Soil carbon stocks in various types of land use in West Lombok

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Abstract. Organic carbon greatly affects soil physical, chemical and biological fertility, so that this soil property is an indicator in determining soil health and quality. The amount of carbon stored in the soil can change due to land use, and its transformation from the ground to the air in the form of CO2, which can lead to global warming. This study aims to determine soil carbon stocks in various types of land use in West Lombok, West Nusa Tenggara Province, Indonesia. A number of soil samples (disturbed and undisturbed samples) were collected from various types of land use (forest, garden, paddy field, dry land and shrubs) using a soil drill (ring diameter 5.8 cm) from 3 depths; 0-10, 10-20, and 20-30 cm. Disturbed samples were dried, ground, sieved with a 2.00 mm sieve diameter, and analysed for their C-organic content using the Walkley and Black methods. Meanwhile, the undisturbed samples were processed in the laboratory to determine the bulk density (BV) of the soil. The results showed that the largest soil carbon stock was found in forests, followed by gardens, rice fields, moorlands, and shrubs. It was also found that the largest carbon stock was at a depth of 0-10 cm in all land use types and decreased with soil depth. These findings can be used as a reference in soil carbon management, considering that the carbon stock in rice fields, moor and shrubs is low to very low, which in turn can reduce soil fertility and productivity.

1. Introduction

Climate change has become an interesting phenomenon that is often discussed in recent years. Climate change is triggered by human activities, especially those related to the use of fossil fuels and land use conversion activities. This activity produces gases that have a greenhouse effect called greenhouse gases (GHG) which accumulate in the atmosphere. These gases include carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4). In Indonesia, GHG is produced from various human activities which can be distinguished into several things, namely excessive energy use, forest destruction, and agriculture and livestock [1].

Organic matter is part of the soil which is all types of organic compounds present in the soil, including litter, light organic matter fractions, biomass of microorganisms, dissolved organic matter in water, and stable organic matter or humus. Organic matter has an important role in determining the ability of the soil to support plants, so that if the soil organic matter content decreases, the soil's ability to support plant productivity also decreases [2].

Lombok Island is categorized as a small island and is an archipelago that is vulnerable to climate change and environmental damage. Lombok Island is a vulnerable area to climate change. This is
indicated by changes and shifts in the pattern of the rainy and dry seasons (3% in 2030); the average temperature increase is 1-2 °C in the last 10 years; sea level rise which can reach 1-7 m by 2050; and exacerbated by increasing population growth (6.3 million population in 2050); exploitation of natural resources and the conversion of natural resources [3].

This situation is exacerbated by the widespread destruction of forest land due to illegal logging, land use change and forest fires. The critical land in West Nusa Tenggara (NTB) Province reaches 527,800 hectares (ha) or 26% of the land area, consisting of 159,000 ha of critical forest and 368,800 ha of non-forest critical land [4]. In addition, 22% of the total forest damage was in the Mount Rinjani National Park (TNGR), while The Indonesian Forum for Environment (WALHI) considered that forest damage in NTB province had reached 78%. Meanwhile, mangrove forests also continue to experience damage. The damage to mangrove forests on Lombok Island reached 1,519.85 ha with the severely damaged category of 906.31 ha from the total potential mangrove area on Lombok Island, which is 3,426.78 ha [5]. If forest land continues to experience degradation, the earth's ability to absorb carbon will decrease so that it is unable to reduce the accumulated GHG in the atmosphere. Therefore, efforts are needed to reduce GHG emissions in the forestry sector. This can be done because in principle, it is reducing emissions by protecting and maintaining existing carbon stocks and increasing absorption through various reforestation programs. This study is aimed at evaluating carbon stocks in various land uses in West Lombok Regency, NTB Province. The results of this study are expected to contribute in building carbon status baseline data on agricultural lands in West Lombok.

2. Materials and methods

2.1. Research sites
This research was conducted in Suranadi Village of Narmada Sub-District, North Kuripan Village of Kuripan Sub-District, and Tempos Village of Gerung Sub-District, West Lombok Regency. This location was chosen because of the representation of various land uses and the clear history of intensive land management that has been carried out over a relatively long period of time. For the forest land and garden, we chose Suranadi Village. For the rice paddy field, we chose North Kuripan Village. As for the type of shrub and moor land, we took it in Tempos Village on the consideration of regional representation in the southern part of West Lombok. This research was conducted from May to October 2020.

2.2. Preliminary survey
Prior to composite soil sampling, we conducted field orientation such as taking coordinates. Implementation of soil sampling using a random method spread over a certain distance in accordance with the area that has been determined based on the base map. Then soil samples were taken using a soil drill at a depth of 0-10, 10-20 and 20-30 cm. From each soil sampling, the results of the coordinate reading on the GPS were recorded.

2.3. Soil physical properties measurement
Soil physical properties were measured on moisture content, soil texture, soil particle density, soil bulk density, and aggregate stability at depths of 0-10, 10-20 and 20-30 cm. Two types of soil samples were taken, namely: disturbed soil samples for soil texture using the pipette method, stability of aggregates using wet sieves method, particle density; and undisturbed soil for measuring the bulk density.

2.4. Soil sampling techniques
The method of taking disturbed soil samples can be briefly explained as follows. First, took soil samples using a hoe from 3 depths: 0-10, 10-20 and 20-30 cm. Then put the soil samples from the sampling point into a plastic container, labelled it and tied it with a rubber band, so that it was safe when brought to the laboratory. After arriving at the laboratory, the soil samples were dried, ground and sieved with a 2 mm sieve. Collect the soils that have passed the filter and put them back into plastic bags that have been labeled and ready for analysis. Meanwhile, for undisturbed soil sampling,
soil samples were taken in sub-plots adjacent to the disturbed soil sampling point, avoiding compacted soil (either by human feet, livestock or tractors). Prepared a 5.8 cm diameter iron sample ring and removed any plant debris above the soil surface (Figure 1). Placed the sample ring into the ground, pressed and hit gently with a rubber mallet until the drill goes into the soil to the desired depth. Dig the soil using a knife; kept hitting the ring slowly with the rubber mallet until the ring is completely in the ground. Covered the top of the soil sample ring with plastic and tied it with a rubber band. Cut the soil under the sample ring using a knife then gently lifted it so that the soil remained intact in the sample ring. Next, levelled the soil at the top and bottom of the box using a soil scraper or knife before placing it in a plastic bag so that it was ready for analysis. Continue taking soil samples at a depth of 10-20 cm and 20-30 cm with the same technique.

Figure 1. The 5.8 cm diameter of an iron sample ring used to collect soil samples.

2.5. Soil organic-C measurement
Measurement of the C-organic content of each selected land was carried out by taking disturbed soil samples at a depth of 0-10, 10-20, and 20-30 cm. Approximately 2 kg of soil samples were taken from the land plot for analysis in the laboratory to determine the state of C-organic in the soil. The data from the C-organic analysis using the Walkley and Black method were grouped into 4 categories, namely: very low, low, medium, and high.

2.6. Data analysis
In accordance with the research objectives, this research method was survey and laboratory analysis. Field survey data and analysis were then processed and presented in the form of tables and graphs. Soil physical characteristics were analyzed by measuring moisture content, soil texture, soil density, soil density, and aggregate stability at depths of 0-10, 10-20 and 20-30 cm. As a basis for determining the level of distribution of C-organic in the soil in the area, laboratory analysis of C-organic was carried out using the Walkley and Black method. The data from the C-organic analysis were grouped based on the criteria for assessing soil properties into 4 categories, namely: very low, low, medium and high. Carbon content per hectare of land (tonnes) was calculated using a practical guide formula for measuring carbon stocks [6].

3. Results and discussion

3.1. Site selection
This carbon stock research was conducted in Suranadi Village of Narmada District, North Kuripan Village of Kuripan District, Tempos Village of Gerung District of West Lombok Regency (Figure 2). These locations were selected because of the representation of various land uses and the clarity of the history of intensive land management that has been carried out over a relatively long period of time.
The work begins with conducting field orientations such as taking coordinates according to the criteria for the planned area. The main survey was carried out with the aim of taking composite soil samples and direct observations in the study area. The forest area is dominated by forest stands, while the garden area is overgrown with various fruit trees, such as avocado (Persea americana), Garcinia mangostana mangosteen, water guava (Eugenia aquea), and various types of grass cover the surface. Rice fields in Kuripan Utara Village, Kuripan District are always used for continuous rice cultivation (Oriza sativa). As for the type of moor and shrubs, we chose Tempos Village, Gerung District. On moor land, farmers in Tempos Village grow peanuts (Arachis hypogaea), cassava (Manihot utilissima), and sweet potatoes (Ipomoea batatas). While the dominant plants in the shrub area are grasses and ornamental plants.

3.2. Characteristics of the physical properties of the research area

3.2.1. Soil texture. Soil texture classes in various land uses are relatively varied. In the mixed garden land use type and moor, the texture class is the same, namely loam. Meanwhile, the other 3 land uses (forest, rice fields and shrubs) have a silty loam texture class. From the results of observations in the field, the five soils did not show signs of cracking, so they could guarantee the accuracy of bulk density measurements using the soil ring technique.

3.2.2. Bulk density. Bulk density for various land uses on the surface from 0 to 10 cm ranges from 1.03 to 1.17 g/cm³, however, the bulk density tends to increase in the deeper layers of soil (Figure 3). At a depth of 10-20 cm, the soil volume in all types of land use increases to around 1.10 to 1.14 g/cm³. At a depth of 20-30 cm, there was an increase in the BV of lowland soil which reached 1.29 g/cm³ and bushes BV (1.2 g/cm³). The high BV value of lowland soil indicates the occurrence of soil compaction, which may be due to intensive cultivation in the paddy field. Measurement of BV in the field used a ring soil sampler with a diameter of 5.8 cm because the soil type observed did not show any cracks (cracking clay) thus ensuring better accuracy during field sample handling according to the procedure.
3.2.3. Soil porosity

Table 1 shows that the porosity of all types of land use at each depth are in the range of 40-50% values. However, there is a change in the value of paddy fields, where the deeper the soil sample is taken, the level of porosity will decrease. Statistically, there is no significant difference between each land use at each depth, except for a depth of 20-30 cm in paddy fields, which has the lowest value and is different from other fields. The decrease in the value of porosity in lowland soil samples is due to the continuous intensive tillage factor. The high value of soil porosity indicates the amount of soil pore space so that it can lead to high soil carbon sequestration [7].

Table 1. Soil porosity classes for different land uses.

| Type of Land use | Depth (cm) |
|------------------|------------|
|                  | 0-10       | 10-20      | 20-30      |
| Forest           | 48.51 a    | 47.29 a    | 45.22 a    |
| Garden           | 48.13 a    | 47.05 a    | 45.09 a    |
| Rice field       | 50.67 a    | 45.70 a    | 39.85 b    |
| Moor             | 49.40 a    | 48.13 a    | 45.81 a    |
| Shrubs           | 49.51 a    | 47.64 a    | 44.25 a    |

Notes: Numbers followed by unequal letters are declared as significantly different based on the honestly significant difference (HSD) test at the 5% level.

3.2.4. Stability of soil aggregates. The results of laboratory analysis show that the five soils on different land uses have different aggregate stability (Table 2). Forest and garden land in the Sesaot area has aggregate stability which is considered very stable [8]. While the land in the paddy fields, Kuripan Utara village, has an unstable aggregate. The stability of different aggregates is found in dry land and shrubs in Tempos Village, Gerung District, which is also considered unstable.

Table 2. Stability of soil aggregates over various land uses.

| Land Use – Sites  | Aggregate Stability | Level (Kemper and Rosenau (1986)) |
|-------------------|---------------------|-----------------------------------|
| Forest – Sesaot   | 113.64 a            | very stable                       |
| Garden – Sesaot   | 108.70 b            | very stable                       |
| Rice field – Kuripan | 38.61 c         | Unstable                          |
| Moor – Tempos     | 35.97 c             | Unstable                          |
| Shrubs – Tempos   | 36.40 c             | unstable                          |

Notes: Numbers followed by unequal letters are declared as significantly different based on the honestly significant difference (HSD) test at the 5% level.
3.3. Soil C-organic content in various land use

Data of C-organic soil in forests (3.7%), gardens (2.3), rice fields (1.5), moor (1.5) and shrubs (0.8) are presented in Figure 4. The largest C-organic content is at a depth of 0-10 cm in all land use types, and decreases with soil depth (Figure 4). The amount of soil carbon is related to the value of soil porosity. While the total amount of porosity is determined by the content of organic matter in the soil. The higher the organic matter content, the higher the porosity value which causes the soil pore space to enlarge so that it can cause a higher soil carbon content [7].

![Figure 4. C-organic soil on various types of land use.](image)

3.4. Carbon Stock

The results of the analysis of carbon stocks covering an area of 1 hectare for each type of land use show a significant difference (Figure 5). The largest soil carbon stock was found in forests (82.89 tons), followed by gardens (49.39), rice fields (38.11), moor (32.81) and shrubs (20.96). Carbon stocks in paddy fields [9], moorlands and shrubs are classified as low and very low.

![Figure 5. Carbon stocks at various land use per ha (Ton).](image)
3.5. Effect of soil depth on carbon stocks

Table 3. Carbon stocks at various soil depths.

| Land Use | Depth 0-10 cm | Depth 10-20 cm | Depth 20-30 cm | Total Carbon stock ton/ha |
|----------|---------------|----------------|----------------|--------------------------|
| Forest   | 39.32         | 23.90          | 19.66          | 82.88                    |
| Shrubs   | 8.41          | 6.41           | 6.14           | 20.96                    |
| Garden   | 23.91         | 13.56          | 11.91          | 49.39                    |
| Rice field | 15.76       | 15.74          | 6.61           | 38.11                    |
| Moor     | 15.35         | 10.45          | 7.01           | 32.81                    |

Soil depth has the ability to store carbon differently. The largest carbon stock is found at a depth of 0-10 cm in all types of land use, and tends to decrease with soil depth. In forest land, the carbon stock on the ground (0-10 cm) is 39.32 tons and the deeper it tends to decrease, namely 23.90 tons at a depth of 10-20 cm and 19.66 tons at a depth of 20-30 cm. The difference in the amount of carbon stock in the forest surface and the depth of 20-30 cm is very large (20.25 tons) compared to the differences in other land uses. The trend of reducing carbon stocks as the soil deepens also occurs in the other four types of land use. In garden land, the difference in the amount of carbon stock on the surface (0-10 cm) and a depth of 20-30 cm is quite significant, namely 12 tons. Meanwhile, the difference in the amount of carbon stock in layers 0-10 cm and 20-30 cm in moor land, rice fields and shrubs is not too big, which is 8.26, 9.15, and 2.27 ton respectively (Table 3).

4. Conclusion

Based on the results of the analysis in the laboratory, several conclusions can be drawn. Soil physical characteristics differ in different types of land uses. The largest soil carbon stock is found in forests, followed by gardens, rice fields, moor and shrubs. The largest carbon stock is found at a depth of 0-10 cm in all types of land use, and decreases with soil depth. This finding can be used as a reference in soil carbon management in mitigating climate change, considering that the carbon stock in rice fields, moor and shrubs is low to very low, which in turn can reduce soil fertility and productivity.

References
[1] Panjiwibowo C, Soejachmoen M H, Tanujaya O and Rusmantoro W 2003 Mencari pohon uang: CDM keforestan di Indonesia (Jakarta: Yayasan Pelangi)
[2] Suwarno, Kartasasmita U G and Djuber Pasaribu 2009 Pengayaan Kandungan Bahan Organik Tanah Mendukung Keberlanjutan Sistem Produksi Padi Sawah Iptek Tanaman Pangan 4 (1) 18-32
[3] Butler J R A, Suadnya W, Puspadi K, et al. 2014 Framing the application of adaptation pathways for rural livelihoods and global change in Eastern Indonesian islands Global Environ. Change 28 368–382
[4] Antara News Agency of NTB 2009 NTB butuh 15 tahun pulihkan kerusakan hutan [Online] Available: https://mataram.antaranews.com/berita/2698/ntb-butuh-15-tahun-pulihkan-kerusakan-forest
[5] Budhiman S, Dewanti R, Kusmana C and Puspaningsih N 2001 Kerusakan hutan mangrove di pulau lombok menggunakan data landsat – TM dan sistem informasi geografis (SIG) Warta LAPAN 3(4) Oktober–Desember 2001
[6] Hairiah K, Ekadinata A, Sari R R and Rahayu S 2011 Pengukuran cadangan karbon: dari tingkat lahan ke bentang lahan. Petunjuk praktis. Edisi kedua (Malang: World Agroforestry Centre, ICRAF SEA Regional Office University of Brawijaya (UB))
[7] Krull E, Baldock J and Skjemstad J 2001 Soil Texture Effect on decomposition and Soil Carbon Storage NEE Workshop Proceeding CRC for Greenhouse Accounting Australia CSIRO Land and Water 18–20 April 2001
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