

Soil Carbon in The Bone Bay Mangrove Ecosystem, Palopo City

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Abstract. *The mangrove ecosystem is one of the many ecosystems found along tropical beaches that have a function as a buffer area between land and sea and produce organic matter. There are several factors that influence the spread of mangrove plants, namely the physical factor of the soil. This study aimed to determine the soil carbon content in the mangrove ecosystem in the village of Temmalebba, South Sulawesi. The data collected in the form of bulk density (BD), organic matter (BO) and percent C for analysis of carbon content was obtained from the analysis of soil samples taken from 10 points with 3 replications for composite samples. The sampling point was determined based on the growth and density of mangroves. Furthermore, the data was analyzed using the organic C equation and carbon content. The results showed that the highest bulk density was found at a depth of 60–100 cm with a value of 1.28 g/cm³. The highest percent of organic matter content found at a depth of 0–30 cm with a value of 9.18%. The highest soil carbon content found at a depth of 60–100 cm with a value of 225.38 (MgC ha⁻¹). Soil carbon content in the mangrove ecosystem of Bone Bay, Temmalebba village is strongly influenced by several factors, including soil depth, bulk density, organic matter, and soil texture.*

Keywords: *bulk density, organic matter, soil carbon.*

Citation

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INTRODUCTION

The Greenhouse Gas effect (GHG) is often referred to as the cause of global warming. One of the biggest contributors to global warming today is carbon dioxide and methane gas produced from human activities such as burning garbage, motor vehicles, and industrial machinery which causes carbon gas to accumulate (Rahman, et al., 2017). The increasing content of carbon dioxide (CO₂) in the air will cause an increase in the earth's temperature due to the greenhouse effect/global warming (Ibrahim dan Muhsoni, 2020). One of the human efforts in dealing

with the increase in carbon dioxide (CO₂) gas is mitigation. According to Wahyudi (2018), GHG mitigation is a form of human intervention that aims to reduce emissions or increase the ability to absorb and convert GHGs. Reduction of GHG emissions in the atmosphere is carried out by increasing carbon stocks contained in biomass and soil. The more carbon stored, the less carbon is in the atmosphere, helping to reduce climate change and global warming.

Plants can absorb emission gases and store them. One of the places where plants store carbon is in the soil or sediment. Based on the results of research from (Kepel et al.,

2019) shows that the carbon storage in the soil or sediment has a greater amount than the carbon storage above the surface and below the surface. According to Siringoringo (2013), the soil is a representation of an organic carbon pool (organic carbon reservoir) which is long-term importance in terrestrial ecosystems, because soil accumulates carbon (C) greater than the amount of C in plant biomass and the atmosphere.

Some types of ecosystems that can store carbon and can be an effort in tackling climate change due to global warming and reducing the effects of greenhouse gases are mangrove ecosystems. Mangrove forests are a transitional ecosystem between land and sea that occurs mostly along tropical and subtropical coastlines (Liu et al., 2014). Ecologically, mangrove forests function as carbon sinks, where this function makes them able to store large amounts of carbon both in vegetation (biomass) and other organic materials found in mangrove forests (Cahyaningrum et al., 2014). According to Suryono et al., (2018), Carbon storage in mangrove forests is higher than those found in other forest types, where mostly found in mangrove sediments. Carbon storage in mangrove sediments is greater because the area or environment where the mangrove grows is muddy beaches, bays, and estuaries (Akbar et al., 2019). Mangrove forests store carbon above and below the soil surface, with most of it being allocated below the soil surface (Alongi, 2012).

Mangrove ecosystems were chosen as one of the topics in this study considering mangrove ecosystems are not only useful as an absorber and store of carbon dioxide but also as a place for various kinds of living things to live and reproduce as well as a place for humans to find sources of livelihood. One of the mangrove ecosystems in Indonesia is found in Bone Bay, located between the provinces

of South Sulawesi and Southeast Sulawesi. Therefore, this study aimed to determine the carbon content of the soil in the mangrove ecosystem in the village of Temmalebba. This research was conducted based on the problems found after initial observations were made at the research location. Several studies have been made regarding carbon stock in the mangrove ecosystem. Arifin et al., (2020) reported carbon stocks in the Wonorejo Mangrove Forest with a soil texture dominated by dusty clay, of course, this condition was different from the mangroves in Bone Bay which were dominated by loamy clay textures. The changes in land conditions are thought to also affect the carbon value of the soil. According to Pasau (2018), the mangrove ecosystem in Tammalebba Village shows a decline in environmental quality caused by land conversion into ponds and abrasion. Karim et al., 2019 conducted a study on mangrove carbon stocks in Bone Bay, precisely in the Songka sub-district, to calculate carbon stocks above the surface. Given the basis of this research, there is currently no data on the potential for carbon storage in the soil in the mangrove ecosystem in Bone Bay, it is hoped that this research can later become the basis for preserving mangrove ecosystems, especially those in Tammalebba Village.

MATERIALS AND METHODS

This research was conducted from September to November 2020 in the Village of Temmalebba, Palopo City (Figure 1). The tools used in this study were a GPS which is used to determine the coordinates, a compass which is used to determine the direction of sampling, a soil drill or pipe for taking soil samples from the location, plastic samples to store soil samples that have been taken from the location, ruler/ meter tape to measure in-

tervals when cutting samples, hacksaw to cut samples that have been taken, sample rings to take intact/undisturbed samples, zipper lock to store samples, labels to mark samples that

have been taken. All the samples were then analyzed in the Chemistry and Soil Fertility Laboratory, Department of Soil Science, Faculty of Agriculture, Hasanuddin University.

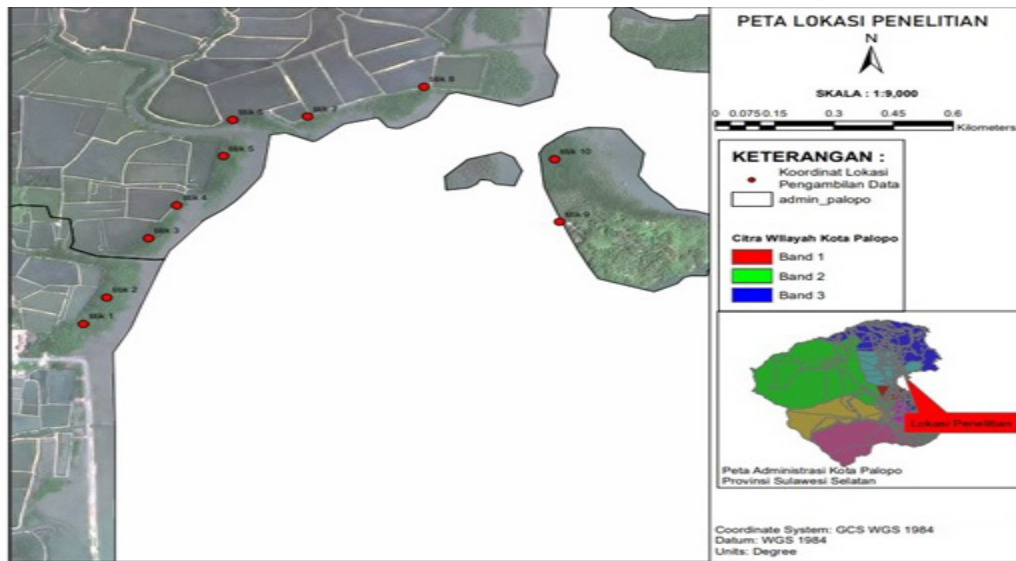


Figure 1. Map of research locations on mangrove ecosystems in Temmalebba Village

Observations in this study were carried out on 10 sampling points chosen based on the growth and density of mangroves in Temmalebba Village (Figure 1). The primary data used in this research is soil carbon stock. Soil carbon stock data was obtained from the analysis of Organic C and carbon content from 10 sampling points in the mangrove ecosystem of Temmalebba Village.

The soil sampling was carried out using a pipe, drill/corer at a depth of 0-100 cm with intervals of 0-30 cm, 10-60 cm, 60-100 cm from the point adjusted to the land conditions at the sampling point. Then the soil samples were stored for three days to facilitate the cutting process, taking rings, and when compositing the soil. Soil samples were cut based on depth intervals using an iron saw, then the soil samples were composited according to each interval so that 3 composite samples were obtained at each point.

Samples were put in a zipper-lock plac-

tic and labeled. From the ring-taking and compositing process, 30 disturbed and 30 undisturbed soil samples were produced. The soil samples were then sent to the Chemistry and Soil Fertility Laboratory, Department of Soil Science, Faculty of Agriculture, Hasanuddin University for analysis of specific gravity, texture, and % of the material organic (%BO) which then be converted into Organic C and soil carbon storage. Data analysis in this study used several methods, including:

Bulk Density (BD) Analysis

Bulk density (BD) or sediment mass density is the dry weight of sediment in a certain volume. The calculation of bulk density is based on the formula (Kepel et al., 2019) as follows:

$$\text{Bulk Density (g cm}^3\text{)} = \frac{\text{sample dry weight (g)}}{\text{sample volume (cm}^3\text{)}}$$

Analysis of Organic Carbon

Organic C is material in or on the surface of the soil that comes from the remains of living things, either those that have undergone further decomposition or those that are undergoing the process of decomposition. Furthermore, this study calculates % C Organic by converting the percentage of organic matter into a percentage of carbon (% C) which can be calculated using the following equation (Verisandria et al., 2018):

$$\% C = (1/1,724) \times \%BO$$

Description:

%C = organic sedimentary carbon content
1,724 = constant for converting % organic matter to % C organic
%BO = organic materials

Content

Soil carbon sequesters carbon with the global carbon cycle, and plays a role in biogeochemistry, climate change mitigation, and building global climate models. The carbon content in the soil can be calculated by the formula (Marbun et al., 2020) as follows:

$$\text{Soil C (MgC ha}^{-1}\text{)} = \text{BD} \times \text{SDI (Soil Depth Interval)} \times \% C$$

Description:

Soil C (MgC ha⁻¹) = estimated carbon storage
BD = bulk density
SDI = depth interval (cm)
%C = carbon content of organic sediment material

RESULTS AND DISCUSSION

Bulk Density

Bulk Density shows the weight of the
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soil mass in oven-dried conditions per unit volume (Sugirahayu and Rusdiana, 2011). The higher the bulk density value obtained, the higher the density in the soil. Hardjowigeno (2003), stated that bulk density is an indication of soil density. The size of the particles indicated in the soil texture will affect the soil weight (Sugirahayu and Rusdiana, 2011). Soil with fine particles will affect the high density of the soil compared to soil with coarse particles. Bulk density is closely related to particle density, Particle density is the weight of dry soil per unit volume of particles (solid) soil. The results of bulk density and particle density analysis at 10 points of the mangrove ecosystem in Temmalebba Village are presented in Figure 2 and Figure 3:

Figure 2 shows that the highest bulk density is at point nine with a value of 1.35 g/cm³ at a depth of 60-100 cm. The high value at point nine is because the soil texture at this point is clay textured. The high bulk density in the clay texture is due to the fine clay particles so the density of the soil is high. This value is higher than the bulk density in the sandy-textured mangrove forest with a value of 0.556 g/cm³ (Sugirahayu and Rusdiana, 2011). While the lowest bulk density is at point seven with a value of 1.20 g/cm³ at a depth of 0-30 cm. Where the soil texture at point 7 is clay textured with also influenced by human activities such as logging. The remaining leaves and twigs can inhibit the flow of water into the soil so that it becomes soil compaction on the surface (Sofyan, 2011). The presence of vegetation and litter can drive the formation of a looser soil structure which results in a lower Bulk density value (Suryani et al., 2012). The condition of the highest particle density at a depth of 0-30 cm (Figure 3) is 2.67 g/cm³, if the particle density value is high, then it is good to be used as a planting medium for plant productivity. Sarief (1986)

stated that the value of soil density can be influenced by various factors including soil cul-

tivation, organic matter, soil compaction by rainwater and agricultural equipment, texture,

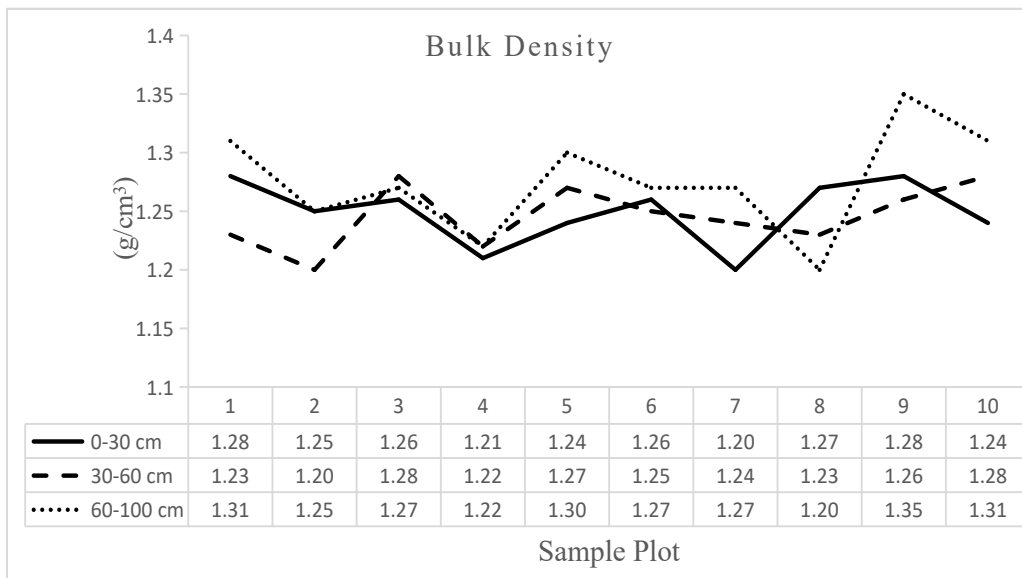


Figure 2. Bulk Density (BD) at 10 Sampling Points in the Mangrove Ecosystem, Temmalebba Village

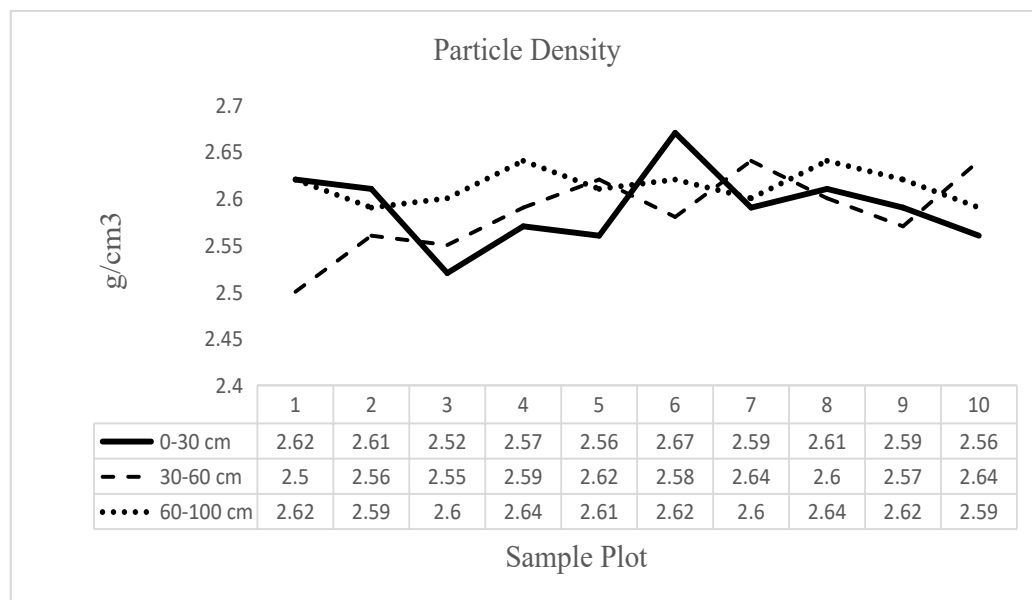


Figure 3. Particle Density (PD) at 10 Sampling Points in the Mangrove Ecosystem, Temmalebba Village

and water content.

The results of bulk density analysis based on depth showed that the highest bulk density was found at a depth of 60-100 cm with a value of 1.28 g/cm³. These results are presented in Figure 4. The average value of

the highest bulk density at a depth of 60-100 cm is 1.28 g/cm³ (Figure 4). This is also in line with the average value of particle density at a depth of 60-100 cm, which is 2.61 g/cm³ (Figure 5). If the particle density of the soil is high, the bulk density is also high. Particle

density is directly proportional to bulk density, but if the soil has a high level of water content, the particle density and bulk density will be below. The high value of bulk density at a depth of 60-100 cm is due to the clay texture at this depth. Br.Tarigan et al., (2014) said that bulk density varies greatly between horizons depending on the type and degree of aggregation, texture, and soil organic matter. The bulk density of the mangrove ecosystem in Temmalebba is higher than the value of the bulk density of the mangrove ecosystem in Paser Regency, East Kalimantan with the val-

ue of 0.556 g/cm^3 (Sugirahayu and Rusdiana, 2011). This difference is caused by differences in soil texture at each location, the soil in the mangrove ecosystem in Temmalebba has a clay texture while the mangrove ecosystem in Paser Regency has a sand texture. Where the soil with a clay texture has macropores while the soil with a sand texture has macropores. This is supported by the opinion of Sugirahayu and Rusdiana (2011), who said that with a large number of macropores, the sand-dominated soil will have a very low water holding capacity, so the soil density is low.

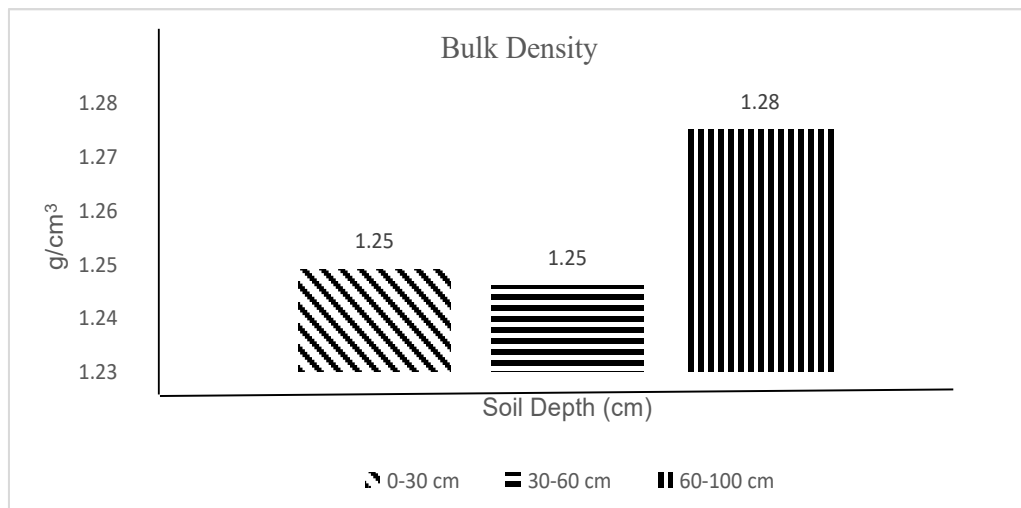


Figure 4. Average Bulk Density (BD) Based on Soil Depth in the Mangrove Ecosystem, Temmalebba Village

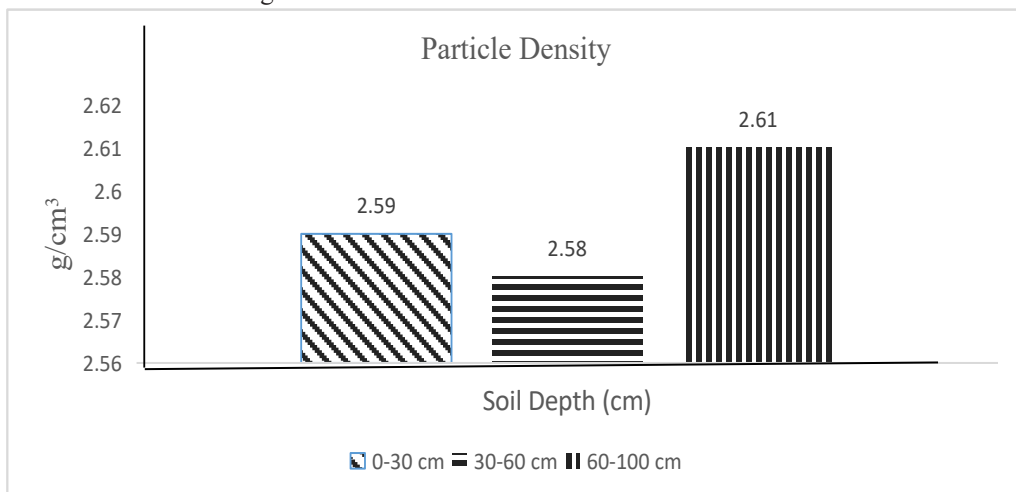


Figure 5. Average Particle Density (PD) Based on Soil Depth in the Mangrove Ecosystem, Temmalebba Village

Organic Materials

Organic materials are one of the important ingredients in the growth of vegetation. The level of organic matter can be indicated by the density and thick leaf growth on the vegetation. According to Nugroho, et al., (2013), vegetation density is related to the addition of organic residues which can increase the content of organic matter and nutrients. The primary source of soil organic matter comes

from plant organic tissue which can be in the form of leaves, twigs and branches, stems, fruits, and roots. Nontji (1993) stated that the fertility of the waters around the mangrove forest area is the key to the input of organic matter originating from litterfall. The fertility of mangrove sediments is due to the organic matter contained in them (Kushartono, 2009). The results of the analysis of organic matter content at 10 sampling points in the mangrove ecosystem of Temmalebba Village presented

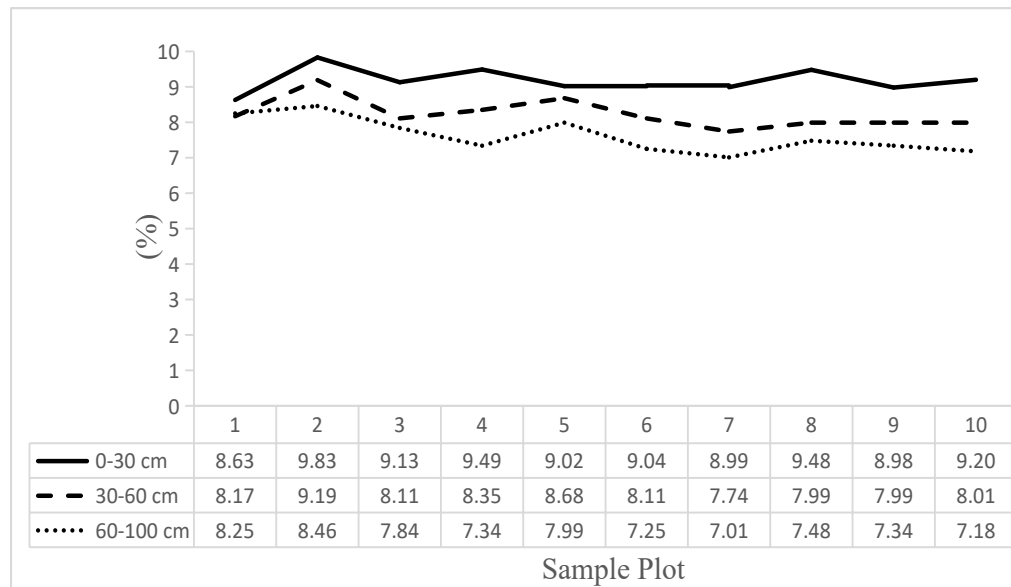


Figure 6. Organic Materials at 10 Sampling Points in the Mangrove Ecosystem of Temmalebba Village

in Figure 6.

The highest organic matter was found at the second point with a value of 9.83% in 0-30cm depth. The high organic matter at this point is caused by large and dense mangrove growth (Figure 7). This is in line with the opinion (Windarni et al., 2018) which states that the larger and denser a mangrove forest vegetation results in the higher its ability to produce organic litter which is the main constituent of organic matter in the soil. While the lowest organic matter content is at points three and six with a value of 8.11% at a depth of 30-60cm. The low organic matter content

at this location is due to the lack of vegetation at one point of repeated sampling. As can be seen in Figure 8, the vegetation at point three is less than those at point two in Figure 7, this results in reduced litter production as the main constituent of organic matter. This is in line with the opinion of Andrianto et al., (2015) who said that the lower the density of mangrove trees, the lower the litter production.

The results of the analysis of the average organic matter content at different depths in the mangrove ecosystem of Temmalebba Village showed that the highest organic matter was found at a depth of 0-30 cm with a



Figure 7. Vegetation Conditions at Point Two in Temmalebba Village



Figure 5. Vegetation Conditions at Point Three in Temmalebba Village.

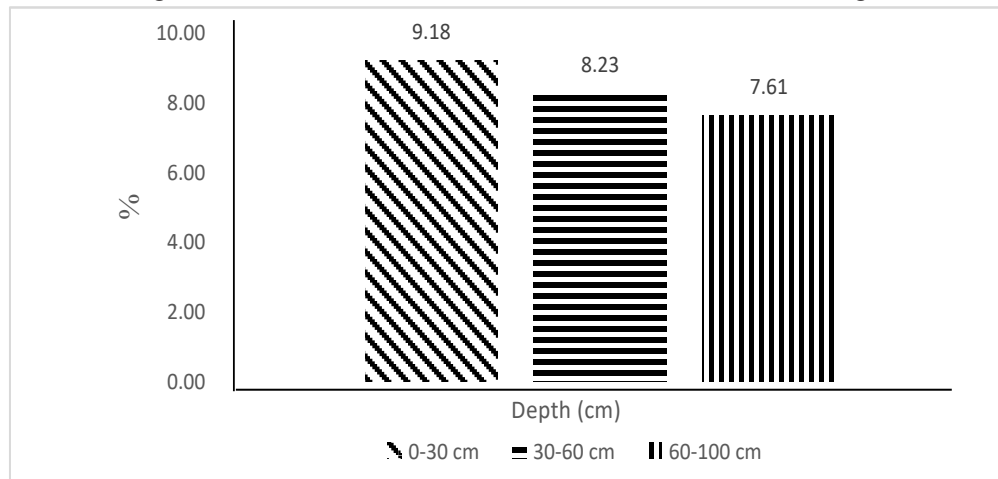


Figure 9. Average organic matter based on depth in the Mangrove Ecosystem of Temmalebba Village

value of 9.18%. This can be seen in Figure 9.

The high content of organic matter at a depth of 0-30 cm is caused by the accumulation of organic matter that occurs in the top layer. This is supported by the opinion of Br.Tarigan et al., (2014) who said that the accumulation of organic matter is concentrated in the upper layer. The slow decomposition of plant material results in significant carbon storage (Indraiswari and Nurweda Putra, 2018). While the lowest organic matter content is at a depth of 60-100 cm of 7.61%. The low organic content at this depth level is due to the decomposition process of organic matter from the accumulation of litter that only occurs in the surface layer. The low lower the

depth of the soil, the organic matter also decreases. This is also supported by the opinion of Kushartono (2009) who stated that the decomposition process of litter (leaves\branches\twigs) only occurs on the surface of the soil while at a depth of more than 20 cm the effect of this process is not significant.

Soil Carbon Content

Organic carbon in sediments is one of the constituents of organic compounds in the waters (Marbun et al., 2020). According to (Supriyadi, 2008), Organic carbon is a priority for soil improvement and carbon storage. The results of the analysis of soil carbon content from 10 different points in the mangrove eco-

system of Temmalebba Village are presented in Figure 10.

According to Siringoringo (2013), the level of soil carbon storage is determined by three interrelated variables, namely organic carbon concentration, soil density, and soil depth. The highest soil carbon content is at point one at a depth of 60-100cm with a value of 250.47 (Mg ha⁻¹) (Figure 10). The high value is influenced by bulk density and organic matter. Where the denser the soil, the strength of the soil in holding organic matter

is higher which ultimately affects the increase in the value of soil carbon content. While the lowest carbon content is at point seven with a depth of 30-60cm with a value of 161.08 (Mg ha⁻¹) (Figure 10). The low carbon content of the soil is also influenced by the content of organic matter. Eluozo, (2013), stated that the subsurface layer of the soil is denser and has less organic matter. Where the value of organic matter content at point seven is lower than the value of organic matter content at other points (Figure 4).

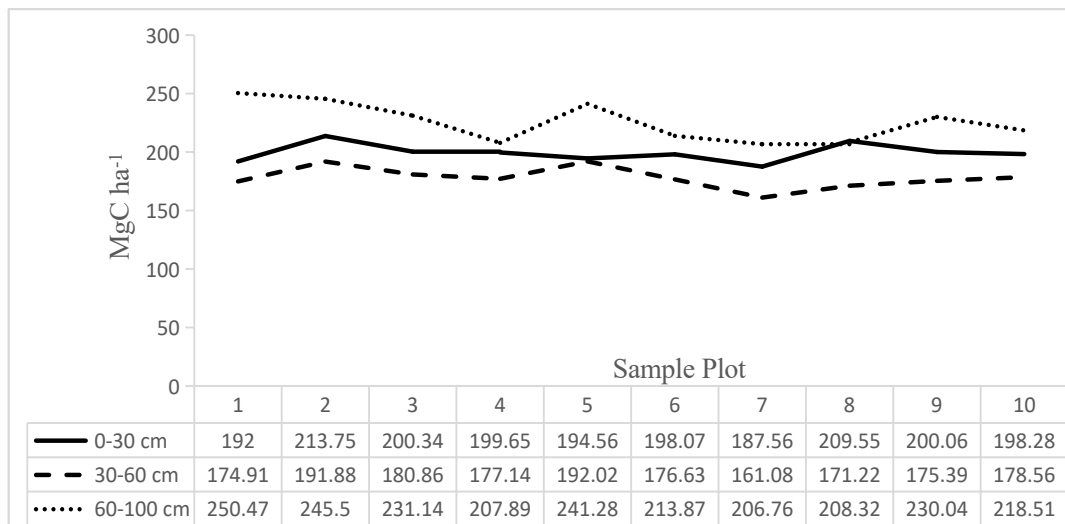


Figure 10. soil carbon content at 10 sampling points in the Mangrove Ecosystem of Temmalebba Village

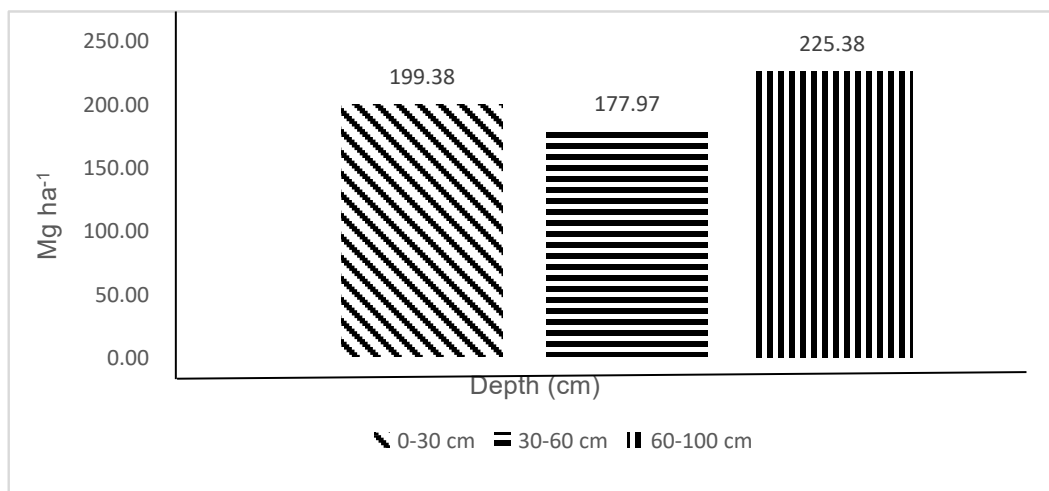


Figure 11. Average soil carbon content based on depth in the Mangrove Ecosystem of Temmalebba Village

According to Herman Siringoringo (2014) the amount of carbon contained in the soil is influenced by clay content, soil depth, soil mass density/Bulk Density. As presented in Figure 11, the highest soil carbon content is at a depth of 60-100 cm with an average value of 225.38 (Mg ha⁻¹). This value is related to the high value of bulk density as can be seen in Figure 3, where the highest bulk density is found at a depth of 60-100 cm. Where the bulk density soil texture at this depth is clay textured. Herman Siringoringo (2014), argued that the higher the percentage of clay texture (heavier texture), the greater the ability of the soil to hold carbon. The value of soil carbon content is higher than the carbon content of research in Indramayu which only has a value of 94.92 MgC ha⁻¹. Siringoringo (2013), stated that soil organic matter tends to be concentrated in the top layer of soil because most of the supply or input of soil organic carbon is from litters above the soil, while the amount surface litter decreases with increasing soil depth so that lead to low soil organic carbon content. This difference is caused by the damage that occurs to the mangrove ecosystem in Indramayu which causes the low value of bulk density in that area. Mangrove areas that have suffered damage and/or land conversion, will experience carbon loss from tree biomass, also from carbon stocks stored in sediments (Kepel et al., 2019).

Carbon content can be interpreted as the amount of carbon that can be absorbed and stored by the soil in the form of organic matter in the soil. The carbon content in the Mangrove ecosystem of Bone Bay in the village of Temmalebba is strongly influenced by soil depth, bulk density, and organic matter. Soil depth in the range of 60-100 cm with clay texture certainly affects the bulk density value. The higher the percentage of clay texture

(heavier), the greater the ability of the soil to hold carbon (Herman Siringoringo, 2014). Clays accumulate carbon relatively quick, whereas sandy textures can only accumulate small amounts of carbon even after a century of high carbon supply (Gobin et al., 2011). Soil organic matter and microorganisms have a major influence on the physical and chemical properties of the soil (Indraiswari & Nurweda Putra, 2018). According to Mahasani et al., (2015) Various factors affect carbon storage in soil, including environmental factors such as land use and soil Physico-chemical factors such as temperature, pH, pores, texture, bulk density, etc). The more carbon stored in the soil as soil organic carbon, it can reduce the amount of carbon in the atmosphere to reduce global warming and climate change (Chan et al., 2008). The results of this study indicated that soil carbon content in Bone Bay has a potential value of soil carbon storage ranging from 177.79 - 225.38 MgC ha⁻¹, this value is greater than soil carbon in the Wonorejo Mangrove Forest. Arifin et al., (2020) stated that the soil carbon content in the Wonorejo Mangrove Forest in Surabaya was 1.04 – 1.45 Mg Ha⁻¹. The disclosure of soil and above-ground carbon storage data (Karim et al., 2019) in Bone Bay has become a database for the Palopo City government in implementing carbon emission reductions through the Reducing Emissions from Deforestation and Degradation (REDD) scheme, using the Measurable, Reportable, and Verifiable method using accurate data and complete carbon storage both above and below the ground surface. Accurate and complete data on carbon storage both above and below the ground surface.

CONCLUSION

The mangrove ecosystem in Bone Temmalebba bay has soil carbon content that is

influenced by various factors including soil depth, bulk density, and organic matter. Soil carbon content is certainly very important to have an impact on the global climate, and the carbon content in the mangrove ecosystem is expected to be a form of mitigation to control the greenhouse effect.

AUTHOR CONTRIBUTION

S.M.A. designed the study, wrote the method and analyzed the data, whereas N.N.N. wrote all of the sections of this the paper and analyzed the data. W. and A. collected and analyzed the data.

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CONFLICT OF INTEREST

We declare that there are no conflicts of interest regarding this research.

REFERENCES

- Akbar, C., Arsepta, Y., Dewiyanti, I. & Bahri, S. (2019). Dugaan Serapan Karbon Pada Vegetasi Mangrove, di Kawasan Mangrove Desa Beureunut, Kecamatan Seulimum, Kabupaten Aceh Besar. *Jurnal La'ot Ilmu Kelautan*, 1(2), 11-22.
- Alongi, D. M. (2012). Carbon Sequestration in Mangrove Forests. In *Carbon Management*, 3(3), 313–322.
- Andrianto, F., Bintoro, A. & Budi Yuwono, S. (2015). Produksi dan Laju Dekomposisi Serasah Mangrove (*Rhizophora Sp.*) di Desa Durian dan Desa Batu Menyan Kecamatan Padang Cermin Kabupaten Pesawaran. *Jurnal Sylva Lestari*, 3(1), 9-20.
- Arifin M., Widijanto, A.P., & Santoso, S. B. (2020). Pengukuran Stok KArbon dan Karakteristik Tanah di Tinjau dari Segi Garis Pantai di Hutan Mangrove Wonorejo Surabaya. *Seminar Nasional Magister Agroteknologi Fakultas Pertanian UPN*, pp. 119-125.
- Br. Tarigan, E. S., Guchi, H., & Marbun, P. (2014). Evaluasi Status Bahan Organik dan Sifat Fisik Tanah (Bulk Density, Tekstur, Suhu Tanah) Pada Lahan Tanaman Kopi (*Coffea Sp.*) di Beberapa Kecamatan Kabupaten Dairi. *Jurnal Agroekoteknologi Universitas Sumatera Utara*, 3(1), 246-256.
- Cahyaningrum, S. T., Hartoko, A. & Suryanti. (2014). Biomassa Karbon Mangrove pada Kawasan Mangrove Pulau Kemujan Taman Nasional Karimunjawa. *Diponegoro Journal of Management of Aquatic Resources*, 3(3), 34–42.
- Chan, K. Y., Cowie, A., Kelly, G., Singh, B. & Slavich, P. (2008). *Scoping Paper: Soil Organic Carbon Sequestration Potential for Agriculture in NSW. NSW DPI Science & Research Technical Paper, NSW, Dept Primary Industries*, w South Wales: NSW Department of Primary Industries.
- Dewanti, N. P., Muslim, M. & Prihatining-sih, W. R. (2016). Analisis Kandungan Karbon Organik Total (KOT) dalam Sedimen di Perairan Sluke Kabupaten Rembang. *Jurnal Oseanografi*, 5(2), 202-210.
- Eluozo, S. N. (2013). Predictive Model to Monitor the Rate of Bulk Density in

- Fine and Coarse Soil Formation Influenced Variation of Porosity in Coastal Area of Port Harcourt. *American Journal of Engineering Science and Technology Research*, 1(8), 115-127.
- Gobin, A., Campling, P., Lavelle, P., & Berman, S. (2011). *Soil Organic Matter Management Across the EU Best Practices, Constraints and Trade-offs Annex II Case Studies*. (Final Report). The European Commission's DG Environment.
- Hardjowigeno, S. (2003). *Ilmu Tanah*. Penerbit Akademika Pressindo. Jakarta.
- Herman Siringoringo, H. (2014). Peranan Penting Pengelolaan Penyerapan Karbon dalam Tanah. *Jurnal Analisis Kebijakan Kehutanan*, 11(2), 175–192.
- Ibrahim, A., & Muhsoni, F. F. (2020). Estimasi Stok Karbon Pada Ekosistem Hutan Mangrove di Desa Lembung Paseser, Kecamatan Sepuluh, Kabupaten Bangkalan. *Juvenil: Jurnal Ilmiah Kelautan dan Perikanan*, 1(4), 498-507.
- Indraiswari, I. A. M., & Nurweda Putra, I. D. N. (2018). Estimasi Persentase Karbon Organik pada Tanah di Hutan Mangrove Alami, Perancak, Jembrana, Bali. *Journal of Marine Research and Technology*, 1(1), 14-18.
- Karim, H.A., Ahmad, A., & Rosdayanti, A. (2019). Komposisi dan Cadangan Karbon Ekosistem Mangrove Teluk Bone Palopo, Sulawesi Selatan. *Gorontalo Journal of Forestry Research*, 2(1), 12-19.
- Kepel, T. L., Ati, R. N. A., Daulat, A., Rustam, A., Suryono, D. D., Sudirman, N., & Hutahaean, A. A. (2019). Cadangan Karbon Ekosistem Mangrove di Sulawesi Utara dan Implikasinya Pada Aksi Mitigasi Perubahan Iklim. *Jurnal Kelautan Nasional*, 14(2), 87–94.
- Kushartono, E. W. (2009). Beberapa aspek Bio-Fisik Kimia Tanah di Daerah Man-
grove Desa Pasar Banggi Kabupaten Rembang. *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, 14(2), 76-83.
- Liu, H., Ren, H., Hui, D., Wang, W., Liao, B., & Cao, Q. (2014). Carbon Stocks and Potential Carbon Storage in the Mangrove Forests of China. *Journal of Environmental Management*, 133, 86–93.
- Mahasani, I. G. A. I., Widagti, N., & Karang, I. W. G. A. (2015). Estimasi Persentase Karbon Organik di Hutan Mangrove Bekas Tambak, Perancak, Jembrana, Bali. *Journal of Marine and Aquatic Sciences*, 1(1).14-18.
- Marbun, A., Rumengan, A. P., Schadu, J. N. W., Paruntu, C. P., Angmalisang, P. A., & Manopo, V. E. (2020). Analisis Stok Karbon Pada Sedimen Mangrove di Desa Baturapa Kecamatan Lolak Kabupaten Bolaang Mongondow. *Jurnal Pesisir Dan Laut Tropis*, 8(1), 20-31.
- Nontji, A. (1993). *Laut Nusantara*. Djambatan. Jakarta.
- Nugroho, R. A., Widada, S., Pribadi, R. (2013). Studi Kandungan Bahan Organik dan Mineral (N, P, K, Fe dan Mg) Sedimen di Kawasan Mangrove Desa Bedono, Kecamatan Sayung, Kabupaten Demak. *Jurnal Of Marine Research*, 2(1), 62-70.
- Pasau, M. S. (2018). Biomassa dan Cadangan Karbon Mangrove pada Teluk Bone (Studi Kasus Jalan Lingkar Palopo). *Skripsi*. Fakultas Kehutanan Universitas Andi Djemma Palopo. Palopo
- Rahman., Effendi, H., & Rusmana, I. (2017). Estimasi Stok dan Serapan Karbon pada Mangrove di Sungai Tallo, Makassar. *Jurnal Ilmu Kehutanan*, 11(1), 19-33
- Sarief, E. S. (1986). *Kesuburan dan Pemupukan Tanah Pertanian*. Pustaka Buana. Bandung.
- Siringoringo, H. H. (2013). Potensi Sekuestra-

- si Karbon Organik Tanah Pada Pembangunan Hutan Tanaman Acacia mangium Willd. *American Journal of Engineering Science and Technology Research*, 1(8), 115-127.
- Sofyan, M. (2011). Pengaruh Pengolahan Tanah Konservasi Terhadap Sifat Fisik dan Hidrologi Tanah (Studi Kasus di Desa Babakan, Kecamatan Drama-ga, Kabupaten Bogor). *Skripsi*. Bogor: Fakultas Pertanian, IPB University.
- Sugirahayu, L. & Rusdiana, O. (2011). Perbandingan Simpanan Karbon pada Beberapa Penutupan Lahan di Kabupaten Paser, Kalimantan Timur Berdasarkan Sifat Fisik dan Sifat Kimia Tanahnya. *Jurnal Silvikultur Tropika*, 2(3), 149-155.
- Supriyadi, S. (2008). Kandungan Bahan Organik sebagai Dasar Pengelolaan Tanah di Lahan Kering Madura. *Jurnal E-Bio-medik*, 5(2), 176–183.
- Suryani, I., Lopulisa, C., Nurkin, B., & Pairunan A. (2012). Dinamika Sifat Fisik Tanah pada Areal Pertanaman Kakao Akibat Alih Guna Lahan Hutan di Kecamatan Papalang Kabupaten Mamuju. *Jurnal Kehutanan*, 3(1), 21-32.
- Suryono, S., Soenardjo, N., Wibowo, E., Ario, R., & Rozy, E. F. (2018). Estimasi Kandungan Biomassa dan Karbon di Hutan Mangrove Perancak Kabupaten Jembrana, Provinsi Bali. *Buletin Oseanografi Marina*, 7(1), 1-8.
- Verisandria, R., Schadow, J., Sondak, C., Ompi, M., Rumengan, A., & Rangan, J. (2018). Estimasi Potensi Karbon pada Sedimen Ekosistem Mangrove di Pesisir Taman Nasional Bunaken bagian utara. *Jurnal Pesisir dan Laut Tropis*, 6(1), 81-97.
- Wahyudi, J. (2018). Mitigasi Emisi Gas Rumah Kaca. *Jurnal Litbang: Media Informasi Penelitian, Pengembangan Dan IPTEK*, 12(2), 104–112.
- Windarni, C., Setiawan A., & Rusita (2018). Estimasi Karbon Tersimpan pada Hutan Mangrove di Desa Margasari Kecamatan Labuhan Maringgai Kabupaten Lampung Timur. *Jurnal Sylva Lestari*, 6(1), 66-74.