Study of Water Balance for Tropical Peatland Restoration
Case Study: Sinarwajo Village, Jambi Province, Indonesia

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Abstract. Efforts to restore degraded peatlands that have declining groundwater levels are carried out to prevent disasters such as forest fires and carbon emissions into the atmosphere. At present, peatland restoration is an essential topic for researchers, especially regarding hydrological restoration (the re-wetting). Water balance calculation is needed in providing hydrological information and supporting re-wetting of degraded peatlands. In this paper, a study of water balance was conducted for peatland re-wetting in Sinarwajo Village, the Province of Jambi. The result showed that the evapotranspiration budget is 56% from the rainfall. Besides, run-off and groundwater storage is about 32% and 12% respectively. This information can be a primary goal of re-wetting, so the efforts of re-wetting should increase more groundwater storage and limit the water discharge from peatland.

Keywords: water balance, hydrology, tropical peatland, restoration, re-wetting.

1. Introduction

Peatland restoration efforts to prevent fires and reduce carbon emissions have become an essential agenda item over the five years period from 2016 to 2020 in approximately two million hectares of degraded and burned peatlands in Indonesia [1]. These areas are spread across seven provinces: Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan, and Papua [2]. Hydrological restoration or re-wetting through groundwater level managing has succeeded in reducing about 1.5 Mt of CO₂ per year in an area of 590 km² [3]. Another study states that a 30-cm increment of groundwater level (GWL) from the initial condition of 60 cm below ground level can reduce carbon emissions by around 49% [4].

Re-wetting is an effort to increase GWLs on degraded peatlands. By increasing GWLs, land fires are prevented, because the combustible peat material is kept wet [5]. One of these efforts is canal blocking [6]–[8]. By limiting the rate of water coming out of drainage canals, the stream will be blocked and thus able to re-wet peat soil near canals [9], [10].

Research in the field of hydrology supporting re-wetting is growing rapidly. Water balance studies have been conducted in both boreal peatlands (e.g., Thompson et al. [11]) and Borneo’s tropical peatlands (e.g., Kumagai et al. [12]; Ritzema and Jansen [13]). Tropical peatlands in Indonesia differ from temperate or boreal peatlands in both the condition of water sources [14] and in physical properties [15]. Also there are more specific studies on the water balance components, such as
precipitation [16], evapotranspiration [17], and run-off [18]. There is a re-wetting plan in Sinarwajo Peatland, Jambi Province, Indonesia. Water balance calculation is needed in providing hydrological information and supporting the re-wetting of degraded peatlands there. This paper shares the results of the study of hydrological conditions based on water balance calculation.

2. Data and Methods

2.1. Data Collection

Data in this study can be divided into two parts: hydrological data and geological data. The former consists of (1) monthly average weather data from the Sultan Thaha Jambi Meteorological Station (WMO ID: 96195) and in situ measurements of rainfall and temperature in Sinarwajo Village, (2) Sinarwajo Canal and Mendahara River data obtained from field surveys, and (3) GWL data measured from 21 observation points. The geological data consists of (1) land cover images from Landsat satellite imagery, (2) data on the hydraulic properties of soil from literature.

2.2. Study Site and Field Survey

We conducted the following activities during the field survey (on January 2018): observed and measured some parameters consist of: GWL measurements at 21 observation points (figure 1); geometry, discharge water, and fluctuations of water level in canals and rivers; ground-check topographic elevation; land use observation; vegetation observation; and soil sampling.

2.3. Water Balance and Water Budget

Water balance is the balance of the input and output of water mass in a system in the form of components of the water cycle. In this study, water balance is calculated using the Mock method [19]. In general, the balance of water balance in one year can be written as in equation (1):

\[ P = ET + I + Ro \pm \Delta S, \]  

(1)

Where \( P \) is precipitation (mm), \( ET \) is evapotranspiration (mm), \( Ro \) is run-off (mm), \( I \) is infiltration (mm), and \( \Delta S \) is storage (mm). Evapotranspiration in the Mock method (1973) was calculated by Penman’s (1984) formulation, which combines energy balance and aerodynamic effects that are influenced by the removal of water vapor by wind movement. This water balance calculation was needed to analyze the water budget.

3. Case Study Results and Discussion

3.1. Results of Area Study and Field Survey

The peatland studied is located in Sinarwajo Village, in the western region of Tanjung Jabung Timur District, Jambi Province, Indonesia. This peatland is a part of the Mendahara River–Batanghari River Peat Hydrological Unit (KHG) and was burned in September 2017. From the geomorphological perspective, this peatland has tidal swamp landscapes with a sloping topography of 0–25 masl, and the slope range is between 0–3%. Two rivers flank this peat area: the Mendahara, with a length of 49.5 km, and the Lagan in the east, with a length of 40.9 km [20]. Both rivers flow into the Berhala Strait. There is a transverse canal with a length of 8 km and a depth of 1.8 m (figure 1).
Figure 1. Map of Sinarwajo Village peatlands, with the Canal crossing from the east (upstream) to the west (downstream). The yellow circles are the GWL measurement points.

Based on Jambi climatology data, the study area has a tropical climate, with a rainy season from October to May and a dry season from June to September. Rainfall in this area has a bimodal equatorial pattern, with two rain peaks in different months. Air temperature ranges from 26.2°C to 32°C. Based on temperature measurements obtained in the field, the temperature in degraded peatlands was about 1 to 2 °C higher than at the Sultan Thaha Meteorological Station. Based on the Jambi Geological Sheet Map, the area is composed of three formations: (1) alluvium (Qa), consisting of greed, gravel, sand, silt, and clay; (2) swamp deposits (Qsw), consisting of sand, silt, clay, mud, and peat, and the (3) Kasai Formation (QTk), consisting of tuffaceous sandstone and tuffaceous claystone.

In the Sinarwajo peatlands, land use is divided into two functions. In the eastern area, there is a protected forest (PF), while the western part features other land use (OLU). The PF area is dominated by shrubs, while the vegetation in the OLU area consists of oil palm trees, coconut trees, and areca trees and shrubs. Peat thickness distribution shows that the eastern part of the study area can reach more than 4 m in thickness, which decreases to the west. Overlaying the land use information with GWL measurements reveals that the GWLs in the PL area are quite shallow with a value higher than -40 cm. Conversely, the GWL in the oil palm plantation is more in-depth, less than -40 cm; the GWL can even reach -125 cm (Figure ). The reason supposed because the different types of vegetation affect the evapotranspiration rate and water requirement for each plant. Hence, oil palm plantation seemingly needs more water in the evapotranspiration process, thus causing deeper GWL in oil palm areas.
3.2. Water Balance and Water Budget
The water balance reported in Table 1 shows that the peak of the dry season occurred in August, with rainfall beginning to decline in May, and that the rainy season peak occurred in November. The annual rainfall of 1711 mm is lower than the annual rainfall in other parts of Indonesia, where average annual rainfall reaches more than 2500 mm [21]. The lower annual rainfall may be a reason for the area’s drought and land fire vulnerabilities. Rainfall in Jambi is influenced by the Indian Ocean Dipole (IOD) phenomenon, so there should be further research on the possible effects of the IOD on peatlands in the study area.

Monthly average evapotranspiration in the study area reached 80 mm; annual evapotranspiration was 961 mm (56% of rainfall). This evapotranspiration value is in the middle of oil palm plantations (851 mm or 43% of rainfall) and swamp forests (1093 mm or 69% of rainfall) in the Sarawak region of Malaysia [17].

Table 1 shows that run-off pattern is more fluctuate than rainfall and groundwater storage patterns. The percentage of rainfall that became run-off was 32%, but only 12% becoming groundwater storage. It is expected that the percentage of groundwater storage could be increased through hydrological restoration efforts. As a comparison, the run-off budget in the peatlands of Johor, Malaysia, can reach 62% of rainfall [18], while in the Pennine blanket peatlands in the UK, the run-off was up to 40% [22].

In short, either by evapotranspiration or run-off exceed, the decrease of GWLs is inevitable. Therefore, if the degradation of peatlands is not immediately reversed, then the area will be more vulnerable to drought during the dry season and prone to flooding in the rainy season, due to the loss of peat’s hydrological function that is supported by Miettinen’s study [23] that urgent to take efforts to mitigate peat drainage, while reducing carbon emission or fire.

Table 1. Water balance in the study area.

|          | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Sum | Percentage |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------|
| Rainfall | 145 | 162 | 140 | 186 | 120 | 97  | 99  | 86  | 103 | 132 | 223 | 217 | 1711 | 100%       |
| ET       | 82  | 77  | 95  | 77  | 90  | 73  | 73  | 70  | 83  | 82  | 86  | 73  | 961 | 56%        |
| Run-off  | 46  | 61  | 33  | 79  | 22  | 17  | 19  | 11  | 14  | 36  | 98  | 104 | 540 | 32%        |
| Groundwater storage | 52  | 15  | 16  | 17  | 18  | 15  | 13  | 11  | 9   | 9   | 14  | 21  | 210 | 12%        |
4. Conclusion

Peatland restoration efforts become an essential agenda in Indonesia. One kind of restoration is re-wetting, which focuses on restoring the hydrological condition. Water balance calculation is needed in providing hydrological information and supporting the re-wetting of degraded peatlands. The result showed that the evapotranspiration budget is 56% from the rainfall. Besides, run-off and groundwater storage is about 32% and 12% respectively. This information can be a primary goal of re-wetting, so the efforts of re-wetting should increase more groundwater storage and limit the water discharge from Peatland.

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