Carbon dioxide (CO\textsubscript{2}) emissions on highland peatland that has been planted with coffee in Humbang Hasundutan Regency, North Sumatra Province

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Abstract. Peatlands in Indonesia are estimated at 26 millions ha. These peatlands are spread across Sumatra on of 8.9 million ha areas. Humbang Hasundutan is one of the area that spread peatlands in North Sumatra with an estimated area of around 1,042 hectares spread in Lintong Nihuta District, Pollung District and Dolok Sanggul District. Peat in this area is unique and rare because the general peat is found in lowlands adjacent to the coast, but peat in Humbang Hasundutan area is a highland (topogenous) peat which lies at altitude 1000-1450 meters above sea level. The purpose of this study was to determined the amount of CO\textsubscript{2} emissions on peatlands cultivated with coffee in Dolok Sanggul District, Humbang Hasundutan Regency. This study was conducted in Huta Bagasan Village, Dolok Sanggul District, Humbang Hasundutan Regency. This research method is a survey research of the amount of CO\textsubscript{2} emissions on highland peatlands that are cultivated with coffee. CO\textsubscript{2} sampling using a closed hood method. The sampling point is determined 75 cm from the plant. The sampling was taken 3 times a day, namely at 07.00 WIB, 12.00 WIB and 17.00 WIB. Based on the research was known that the highest CO\textsubscript{2} emissions were found during the day at 8.12 mg/m\textsuperscript{2}/day, followed by the afternoon at 7.67 mg/m\textsuperscript{2}/day, and the lowest in the morning at 4.21 mg/m\textsuperscript{2}/day.

1. Introduction

One of the ecological functions of peatlands is as a storehouse of carbon. Total carbon in peatlands in Indonesia is estimated to be around 44.5 Gt. Conversion of peat swamp forests is a source of CO\textsubscript{2} emissions [1]. The definition of greenhouse gases in relation to global warming includes carbon dioxide (CO\textsubscript{2}), nitrous oxide (N\textsubscript{2}O), methane (NH\textsubscript{4}) and hydrocarbons such as (CFC). Earth's surface temperature increases due to the concentration of greenhouse gases in the atmosphere, especially carbon dioxide, methane, and nitrous oxide has increased [2].

Traditional systems of food and vegetable crops have deliberately burned bushes and peat layers to get several tons of soil fertile ash. If 2.5 cm of peat is burned every year, the emissions that occur are around 55 t CO\textsubscript{2} / ha / year. Drainage which is generally 30 cm deep has the potential to contribute CO\textsubscript{2} emissions of 27 t / ha / year so that emissions amount to 82 t / ha / year or 2,050 t CO\textsubscript{2} / 25 years. This amount is more than three times the emissions from forest clearing [3].

As per the development of national land surveys and mapping, estimates of Indonesia's peatland area have fluctuated from 13.2 to 26.5 million hectares. The broad reference referred to in...
international literature is 20.6 million hectares [1, 3]. This figure is based on a peatland map written by Wahyunto et al. published in 2003, 2004 and 2005 by Wetland International. These estimates are based on land survey data that is relatively limited, especially for Papua because accessibility constraints are only based on the results of analysis of satellite imagery. The latest peat data, issued by the Indonesian Center for Agricultural Research and Development of Land Resources [4], covers an area of 14.9 million ha. Data on the characteristics, distribution, and extent of peatlands are very dynamic and will continue to experience changes, therefore it needs to be updated regularly, by increasing / adding data from the validation results (ground truth) in representative regions to obtain information that is almost close actual conditions [5].

Peat forest is one type of forest that has an important role as an environmental buffer. This is related to the function of peat in gatra hydrological, biogeochemical and ecological. Hydrologically peat can store water where raw peat (fibric) can store very large water between 500% - 1000% weight. Natural swamp peat as well as a water reservoir area also balances the regional water control system (control water system). Peat is an absorbent and storage area for water (aquifer) during the rainy season, but when rainfall is small it slowly releases its stored water [6].

The area of the world peatland ranges from 38 million ha with more than 50% in Indonesia. Peatlands in Indonesia are estimated at 26 million ha [7]. Almost all of the peat reserves in Indonesia are located outside of Java, which are transmigration destination islands. These peatlands are spread on Sumatra Island 8.9 million ha, Kalimantan Island 6.3 million ha and Papua 10.9 million ha. In the Sumatra region, most of the peat is on the east coast, while in Kalimantan there are in West Kalimantan, Central Kalimantan and South Kalimantan.

Humbang Hasundutan is one of the areas that spread peatlands in North Sumatra. According to [8], the area of peat land in Humbang Hasundutan is estimated to be around 1,042 hectares spread in Lintong Nihuta District, Pollung District and Dolok Sanggul District. Peat in this area is unique and rare because in general peat is found in the lowlands adjacent to the coast, but peat in the Humbang Hasundutan area is a highland (topogenous) peat which lies at an altitude of 1000-1450 m asl.

Peat soils in the Humbang Hasundutan area include fibric peat (immature) and based on its depth are still classified as deep peat. This type of peat is prone to fire and cannot be used as an agricultural area, so most people use it as fuel wood. However, a small portion of the peat in this area is already classified as saprik peat (ripe), because it has been processed and made drainage by the local community and is used as an agricultural area such as in the District of Dolok Sanggul.

Peatlands have a real potential in producing greenhouse gases such as CO$_2$ and CH$_4$ [9]. Along with this, the increase in the concentration of CO$_2$ in the atmosphere has become a hot issue today where the effects of greenhouse gases can affect living systems on earth. Increasing the concentration of greenhouse gases (GHG) results in absorbed solar radiation energy

2. Material and Methods
2.1. Place and time of research.
The study was conducted in Huta Bagasan Village, Dolok Sanggul District, Humbang Hasundutan Regency. Laboratory analysis was carried out at the Jakenan, Pati, Central Java Greenhouse Gas (GHG) Research Institute (BALINGTAN) Laboratory and the USU Agriculture Faculty Soil Biology Laboratory. The study took place in March 2017 until June 2017. The research method is a survey research on the amount of CO$_2$ emissions on highland peatlands that are cultivated with coffee plant.

2.2. Materials and tools
The materials used in this study include research location maps, and climate data in the research area. The tools used in this study include the closed chamber to take CO$_2$ from the ground, the vial tube as the place where the gas has been taken, and the GPS (Global Positioning System) to determine the geographical position.
2.3. Implementation of research
CO₂ gas sampling using a closed hood method. The sampling point is between plants with a distance of 100 cm from the plant. The sampling time is done 3 times, namely at 07.00 AM, 12.00 AM and 17.00 PM. The number of samples taken for each time is 5 samples with an interval of 10 minutes, so that the total sample taken is 3x5x6 days = 90 samples.

At each observation point, a lid is placed which is made of fiberglass measuring 50 x 50 x 30 cm. Sampling is carried out for 6 (six) consecutive days at 3 (three) different times namely 07-08 am, 12.00-13.00 noon, and 17.00-18.00 afternoon.

2.3.1. Observation parameters. The parameter observed in this study is CO₂ emissions. Samples were taken using 20 ml of polyethylene chamber installed on peatlands. Gas is inserted into a 35 ml vial. The gas taken is then analyzed using Chromatography Gas at the Greenhouse Environment Laboratory (BALINGTAN) GHG laboratory, Pati, Central Java.

Calculation of emissions is adopted from Balingtan (2007), using the formula:

\[ E = \frac{dc}{dt} \times V_{ch} \times mW \times \frac{273.2}{dt} \times A_{ch} \times mV \times 273.2 + T \]

Where:
- \( E \) = CO₂ gas emissions (mg / m² / minute)
- \( \frac{dc}{dt} \) = Difference in CO₂ concentration (ppm / minute)
- \( V_{ch} \) = Sungkup Volume (m³)
- \( A_{ch} \) = Sungkup Large (m²)
- \( mW \) = Molecular Weight of CO₂ (g)
- \( mV \) = Volume molecular of CO₂ (22.41 L)
- \( T \) = Average temperature (°C)

3. Result and Discussion
3.1. General conditions of the research area
Hutabagasan Village is ± 1 Km from the Capital of Humbang Hasundutan, Dolok Sanggul which borders:
- East side : Sijamapolang district
- West side : Matiti village
- North Side : Sihite II village
- South side : Janji village

Hutabagasan village is divided into 3 hamlets with a number of family heads of 445 families with a total population of 2,031 [10]. The average resident of Hutabagasan Village has a livelihood as a farmer, according to the type of plant that matches the type of soil that is in the village of Hutabagasan. The most planted types of plants are coffee, rice, chili, tomatoes, onions, and various types of vegetables.

The area of Hutabagasan Village is 815 Ha which is divided into several areas such as the following:
- Settlement of residents : 45 ha
- Planting : 50 ha
- Rice fields : 302 ha
- Gardens : 170 ha
- School : 2 ha
- Sleep area : 246 ha

Hutabagasan Village, Doloksanggul Sub-District, Humbang Hasundutan Regency has some Topogen Peat soil types with three different land uses in one area. The three land uses in question
include rice fields, annual crops (coffee), and seasonal crops (horticulture) such as tomato plants, peppers, onions, and various types of vegetables. Located at an altitude of 1,411 meters above sea level. Geographically, this region is at 02º15,552' LU and 098º43,366' BT. Topogen Peat Soil in this region comes from woody material (peat from wood). According to Munir (1996), peat from Kayukayuan material, formed from the remaining trees, also from scrubs (scrubs) and other plants from the swamp (swap forest). Organic material that is accumulated is rather homogeneous except if it contains fibrous ingredients. Woody peat is brown or black and the color depends on the level of decomposition, is loose and open when dry and not fibrous. The average annual rainfall data in this region is 10 wet months, 1 month moist and 1 dry month. This climate classification is based on Schmidt and Ferguson, ie wet months if rainfall is >100 mm, moons are humid if rainfall is 60-100 and the moon is dry if rainfall is <100 mm. Determination of soil temperature is obtained from the average annual air temperature approach of +1 ° C, so that the average soil temperature obtained is 18.7 ° C [11].

Fertilization for paddy fields is carried out in two stages, namely the administration of NPK fertilizer at the time of initial planting and at the vegetative end of the rice plant in a dispersed manner. Arabica coffee plants are carried out twice a year, namely NPK fertilizer with applications in planting holes at the beginning of planting and then take turns fertilizing twice a year for manure, urea and NPK fertilizer with applications in beds. In horticulture plants, fertilizing plants is carried out every planting period even sometimes 3-4 times during the planting season depending on the type of horticultural plants being cultivated. The type of fertilizer and application carried out is the same as in Arabica coffee plants. For the doses given, farmers in this region have never calculated the amount of fertilizer given, both for paddy fields, Arabica coffee plants and seasonal crops.

3.2. Flux of CO$_2$

Flux of CO$_2$ in coffee plants shows fluctuations from March 3 to March 8, 2017, observations on the 3rd can be seen that CO$_2$ flux in the afternoon is higher than daytime or morning time (Figure 2). This is not in accordance with [6] which says that CO$_2$ flux is influenced by air temperature. CO$_2$ gas produced from decomposition of organic matter on peatlands is controlled by changes in temperature, hydrological conditions, availability and quality of peat material. In addition decomposition also depends on environmental factors, soil properties, and agricultural cultivation techniques. At high temperatures, CO$_2$ and CH4 gas is a form of gas that is immediately formed in large quantities. The temperature and humidity of both the air and peat soil in the tropics are strongly influenced by the type and density of vegetation that covers it. High temperatures in open conditions will stimulate the activity of microorganisms so that peat reshuffle is faster [6].

![Figure 1. Flux of CO$_2$ in coffee](image-url)
## Table 1. Flux of CO$_2$ in coffee based on observation time and average temperature for each observation date

| Date of observation | Morning | Noon | Afternoon |
|---------------------|---------|------|-----------|
| Tempeature (°C)     | Flux of CO$_2$ (mg/m$^2$/minute) | Tempeature (°C) | Flux of CO$_2$ (mg/m$^2$/minute) | Tempeature (°C) | Flux of CO$_2$ (mg/m$^2$/minute) |
| 03-March 19         | 2,98    | 25   | 5,54      | 23 | 7,38 |
| 04-March 19         | 5,05    | 37   | 4,51      | 22 | 4,96 |
| 05-March 21         | 6,21    | 37   | 6,80      | 21 | 6,73 |
| 06-March 20         | 5,12    | 32   | 7,13      | 24 | 9,67 |
| 07-March 19         | 6,42    | 37   | 10,70     | 23 | 7,41 |
| 08-March 22         | (0,48)  | 36   | 14,06     | 22 | 9,86 |

Based on the research conducted, the highest CO$_2$ emissions were found during the day at 8.12 mg / m$^2$ / minute, followed by the afternoon at 7.67 mg / m$^2$ / minute, and the lowest in the morning at 4.21 mg / m$^2$ / minute. Drainage at a depth of 30 cm has the potential to contribute CO$_2$ emissions of 27 t / ha / year. This amount is more than three times the emissions from forest clearing [2].

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### 4. Conclusion

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