan, West Nusa Tenggara, Indonesia. Soil samples taken at five points based on the height of 310-350 masl. Measurements were carried out directly and indirectly, using soil physical and chemical laboratory tests. Lab test results were then analysed using a cost-based approach to determine their ecological value. The results showed ecological values based on C, N, P and K (SOM) content of land contributed around 5609.74 USD / ha or 78,990,748, 9 IDR / ha and 5830.82 USD / ha or 82,103,776.4 IDR / ha. This value is an award given to Mandala customary forests in protecting SOM to maintain a biogeochemical cycle in forest ecosystems. However, it's protection requires sustainable forest management.

1. Introduction

Forests as ecosystems are able to provide various benefits in tangible and intangible ways. The benefits of tangible are real benefits such as wood, rattan, etc., while the unmeasured benefits are called intangible in the form of environmental protection, soil fertility, erosion prevention, springs preservation and others. Forest resources produce comprehensive benefits at the local, national and global levels in tangible and intangible ways [1], [2] state that forests are renewable ecosystems that provide environmental, economic, social and cultural benefits. In fact, these benefits are still considered low, as evidenced by excessive exploitation, which causes forest degradation. Forest degradation creates unstable conditions, decreases productivity and unwanted impacts [3], [4], [5] thus it adversely affects forest ecosystems and the surrounding environment.

Unstable conditions in forest ecosystems due to over-exploitation cannot be separated from an understanding of the forest benefits value that have not been comprehensive. This understanding needs to be done to assess the benefits generated by the forest. Through these assessments, it can be used as a

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consideration in deciding the policy of utilizing forests fairly, thus creating a stable forest condition in accordance with its functions. The function of forests is most often an issue in regulating global climate, namely carbon storage that can absorb carbon dioxide. Tropical forests are the largest store of carbon and contributors to regulating global climate [6].

Carbon storage in forest ecosystems is one of them on the ground. Carbon storage in forest ecosystems is found in biomass (live plants), necromass (dead plants), and soil organic matter [7]. [6].Forest land plays a role in the formation of the composition and structure of forest vegetation [8] that supports ecological processes in producing plant feedback in the carbon cycle [9], [10]. The soil contains approximately 2,344 Gt (1 Gigaton = 1 billion tons) of organic carbon globally [11]. Thus, land is a support service for forest ecosystems [12], [13], [14], [15]. In 2007, the IPCC reported that around 5 tons of CO2 per year could be absorbed by the soil [16].

Storage of carbon in soil in forest ecosystems is inseparable from biogeochemical processes that are stored in the form of organic matter. Soil biogeochemical processes in forest ecosystems store more carbon stored in organic matter than living organisms [17]. While the decomposition of organic matter is influenced by climate, temperature and humidity supported by microbial action [18]. Based on this matter, organic matter affects the ecological value of soil carbon stocks. [19]concluded that organic soil carbon is the largest carbon stock in terrestrial (forest) ecosystems and plays a role in biosphere feedback for increasing atmospheric carbon dioxide in the world. Organic matter (SOM) consists of organic elements C, N, P, and K contributing to the biogeochemical cycle. Therefore, it can be concluded that soil organic carbon stocks affect the concentration of carbon in the atmosphere. [20].states that carbon stocks can be used to estimate the amount of carbon dioxide uptake by plants, including soil. Therefore, land and plants play an important role in preventing global warming.

Based on this description it is interesting to study soil carbon stocks in supporting the ecological process of the forest. The ecological value of soil carbon stocks can provide knowledge and understanding of forest benefits, which will subsequently have an impact on awareness of forest conservation. This study aims to determine the ecological value of soil organic matter (SOM) in the Mandala customary forests of Bayan, West Nusa Tenggara Indonesia.

2. Methodology

2.1 Research sites

The study was conducted by taking soil samples in the Bayan mandala customary forests of West Nusa Tenggara on 08o16'41.2 "LS and 116o25'34.2" BT with the area of 10.33 ha of Mandala customary forest. The sampling technique uses an expectation method (judgment sample) because the land-mapping unit found is homogeneous from the type of soil and vegetation cover land. Sampling of five points from north to south with different topography can be seen in figure 1 below.

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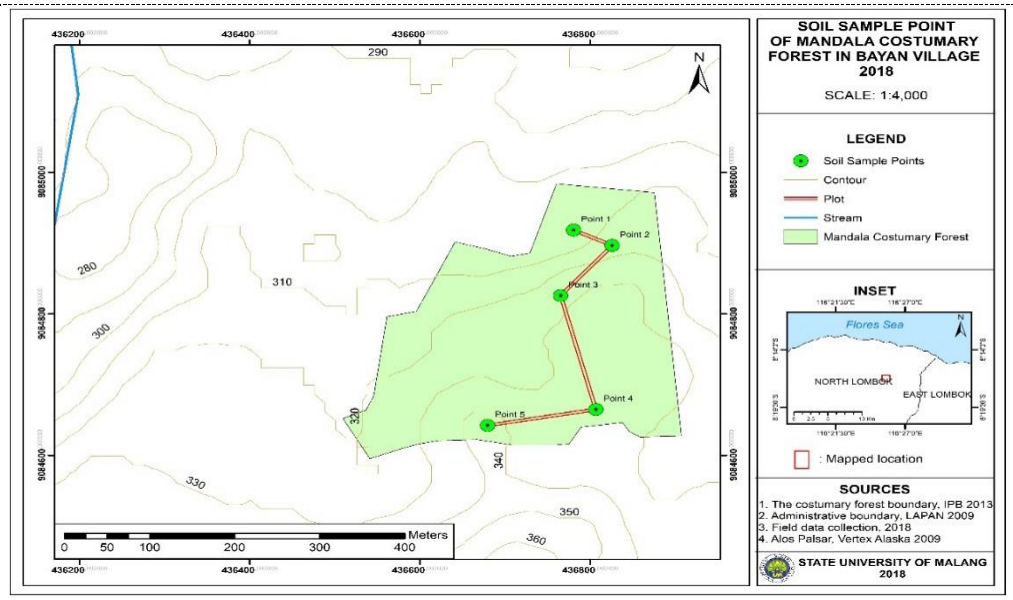

Figure 1. Map of the Mandala Customary Forest Land Sample Plot of Bayan Village

The topography of the five points in figure 1 is at point 1 (08°16'40.947" LS and 116°25'33.357" BT), point 2 (08°16'41.653"LS and 116°25'34,841"BT), point 3 (08°16'43,960" LS and 116°25'32,856" BT), point 4 (08°16'49,180" LS and 116°25'34,200" BT), and point 5 (08°16'49,932" LS and 116°25'30,036" BT). Soil samples taken on a variety of different topography with a homogeneous canopy can provide a total average ecology of soil organic matter and good content. The sampling technique uses an expectation method (judgment sample) with the consideration that the land mapping unit found is homogeneous from the type of soil, vegetation cover land and sampling is five points from north to south with different topography (figure 1).

2.2 Soil Samples

Measurement of soil samples is carried out directly and indirectly. Direct measurements are carried out in the field by measuring soil moisture, pH, and solum. This activity can be seen in Figure 2 below.

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Figure 2. Measurement of soil moisture and Ph

Indirect measurements were done by laboratory tests. Before laboratory tests, 100 grams of soil samples and soil samples in the ring 10 cm were taken for representatives of each top soil and sub soil. Soil samples were then tested in physical and chemical laboratories. Physics laboratory test was done to determine the texture class with the content of clay, dust and soil sand. Chemical laboratory test was done to determine the content of organic C, N, P, and K soil.

2.3 Data analysis

Determination analysis of C, N, P and K was carried out at the Soil Science Laboratory, Faculty of Agriculture, Mataram State University, Indonesia. After soil testing related to SOM elements (C, N, P and K), it was analyzed using a cost-based approach. A cost-based approach is an action to maintain or replace forest goods and services in a valuation method that has been widely carried out in research [2], [21]. This approach refers to the national standard prices of N, P and K fertilizers on the market. Determination of soil ecological value from SOM based on a cost-based approach that is the equation developed by Sulistiyowati et. al [22]. focuses on elements of organic C, N, P and K which are combined as follows:

$$IЄ\ (USD) = \{ bS*E\} + \{bF*3{,}667W\}$$

$$= \{(bSN*N) + (bSP*P) + (bSK*K)\} + \{(c + o)*3{,}667W\}$$

Based on this formula, the ecology value (IЄ) is in USD. S represents the ecological structure value in USD. bS is the S ecological base value in USD which refers to the price of NPK fertilizer. E is the NPK element as the content of SOM with the weight of Mg. bF is the F ecological base value in USD. Furthermore, c is a carbon credit and o is the resource ecology that is balanced. 3,667 is the conversion of C to carbon dioxide and w is the dry weight of organic C in Mg. The value of SOM uses NPK prices

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based on Indonesian Minister of Agriculture Regulation No. 130 / Permentan / SR.130 / 11/2014 [23]. Fertilizer prices are based on this regulation in IDR which is 2300 per kg which will be converted to USD. The composition of NPK (16% NH3, 16% P2O5, 16% K2O) is 0.16 USD / kg as the market price (1 USD = 14081 IDR per 28 February 2019). Composition and chemical weight of 16% ie N of NH3 is 0.824; P of P2O5 is 0.437, K of K2O is 0.829, then the price of each element N, P, and K is 0.022 USD per kg, 0.011 USD per kg, and 0.022 USD per kg.

The basic ecological value of the function is based on carbon credits (c) with the price of carbon in USD. The carbon credit standard price of $ 40 / t CO2 is based on the Global Carbon path to Climate Cooperation in 2007. Therefore, 3,667 is used to convert carbon content to CO2 to calculate bF IPCC [7]. The ecological resource offset (o) price of $ 8.99 [24] was used to ratify the forest transaction cost of forest carbon offset of CO2 of its market price. However, before using the ecological value formula, the weight of each SOM contents must be looked for, namely C, N, P and K through the following formula.

Weight of organic C (Mg/ha) = % Organic C x soil weight Mg/ha

Weight of N total (Mg/ha) = % N total x soil weight Mg/ha

Weight of P of P2O5 (Mg/ha) = P2O5 ppm x soil weight Mg/ha

Weight of K of K2O (Mg/ha) = (K2O me 100/g x soil weight Mg/ha)/(2*100)

3. Result

3.1 Characteristics of Land in Mandala Customary Forests

The soil layer (horizon) in Mandala customary forest with solum (soil depth) is between 10-36 cm consisting of top soil at 5-16 cm and subsoil at 5.5-20 cm. Land in Mandala customary forest is included in the class of sandy clay texture. Solum analysis and soil texture on top soil and sun soil can be seen in table 1 below.

Table 1. Solum analysis and soil texture on top soil and sub soil in Mandala customary forests

Parameter	Solum	
	Top Soil	*Sub Soil*
Clay (%)	1,58	1,72
Dust (%)	39,85	32,28
Sand (%)	58,52	66,00
Texture Class	Sandy Clay	Sandy Clay

Source: results of soil physical laboratories, 2018

Table 1 provides information on the parameters of soil texture consisting of clay, dust and sand on the soil in the Mandala customary forest with a composition of sand which is more between dust and

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clay. Average soil pH of 4.5-6.2. The soil density is 1.25 gr / cm3 based on the total dry mass of the soil, so that the total average weight of land in Mandala customary forest reaches 2500 Mg / ha from the accumulation of top soil weight 1125 Mg / ha and sub soil 1375 Mg / ha.

3.2 SOM Dynamics

SOM dynamics are based on soil chemical analysis of C, N, P and K content. SOM values affect plant growth. Plant growth is influenced by various factors including: sunlight, temperature, air, water and nutrient elements of the soil (N, P, K, etc.) [25]. The results of chemical composition of C, N, P, and K soil in Mandala customary forest can be seen in table 2 below.

Table 2. Variable analysis of SOM elements in top soil and sub soil in Mandala customary forests

Parameter	Solum	
	Top Soil	*Sub Soil*
Soil Weight (Mg/ha)	1125	1375
Organic C (%)	1,59	0,97
Weight of C (Mg/ha)	18,39	12,91
N Total (%)	0,08	0,05
Weight of N (Mg/ha)	0,96	0,65
P of P2O5 (ppm)	52,85	32,62
P weight of P2O5 (Mg/ha)	6,20	3,82
K of K2O (me/100gr)	3,17	3,21
K Weight of K2O (Mg / ha)	17,55	21,95

The average soil containing organic C elements was around 2.56% of the accumulation of 1.59% top soil and 0.97% sub soil. The value of organic C soil is classified as moderate, based on the soil research center and agroclimate [26], the organic C value is classified as very low (<1%), low (1-2%), sufficient (2.01-3%), high (3.01-5%) and very high (> 5%). This value is influenced by soil respiration by living organisms in the forest that release organic C in the form of CO2 into the atmosphere [22], so that the total weight is C 31.3 Mg of the weight of top soil 18.39 Mg / ha and sub soil 12.91 Mg / ha. Whereas the elements of N, P in (P2O5), and K (K2O) on the soil volume of 1.25 gr / cm3 showed the contents of SOM with a higher average N in top soil than sub soil (table 2). The total N weight is 1.61 Mg / ha

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based on top soil accumulation 0.96 Mg / ha and subsoil 0.65 Mg / ha. Furthermore, based on table 2, it can be concluded that the weight of P (P2O5) in top soil is higher than sub soil, whereas the weight of K (K2O) is lower in top soil than in subsoil.

3.3 Ecological Value of SOM

The SOM ecological value is obtained from bS and bF. The ecological value of SOM is one of the factors that play a role in maintaining the sustainability of the ecosystem. Ecological values in Mandala customary forests can be seen in table 3.

Table 3. Analysis of Ecological Values in SOM in Mandala Customary Forests

Paramete Equation	Element	Top Soil	Sub Soil	Total
	N	21,12	14,30	35,42
	P	70,68	43,55	114,23
bS (USD)	K	386,10	482,90	869,00
	∑	477,90	540,75	1018,65
bF (USD)	c	2697,45	1893,64	4591,09
	o	81,82	57,44	139,26
I€$_{som}$ Without o (USD)	bS + bF	3175,35	2434,39	5609,74
I€$_{som}$ With o (USD)	bS + bF	3257,17	2573,65	5830,82

Note: *bS* is a structural ecological value, *bF* basic ecological value, *c* is a carbon credit from organic C content, *o* is an eco-system of offset power, I€$_{som}$ is the SOM ecological value.

The total soil organic weight of 82.43 Mg / ha of elements C, N, P, and K has an ecoval value reaching 5609.74 USD / ha or 78,990,748.9 IDR / ha without burdening o, this value is 62-68% accumulated from the bF value of organic C content in SOM. The bS value is relatively low at 1018.65 USD / ha. Among the SOM elements, the bS K element contributes the highest monetary value and the bS N element contributes to the lowest monetary value. While the ecological value can increase to 5830.82 USD / ha or 82,103,776.4 IDR / ha from the additional cost of 139.26 USD / ha as a replacement cost of damaged or missing SOM values. This value takes into account the increasing decline in CO2 and SOM emissions that are restored for the future. This is the cost of replacing ecological resources from one hectare of forest damage at present.

4. Discussion

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4.1 Land Texture of Mandala Customary Forest

The soil texture at the study site in the 5-20 cm layer was in the sandy clay class with a comparison of the particles namely clay 1.65%, dust 36.07% and 62.26%. Soil texture is one of the factors that determine the ability of the soil to support plant growth. It is caused the texture of the soil as physical soil determines the penetration of roots in the soil, the ability of the soil to hold water, drainage, soil aeration and the availability of soil nutrients [49]. The sandy clay texture in the Mandala customary forest shows a fairly loose density. This is based on the percentage of the proportion of clay, dust and sand in the soil [27]. Soils dominated by sand particles are much larger and have a smaller surface area than land dominated by dust and clay particles [28]. Clay-textured soils have good ability in storing water for plant growth, due to a combination of surface area and soil pore size. Thus, clay-textured soils are more fertile than clay, dust and sand [29].

Soil texture is influenced by soil organic matter, [30] states that organic matter can increase the amount of soil pore space that affects the texture conditions. Soil organic matter also plays a role in nutrient availability in the soil through mineralization. This process releases plant nutrients completely (N, P, K, Ca, Mg and S in uncertain amounts and is relatively small) [31].Organic matter contained in the soil supports plant growth, which affects the quality of the environment. It meas that when vegetation cover in the forest is high, the environmental quality is good, because plants are able to absorb pollutants (CO2) [32] and the soil is able to absorb CO2 [16].

Forest management that takes into account its sustainability influences high forest vegetation. For example, the use of forests in the form of illegal logging without regard to the environment will reduce the extent of vegetation cover forests and nutrients. Forests that are utilized without regard to their sustainability have a negative impact on land, water, flora and fauna, climate change and nutrients so that certain types of plants can survive on the land [33] , [34]. Therefore, it is important that forest management is able to maintain nutrient availability. Mandala customary forests has increasing vegetation cover from 2000-2012 were 0.6% [39]. One of the reasons for the increase in vegetation is the organic matter content of the Mandala customary forest.

4.2 Ecological Value of SOM

Ecological values are found based on replacement prices for 16-16-16 NPK fertilizers and carbon credits used in Indonesia. The price of organic C has the highest value of 4591.09 USD / ha compared to other SOM elements. Other SOM elements have the highest K and lowest N values. These values are based on the amount of nutrients stored in the soil. The amount of these elements affects the level of soil fertility, if the CNPK element is lacking, soil fertility decreases [35] , [36], [37], [38], thus impacting plant growth. The price of N, P, K element accounts for around 1018.65 USD / ha for forest ecosystems. The price of P soil has a very high content reaching 114.23 USD / ha at the study site. The high P content in Mandala customary forest is evident from the vegetation that thrives. States that vegetation increased from 8.90 ha in 2000 to 9.50 in 2012 [39]. Phosphorus (P) is an important element for plants since it limits growth and production [40]. This important role of the P element causes it to be always available in the soil.

The K element is also important for plant growth because, according to[41], the K element serves to strengthen plant stems, when the quality of plant stems is not good because of the low potassium in the soil. Potassium functions to improve enzymes, regulate nutrient absorption, and root growth [25]. Lack

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of nutrient potassium causes vegetative and generative growth that is not good so that production decreases. The results of the K elemental laboratory analysis fall into the very high category at a price of 869.00 USD / ha. N element is also often used as a barrier in soil fertility because N is needed in large quantities. Based on the analysis, N elements is in the low category on the land in Mandala customary forests at a price of 35.42 USD / ha. The N element is a problem in all types of soil, especially coarse textures and low levels of organic matter [42].

The ecological value in Mandala customary forest contributed around 5609.74 USD / ha or 78,990,748.9 IDR / ha and 5830.82 USD / ha or 82,103,776.4 IDR / ha (table 3). This value can be used as a conservation consideration to protect SOM as a source of plant nutrition. Thus, the ecological values obtained from economic methods are integrated into the ecological assessment approach [6] , [14] , [43]. Then, the analysis of market-based ecological values is used to convert them in monetary form from land. The ecological value of SOM is used to find out information on how valuable SOM is in Mandala customary forest so that it will result positive actions towards SOM availability. Forest management affects the availability of organic matters [44]to support human life as a part of it.

The forest management of the Bayan indigenous people influences adequate organic matter content in the study sites. They manage the forest with their local wisdom, which is commonly called awiq-awiq. Awiq-awiq local wisdom is a customary law that regulates the behavior of the community to conserve the forest with a number of prohibitions, one of which is not to cut down trees without the permission of traditional institutions. Logging is a form of disturbance that affects nutrient cycles in forest ecosystems. Several studies have shown that logging affects soil nutrients in the medium term and decreases long-term land productivity [45] , [46], [47]. The prohibition on cutting down trees based on awiq-awiq in the Mandala customary forest for the Bayan indigenous people is an effort to preserve the forest ecosystem. The experience and habits of managing forests form a community ecological knowledge system in managing and using resources wisely [48].

5. Conclusion

Weather, climate, and biodiversity are closely related to soil conditions, especially in forests. Land as a carbon source along with N, P, and K in biogeochemical processes contributes to the value needed to maintain ecological sustainability. Ecological values based on C, N, P and K (SOM) content in Mandala customary forests accounted for around 5609.74 USD / ha or 78,990,748.9 IDR / ha and 5830.82 USD / ha or 82,103,776.4 IDR /Ha. This value contributes to determine the ecological value in an ecosystem. Ecological values are based on the integration of cost-based approaches with soil organic content, namely C, N, P, and K. The value of SOM (soil organic matter) as a carbon source was used to obtain information about how valuable land in the forest, so that the availability of SOM must be protected to maintain soil carbon content which supports living things in an ecosystem. Then, ecological values can be used to propose natural resource management for each ecosystem that is developed through a relationship of standardization of prices and costs of land in the forest. Forest management that pays attention to ecosystem balance is able to maintain the availability of SOM (soil organic matter). This action is one way to preserve ecological functions in the forest ecosystem.

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