Carbon dioxide mitigation with tabat system on peatland

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Abstract. Peatland conservation to maintain the natural condition is the best way to resolve carbon dioxide emission problem due to land use change; and to reduce fire in peatland. However, peatland conservation in extensive agricultural peatland is difficult to execute (or accomplish). Peatland can be productive for agriculture with the appropriate technology. Water management is required to regulate groundwater level which is suitable for plants and maintain soil moisture. Tabat is a water management system carried out with the installation of water-gate in the drainage channels to regulate groundwater level. The purpose of this study was to determine the role of tabat system in mitigating CO₂ emissions. This research was conducted by survey method and then field sampling on rubber land use. The research carried out in two experimental units in the peatland; 1) the drainage channel is equipped with the water-gate/Tabat (RST), Tabat size adjusted to the channel dimensions, and 2) there are no water-gate on the drainage channel (RNT). The parameters of CO₂ fluxes, groundwater levels, and water content were carried out from January to December 2015. The results showed that the water management of Tabat System reduced CO₂ emissions by 23.6% and enable to prevent loss in water-holding ability of fibric peat by 13.9%. This indicates that water management Tabat System enable maintain peat moisture and as a CO₂ mitigation.

Keywords: Groundwater level, Rubber, Soil moisture.

1. Introduction
Tropical peatlands represent 12% of the global peatland area of 381 Mha [1] and more than 54% (24 Mha) of the tropical peatland area in South-East Asia [2]. Indonesia has the largest area of tropical peatlands. Peatland ecosystems are formed from deposits of organic matter and are affected by hydrological conditions. In drained peatlands, a decline water content due to the decreased groundwater level able to release CO₂ gas into the atmosphere. Drainage is required to make peatland naturally flooded suitable for agriculture or other land uses. Therefore an integrated approach include land and water management in peatland areas is needed. Land management can be done with the land arrangement, improve fertilizer efficiency and the use of materials ameliorant [3,4] whereas water management can be done by applying the appropriate water management system for the plant [3,4,6]. These actions contribute to mitigate Green House Gas (GHG) emissions on peatlands. Mitigation is a way to reduce GHG emissions and increase carbon sequestration from various sources of GHG emissions which further reduce the impact of climate change.

The main controlling factor of CO₂ emissions in tropical peatlands is local hydrology which is mainly controlled by the amount and time of rainfall based on relatively constant evapotranspiration.
on peatlands [7] and soil and air temperature fluctuations are low. The high temperature in the formation of tropical peat cause fast degradation of peat when the ecosystem is change naturally, climate change mainly or by human activity such as drainage and fire would increase CO$_2$ emissions [8]. This is related to the depth of the groundwater level. The depth of the groundwater level will change throughout the year which resulted in a change in aerobic and anaerobic zone [9,10]. The greater the aerobic zone, the potential decomposition of organic materials into CO$_2$ becomes larger. Water management such as the application of Tabat System, are needed to maintain soil moisture to slow down aerobic decomposition. This study aims to determine the role of tabat system in mitigating CO$_2$ emissions on peatlands.

2. Materials and Methods

This research was conducted by survey method and then field sampling on rubber land use in Jabiren Village, Central Kalimantan Province in 2015. The land was accidentally burned in 2013. The research area is a peatland affected by tidal of Kahayan river. Peat thickness of the study area ranged from 437 – 600 cm (RST) and 420 – 478 cm (RNT); the dominant degree of peat maturity is fibric. Sampling of soil and CO$_2$ gas, as well as observations of groundwater levels were carried out from January to December 2015.

2.1. Materials

Water management carried out with the installation of water-gate in the drainage channels (Tabat System, Figure. 1). The two experimental units in peatland, were 1) the drainage channel is equipped with the water-gate/tabat (RST) and the tabat size was adjusted to the channel dimensions, and 2) there are no water-gate on the drainage channel (RNT).

![Figure 1. Water management at the study site.](image_url)

Gas chamber was in block-shaped made of polycarbonate material (50 cm in length; 15 cm in width; 30 cm in height). The top chamber is equipped with a hole covered with a septum for gas sampling and the hole for the thermometer. Gas sample was taken using a syringe with the size of 10 mL (five syringe) The sample was then analyzed using micro GC type 4900 with TCD detector (thermal conductivity detector). Soil samples were taken at a depth of 0-50 cm, 50-100 cm and 100-150 cm by using peat auger (Eijkelkamp model) with three replicated.
2.2. Methods
The sampling of CO$_2$ was conducted in the morning (from 6 am to 8 am). The interval time of gas sampling was five minutes in a row (5, 10, 15, 20, 25 minutes). The measurement of CO$_2$ fluxes was carried out by using the method of closed chamber technique adopted from the International Atomic Energy Agency [12]. The calculation of fluxes at each observation point was performed by using the following equation:

\[ E = \frac{Bm \times \delta Csp}{Vm} \times \frac{V}{A} \times \frac{x}{T + 273.2} \]

Where:
- \( E \): CO$_2$ emissions (mg m$^{-2}$ minute$^{-1}$)
- \( Vm \): chamber volume (m$^3$)
- \( A \): width of chamber base (m$^2$)
- \( T \): average temperature inside the chamber (°C)
- \( \delta Csp/\delta t \): change rate of concentrations of CO$_2$ gases (mg kg$^{-1}$ minute$^{-1}$)
- \( Bm \): molecule weight CO$_2$ gases in an standard condition
- \( Vm \): gas volume at the stp condition (standard temperature and pressure) i.e. 22.41 liters at 23°K

Groundwater level was measured with piezometer which made from PVC pipe with 1.5 inch in diameter and 2 m in length. Piezometer were installed at a distance of 16 m, 24 m, 32 m, 40 m, 100 m, 150 m, and 200 m from drainage channels. Observation of groundwater level is carried out once in a week, during one year. Water content was determined with gravimetric. Variation of data were analyzed with standard error and illustrated with Sigma Plot program.

3. Result
Rainfall data obtained from the ombrometer at the study site showed the amount of monthly rainfall ranged from 56.5 mm to 760.6 mm (Figure 3). In July and September there was no rain at the study site.

![Figure 3. Rainfall research location [Source:13].](image-url)
In the tidal swamp areas, groundwater level fluctuates due to either tides or rainfall. This causes the drying and wetting of peat which affects the soil water content and carbon emissions.

**4. Discussion**

The peat (organic soil) was distinguished from most other types of soil by having different aerobic and anaerobic zones. Fluctuations in these zones influence soil moisture which in turn affect the distribution and activity of microbes in peat decomposition and the production of CO\textsubscript{2} [14,15]. Soil moisture was represented by soil water content. Changes of soil water content will affect the solubility of the substrate, not only volume but also water movement. Substrate availability is an important factor in CO\textsubscript{2} production by microbes [16,17,18]. Groundwater movement is influenced by water potential, especially the matrix potential. When the soil is dry, the matrix potential is very low; consequently, there is no microbial activity. Whereas in wet soils, the pore space is filled with water, because the level of oxygen diffusion through water is much lower than through air, causing low metabolic activity of aerobic microbes [18]. Diffusion is an important process in fast reaction kinetics in a solution and is an important step for heterogeneous reactions that occur on solid surfaces [19].

Figure 4 showed that the RNT groundwater level lower (far from the ground surface) compared to RST. Likewise in soil water content, RNT is lower than RST (Figure 6). The soil water content in two experimental units decreased with increasing soil depth. Water management can prevent decreasing ability of fibric peat to store water 13.9\% . This showed that water management minimize water loss, especially in the dry season and maintain a moisture. Soil moisture affects the dynamics of soil organic matter and is an important environmental variable that predicts CO\textsubscript{2} production [14,18]. Moisture in the soil is very important for plant growth and soil microbial activity, especially decomposer activities, which affect carbon input and the breakdown of litter and soil organic matter, and have an impact on carbon emissions.
Carbon dioxide flux in two experimental units fluctuated between the observation periods (Figure 5). The lowest CO$_2$ concentration is shown in April, the month in which the water level in a state close to the soil surface. Moist soil conditions can limit the diffusion of oxygen to the atmosphere and microbial activity so that CO$_2$ gas production decreases. In the RST and RNT, the highest CO$_2$ flux occurred in October 2015 which was 12112.76 ± 995.97 mg m$^{-2}$ day$^{-1}$ and 16520.28 ± 87.44 mg m$^{-2}$ day$^{-1}$, respectively. The high CO$_2$ flux was caused by reduced soil moisture due to low rainfall, resulting in a significant decrease in groundwater level. Drawdown of groundwater level during dry season deepens the oxic peat profile, and thus the potential of peat to decompose the greater which will release CO$_2$. Oxygen availability, ground water level, temperature, nutrient availability and root exudate may affect the level of CO$_2$ emissions (Note: Letakan semua references di akhir kalimat) [20,21,22,23,24].

Efflux CO$_2$ from the soil basically depends on the rate of CO$_2$ production in the system of root-soil-plant, and subsequently on the rate of gas diffusion and mass flow from the soil to the atmosphere; as well as the function of soil moisture and texture properties [24] or the degree of peat decomposition [18,25,26]. studies about CO$_2$ efflux with groundwater level and temperature showed the different results. The non-linear relationship between groundwater level and CO$_2$ efflux is due to large variations in soil properties, especially the complexity of peatland behavior after persistent groundwater decrease, with several interactions between many factors such as time scale, the degree of decomposition and availability oxygen. Besides, the difficulty of separating the osmotic effect and the diffusion of solutes in relation to soil moisture [17]. However, it should be emphasized that CO$_2$ production is a continuous process and involves biochemical reactions. Peat decomposing microbes that cannot activity on the environmental conditions are too dry. Therefore, regulating groundwater level needs to be done not only for plant but also to maintain soil moisture. So that the potential of peat to release CO$_2$ because aerobic decomposition can be minimized.

From the research that has been conducted, it is known that Carbon dioxide emissions in two experimental units (RST and RNT) were 26.59 ± 2.66 (Mg ha$^{-1}$ year$^{-1}$) and 34.79 ± 2.33 (Mg ha$^{-1}$ year$^{-1}$), respectively. Overall, it can be seen that the water management “tabat system” can reduce CO$_2$ emissions in the amount of 23.6% compared with the peatland there are no water management. The elimination of carbon dioxide emission from peatland utilization is hard to achieve. The decomposition process is a natural process that is also needed in the supply of nutrients to plants. Peatland sustainable management should emphasized on increasing productivity and low level of CO$_2$ emission.

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