Preliminary study on C-organic and C-microbial biomass of peatland in Toba highlands

H Munawaroh, A Rauf, Razali, Bintang and T Sabrina*

Universitas Sumatera Utara, Medan, Indonesia

*E-mail: t.sabrina@usu.ac.id

Abstract. Toba highlands is unique and covers a large area. Peat plays an important role as a carbon sink, and is currently utilized for agricultural purposes, use as firewood, and left to degrade. The use of peatlands will impact the maturity of peat, and the emission of carbon dioxides and other gases caused by the decomposition process of microbes. A brief transformation of organic carbon from peat into carbon dioxide negatively impacts the environment, especially in increasing the greenhouse gas emissions. C-organic and C-microbial biomass was observed in peatlands of the Toba Highlands in Humbang Hasundutan, employing the Walkey and Black method, and fumigation and extraction methods to calculate the microbial population involved in the decomposition process or called C-microbial biomass. Moreover, descriptive method were used to map their distribution in the peat areas. The results showed that the highest C-organic was found in barren land at 22.05% and soil C-microbial biomass population was 3.24 µg g⁻¹ soil, whereas the least C-Organic was found in peatland transferred to coffee fields, at 5.23% while the least C-microbial biomass was in peatland transferred to onion fields at 0.28 µg g⁻¹ soil. There was a relatively small amount of organic matter and C-microbial biomass in paddy field, shallots, and grasses. Therefore, the results indicated that converting peatland into agricultural land would likely change the value of organic matter and C-biomass population.

1. Introduction

Peatlands have a vital role as carbon storage. The storage can decrease due to human activities such as land use change caused by fire and soil tillage. The storage should be conserved to minimize carbon emissions and to achieve sustainable peatland management systems [1]. Peat forests function as carbon sinks, reduce the amount of carbon in the earth's atmosphere and prevent the effects of greenhouse gases, that can cause global warming [2]. Type of vegetation, plant density, and implemented management affect the amount of carbon storage. Woody vegetation of forest generates a higher storage compare to shrubs. Plant density affects the light intensity used for photosynthesis, meanwhile CO₂ from respiration is absorbed and converted by plants into organic carbon in the form of biomass. Plant maintenance affect the process of carbon storage on peatland.

One of the biological problems of peatland is the loss of C and N due to organic mineralization [3]. In a reductive peat environment, the rate of decomposition of peat is somewhat slow and a lot of toxic organic acids are produced, including CO₂ and CH₄ [4]. CH₄ and CO₂ are the main gases that determine the greenhouse effect or global warming [5]. Peatlands are generally found in the lowlands. This peatlands are formed in a basin, flooded with water [6]. This condition causes the decomposition process of organic matter to be slower than the accumulation process, resulting in the accumulation of organic...
matter getting thicker over time. Other instances, peatlands may be found in tidal swamp or in peat lowland swamp areas [7].

Identification of C-microbes is needed to determine population diversity of carbon microbial biomass in the soil. The difference between natural and disturbed peatlands relates to the carbon storage, in which the storage at natural peatlands is relatively stable [8]. Peat thickness can increase up to 3 mm year$^{-1}$ [9]. However, disturbing natural condition will accelerate the weathering process (decomposition) resulting in greenhouse gases emission especially CO$_2$. The process is commonly related to draining areas which accompanies peatlands uses.

The research site was chosen since it is a unique mountainous peatlands in Indonesia, located in the Districts of Humbang Hasundutan, Dolok Sanggul and Pollung sub districts, North Sumatra Province. A large area of peatlands in this area are currently used for agriculture, and partly for mining firewood.

2. Methodology

2.1. Test site

This research was conducted in March-May 2021 in peatlands area of Toba highlands, Humbang Hasundutan with an altitude of 1338-1414 m above sea level. Total peat area is ±1679.742 ha. The average rainfall is 197.8 mm classified as type B, indicated by a wet climate, with an average dry month of 1.5 and wet month of 9. Samples were taken using the purposive sampling method in two sub-districts of Humbang Hasundutan Regency, i.e. Pollung sub-district and Doloksanggul sub-district. From these two sub-districts, samples were taken representing various land use in the field, including peatlands. The distribution of sample points relative to administrative areas representing four land uses is presented in Figure 1.

![Figure 1. Site location.](image)

2.2. Data and analysis

In this research, we observed a few variables, including: 1. Soil pH which was measured as saturating peat soil with water ratio of 1:5 by using a pH meter 2. C-organic that is approximated from carbon organic compound. The reduced form of the compound is Cr$_{6+}$ indicated by orange color, whereas when the compound is acidic, in form of Cr$_{3+}$, the indicator will be green. The intensity of the green color is equivalent to the carbon content measured by spectrophotometer at a wavelength of 561 nm. 3. C-
microbe biomass. The C-microbe was estimated by using fumigation and extraction. Fumigation with chloroform kills and dissolves microbial cells by releasing the cytoplasm into the environment. Then, cell materials can be extracted from the soil with 0.5 M K₂SO₄ [15][10]. C-microbial biomass sample were taken from four types of land use. C-Microbial biomass is defined as the part of soil organic matter consisting of living organisms with the size 5 – 10 um³. In general, C-microbial biomass is expressed in mg C kg⁻¹ soil or g C mg⁻¹ soil, especially in soils which has a C-organic content of 1-5%. Soil C-microbial content is relatively small compared to C-soil as a whole, but soil microbes play an important role in the sustainability of the nutrient cycle.

Calculation of C-microbial biomass population is as follows:

\[
\text{C-organic content (mg kg}^{-1}\text{ soil)} = \text{ppm curve } \times \text{ml extract} \times 100 \text{ ml}^{-1} \times 100 \text{ mg sample}^{-1} \times f_k
\]

\[
= \text{ppm curve } \times 0.25 \times 100. 2500 \text{ ml}^{-1} \times f_k
\]

\[
= \text{ppm curve } \times 0.1 \times f_k
\]

Notes:

ppm curve = sample rate of the relationship curve between standard series grades and their readings after corrected for blanks

fk = correction factor for soil water content

C-biomass (µg g⁻¹ soil) = \( \frac{S-C}{0.35} \)

S = the average value of the C-organic content of the sample (with chloroform)

C = the average value of the control C-organic content (without chloroform)

0.35 = kEC factor (conversion of C to C-microbial flow)

3. Results and discussion

3.1. Physical and chemical characteristics of Toba peatland

The upland peat soil physical and chemical characteristics are presented at Table 1.

| Land uses                  | Variables                  | Soil temperature (°C) | Water content (%) | Precipitation (%) |
|----------------------------|----------------------------|-----------------------|-------------------|-------------------|
|                            | C-organic (%), pH, C/N     |                       |                   |                   |
| land without vegetation    | 22.05, 2.7, 37.37          | 18                    | 42.81             | 98                |
| (open peatland)            |                            |                       |                   |                   |
| Grass field                | 19.32, 4.1, 30.18          | 18                    | 28.08             | 85                |
| Paddy field                | 14.15, 4.2, 22.46          | 22                    | 32.80             | 85                |
| Onion field                | 15.64, 3.7, 22.66          | 22                    |                   |                   |
| Coffee field               | 5.23, 3.6, 10.25           | 19                    | 14.28             | 85                |

The type of land uses affected soil temperature, humidity, soil moisture content and soil pH. The lowest soil temperature was found on the open peat land, grass land, and coffee land, which were at about 18°C - 19°C, whilst the highest temperature was found in the paddy field and the onion field, at 22°C. Soil moisture content and altitude affect soil temperature and humidity. The highest soil moisture was found on the open peatlands at 10% and the lowest one was on the coffee vegetation at 7%. The air temperature in an area or region can be estimated considering its altitude (m above sea level), where every 100 m above sea level place, the temperature tends decreasing by 0.61°C [11].

Soil temperature of open peatland and grass areas was the lowest viz. 18 ⁰C. The dynamics of soil temperature caused fluctuation of C-microbial biomass number. Plant canopy limits the intensity of sunlight reaching soil surface. However, if fully open-up surfaces may cause excessive sunlight on the soil surface, leading to increasing soil temperature, and decreasing carbon microbial biomass.
Vegetation types have significant influences on the dynamics of soil carbon and soil microbial structure [12]. The differences in climate, measured by temperature and precipitation, steer the difference of soil organic matter decomposition. These conditions affect the C-microbial biomass in the soil. In addition, vegetation types determine soil carbon quantity and microbial community structure through direct effects of quantity and quality of inputs and indirect effects of soil physiochemical modifications and constituent materials. Therefore, soils under different climatic and vegetation conditions may result in different soil microbes, and consequently diversify microbial functional activity and carbon utilization.

The soil water content on the coffee fields was 14.28%, which is the lowest value compared to other land types. Whereas, the highest soil water content was found in the open peatlands (89.03%). This difference may be due to the presence of vegetation above the soil surface and dissimilar management of peatlands. The pH (soil acidity) was varied over differing land uses. The lowest soil pH was at the open peat land, at 2.7 and the highest pH was at the coffee land, at 4.2. Those values indicate hydrogen ion concentration in the soil, in which the higher the H⁺ content, the more acidic the soil. The pH affect the living of microorganisms in the soil [13].

Microbes as agents of organic matter transformation, which regulate the rate of carbon emissions produce. Their activities are influenced by various factors such as water content, temperature, nutrients and types of organic matter, pH, clay content, level of diversity and microbial community structure. The high organic matter in peat soil is a characteristic possessed by peat soil. The productivity and carrying capacity of the soil depends on the microbial activity contained in it [14]. Microorganisms that break down organic matter consist of fungi and bacteria, in which in anaerobic conditions most of the decomposers of organic matter are bacteria.

### 3.2. C-Microbial biomass

The population of C-Microbial Biomass (µg g⁻¹ soil) are shown at Table 2.

| Peatland use type   | C-Microbial biomass (µg g⁻¹ soil) |
|---------------------|----------------------------------|
| Open Peatland       | 3.250 ± 0.008                    |
| Grass field         | 1.163 ± 0.073                    |
| Paddy field         | 0.611 ± 0.024                    |
| Onion field         | 0.308 ± 0.025                    |
| Coffee field        | 0.990 ± 0.027                    |

Note: replication 2 each samples from 5 sample point

The highest C-microbial biomass was found in open land and, at ±3.24 µg g⁻¹ of soil, and the lowest was on the onion field at ±0.30 µg g⁻¹ soil (table 2). Soil microbial activity is influenced by several factors, including land use, soil management techniques, use of fertilizers or pesticides and other anthropogenic activities. Land management practices can change the structure and pores of soil causing changes in the microenvironment of microbes. This will result in changes in community composition and soil microbial activity [16].

Microbes’ population is an indicator of ecosystem quality. Activities of microbes in certain ecosystems may be observed from the overall metabolic activity of all soil microbes including bacteria, actinomycetes, fungi, algae, protozoa, plants and microfauna in the site. Common indicators of soil biological quality are soil respiration, microbial biomass, and soil exoenzymes.

The coffee land had more C-microbial biomass population compared to other land uses, which was ±0.99 µg g⁻¹ soil (table 2). This high C-microbial biomass was due to the supply of soil organic matter from the litter of coffee leaves and flowers. In addition, the intensity of cultivation differ between coffee and seasonal crops (paddy field and onions field).
The relationship between microbial biomass response, enzyme activity, and soil properties suggests that microbial biomass levels and enzymatic responses to depletion. The process may depend on post-thinning changes in soil microclimate and substrate availability. Changes in these factors can increase or decrease microbial metabolism using organic carbon and nitrogen depending on vegetation types [17].

Carbon Microbial Biomass number is the earlier indicator to inform the impact of changes in total soil organic matter, since microbes provide nutrients and decomposition agents to forming soil organic matter [18]. Microbes are agent of decomposition and mineralization of N. Increasing the availability of soil organic matter will increase the mineralization of N.

4. Conclusion
A brief changes of organic carbon from peat into the form of carbon dioxide have a negative impact on the environment, especially the increase in greenhouse gases. This research found that C-organic content of open land was the largest at 22.05%, while C-microbial biomass population was ±3.25 µg g⁻¹ soil. The least C-organic is found on coffee field at 5.23% while the least C-microbial biomass population was found in onion fields at 0.30 µg g⁻¹ soil. The coffee field had more C-microbial biomass population compare to other land uses, at ±1.09 µg g⁻1 soil. Furthermore, there was a small amount of organic matter and C-microbial populations in paddy field, onion field and grass vegetation. The results showed that both the organic matter and the C-microbial biomass population of peatlands changed by using peatland for agricultural cultivation. The more disturbed peatland, the more decreasing organic matter and C-microbial biomass population could be.

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