Study on the impact of canal blocking on groundwater fluctuation for tropical peatland restoration

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Abstract. Peatland fires occur almost every year in Indonesia that might be caused by over-drained peatland due to canalization for a certain purpose. Canalization in the peatland leads to a significant decreasing change of groundwater level that might cause peatland very vulnerable against fire. The rewetting approach by the Peatland Restorations Agency of Indonesia using canal blocking is expected to keep groundwater level high so that the peatland is maintained in an always wet condition. Therefore, it is important to study the impact of canal blocking on the fluctuation of groundwater level in peatland ecosystems. This study was carried out at a research site which is located in Pulau Tebing Tinggi peatland hydrological unit, Kepulauan Meranti Regency, Riau, Indonesia. Groundwater level fluctuation as the impact of canal blocking was monitored using eight dipwells that were set with a distance of 1 m, 51 m, 101 m, and 201 m from the canal for each transect of the three transects. The result of this study showed that the canal blocking has a good impact for keeping groundwater level and keeping peatland on an always wet condition for peatland restoration and peat fire prevention until 400 m distance to the upstream area from canal block and about 1 m distance perpendicular to the canal. The canal blockings will have a good impact on rewetting at the peatland area up to 201 m distance perpendicular to the canal if the rise of water level at the canal is more than 0.6 m for peatland restoration.

1. Introduction

Peat is an organic material that has been formed from the weathering process of plant growth and has unusual characteristics. Because about half of the peat is carbon, peat is also a form of carbon sinks on the surface of the earth. They contain nearly 30% of all carbon on the land although covering only 3% of the land area [1]. It means that peatlands are the most efficient terrestrial ecosystems in storing carbon in the world. Most of the tropical peatland (approximately 65-75%) is found in Southeast Asia, particularly in Indonesia. Indonesia has the largest area of tropical peatland in the world with a total area of 20-21 Mha [2]. Because of the unappropriated management of those tropical peatlands in relation to massive utilization for various purposes, the environmental problems become a serious problem including peat fires, decreasing massive ecosystem functions, and increasing carbon emission [3].

In the last decade, most of the peatlands have been used as dried plantations where so many canals have been made in order to manage the land to dry. This process caused over-drained in the peatland that reduced the groundwater table elevation. Therefore, the peatlands ecosystems became dry and very easy to be burnt during the dry season. Peatland fire becomes the most popular issue in Indonesia since this case often occurs in almost every year. In 2014 and 2015, there were severe peatland fires in Riau, that caused severe haze disaster not only in Riau area but also most of the area in Sumatera and...
Kalimantan. Forest and land fires in Indonesia in 2015 are estimated at about 1.7 million hectares, which about 35.9% and, 45.5% of them are in Kalimantan and Sumatra respectively. The peatlands fire in Indonesia has caused many problems, including the damage of ecosystems and the degradation of environmental conditions, human health, and socio-economic aspects of society [4]. Therefore, an understanding of the factors that can trigger the fire in peatland is very important for such worst disaster prevention. Severe tropical peatland fires are very difficult to extinguish because the incidence of peatland fires occurs below the surface that can only be extinguished in the presence of rainfall or artificial rainfall [5]. Therefore, the prevention of peatland fire has been established by the Indonesian government through the 3R approach, such as rewetting, revegetation, and revitalizations of livelihood that aims to restore the hydrological functions of the peatland areas.

The rewetting approach attempts to keep groundwater elevation high so that the peatlands are always in a water-saturated condition or high soil moisture. The approach that aims to rehabilitate the peatlands hydrologically to a near-natural state and to decrease the effect of greenhouse gas emissions is carried out by canal blocking, canal backfilling, and construction of deep wells [6], [7]. To understand the effectiveness of the canal blocking for the rewetting approach, therefore, it is important to study the impact of canal blocking on the fluctuation of groundwater level in peatland ecosystems. The initial research to investigate the effectiveness of the canal blocking has been studied [8]. This research was still limited to the one transect in the upstream of the canal block, so that the impact was not investigated along the upstream area of the canal. The fluctuation of groundwater lever becomes one of the essential parameters to understand the effectiveness of canal blocking on rewetting of the tropical peatland to prevent the fire.

The purpose of this study is to investigate the impact of canal blocking on groundwater fluctuation for tropical peatland restoration. The study was carried out at a research site which is located in Pulau Tebing Tinggi peatland hydrological unit, Kepulauan Meranti Regency, Riau Province, Indonesia. Groundwater level fluctuation as the impact of canal blocking was monitored using eight dipwells that were set with a distance of 1 m, 51 m, 101 m, and 201 m from the canal for each transect of the three transects. The groundwater level fluctuations were recorded automatically using the water loggers instrument with a one-hour time interval for every eight dipwells.

2. Methodology

2.1 Study area
This research was investigated in Pulau Tebing Tinggi Peatland Hydrological Unit (PHU), which is located in Kepulauan Meranti Regency, Riau Province (See Figure 1a). Pulau Tebing Tinggi PHU is one of the most priority areas for the peatland restoration program by Peat Restoration Agency, Republic of Indonesian (BRG-RI) due to the previous peatland fire and degradation (Anonim, 2016). The peatland area of Tebing Tinggi island is about 94% of the total area of the island. This condition makes Tebing Tinggi island very vulnerable to a peat fire. The investigation was carried out at a series of canal blocks of about 6 km canal at Lukun Village (See Figure 1b). Historically, the village experienced severe peat fires in the last few years.

2.2 Experiment set up
In order to analyze the fluctuations of groundwater level as the impact of canal blocking, eight dipwells were set around the canal with a distance of 1 m, 101 m, and 201 m from the canal for each transect of the three transects as presented at Figure 1b. The dipwells in the first transect are D 1-1, D 1-101, D 1-201, in the second transect are D 2-1, D 2-101, D 2-201, and in the third transect are D 3-1, D 3-101, D 3-201 with the distance of 1 m, 101 m, and 201 m from the canal respectively. The first transect is located in the most upstream of the canal, the second transect is in the middle, and the third transect is in the most downstream of the canal. There are two canal blocks in the study site that were constructed
in November 2018. The first canal block is located about 100 m in the downstream side of the first transect and about 200 m upstream side of the second transect. The second canal block is located about 100 m in the downstream side of the second transect, and about 100 m in the upstream side of the third transect. Additionally, the rainfall data, air temperature and water depth were also considered as a parameter of the analysis that was taken from a real-time telemetry technology, namely SESAME (Sensory Data Transmission Service Assisted by Midori Engineering). The data were recorded every 10 minutes by the SESAME system are rainfall, air temperature, and water depth.

![Figure 1](image1.png)

**Figure 1.** Study area at Pulau Tebing Tinggi peatland hydrological unit (a) and the configuration of dipwells and canal blocks (b), Kepulauan Meranti Regency, Riau Province, Indonesia

3. Results and discussion

3.1 Impact along the canal

The recorded data of the groundwater level fluctuation along the canal at D 1-1, D 2-1, and D 3-1 dipwells in which the distance from the canal is about 1 m, together with the rainfall data, are presented in Figure 2. The figure represents the response of the water table fluctuation at the dipwells because of the water level change before and after canal blocking. The first canal block which is on the upstream side was built in the middle of November 2018, and the second one was built at the beginning of November 2018. When the first canal block was built, the fluctuation of groundwater level at D 1-1 dipwell which is about 100 m distance on the upstream side of canal block, increased significantly, but two other dipwells were not. It means that the canal blocking only has an impact in the upstream area. The groundwater fluctuation at the D 1-1 dipwell was stable at the elevation about of 8.5 m. This means that the canal block has a good function for keeping groundwater elevation and keeping peatland on always wet conditions.

When the second canal block was built, there was groundwater fluctuation impact at the D 2-1 dipwell, which is the distance about 100 m to the upstream side. However, this blocking has no impact at the D 1-1 dipwell which is the distance about 400 m to the upstream side. It means that in this case, the canal blocking has the rewetting impact no more than 400 m distance to the upstream area. The groundwater level fluctuation at the downstream side of the canal block was not impacted by canal blocking in the upstream area. It was impacted only by rainfall as presented on D 3-1 line in Figure-2.

The groundwater depth which is the subtraction between groundwater level and the ground level, is an important parameter in correlation with peatland fire risk. Based on the Indonesian regulation, the minimum groundwater depth in the peatland is 0.4 m in order to keep the peatland area from fire (Anonim, 2016). Considering from the ground level elevation (G 1-1, G 2-1 and G 3-1) and groundwater elevation (D 1-1, D 2-1 and D 3-1), it could be investigated the groundwater depth before and after the canal blockings. The groundwater depth before canal blocking was about 1.5, 1.4, and 1.0 m at upstream area (Transect-1), middle area (Transect-2), and downstream area (Transect-3) respectively. This
situation makes peatland was very vulnerable to the fire because the groundwater level was very low. After canal blocking, the groundwater level increased significantly so that the groundwater depth became about 1.0, 0.8, and 1.0 m in the upstream area, middle area, and downstream area respectively. Although the groundwater level increased significantly because of canal blocking, the groundwater depth has not fulfilled the minimum requirement by Indonesian regulation. However, the canal blocking has reduced the risk of peatland fire because of increasing groundwater level. The crest of canal blocks was not able to be built more raised in order to fulfill the Indonesian regulation because it would be caused flooding in other areas.

![Figure 2. Daily water table fluctuation because of canal blocking and precipitation of three dipwells along the canal with 1 m distance from the canal from October to December 2018](image)

3.2 Impact to the peatland

To investigate the impact of canal blocking for rewetting effort in the peatland area, the groundwater level fluctuation of the three dipwells of each transect with the 1 m, 101 m, and 201 m distance perpendicular to the canal were analyzed. Figure 3(a) presents groundwater fluctuation at Transect-1 of three dipwells with the 1 m, 101 m, and 201 m distance perpendicular to the canal before and after canal blocking. It shows that the groundwater level at D 1-1 dipwells (1 m distance to the canal) increased significantly and quickly after the canal blocking on November 15th. In this area, the groundwater level was stable until the end of monitoring. It means that the rewetting effort for peatland restoration was in a good performance in this area. However, the groundwater level at D 1-101 and D 1-201 (101 m and 201 m distance to the canal respectively) increased slightly in the same time that might be because of canal blocking and rainfall. It means that the canal blocking was not so significantly impacted for keeping groundwater high in this area.

![Figure 3(a)](image)
Figure 3. Daily water table fluctuation because of canal blocking at the Transect-1 (a), Transect-2 (b), and Transect-3 (c) from October to December 2018

Similar situation at the Transect-2 that the canal blocking has a significant impact on groundwater level at 1 m distance to the canal but has a low impact at 101 and 201 m distance to the canal respectively. After the canal block was built on November 7th, 2018, the water table in D 2-1 increased slowly and was stable after reach the maximum level. It means that the rewetting effort for peatland restoration was in a good performance in this area. The groundwater level at 101 m and 201 m distance to the canal respectively increased slightly at the same time that might be because of canal blocking and rainfall. It means that the canal blocking was not so significantly impacted for keeping groundwater high in this area. There was no groundwater level change at the dipwells which is located in the most downstream transect before and after canal blocking, as presented in Figure 3(c). This area has no rewetting impact for peatland restoration due to canal blockings which is located in the upstream area. This means that the upstream areas would be in the same condition with this area if the canal blockings were not applied.

To investigated how big the impact of the canal blockings in the peatland area on increasing groundwater level, the raised of GWL (groundwater level) at 1 m distance to the canal was compared to the raised of GWL at the 101 m and 201 m distance to the canal respectively on each transect (Figure 4). The figures imply that the canal blockings will not impact on rewetting at 101 m and 201 m distance to the canal if the raise of GWL at 1 m distance to the canal is less than 0.45 m. The GWL fluctuation at the canal less than 0.45 m was caused by the rainfall that was not impacted by canal blocking. The raise of GWL because of canal blocking varied at each location, depending on the distance to the canal. The raise of GWL at the Transect-1 for 101 m and 201 m distance from the canal because of canal blocking varied from 0.19 m to 0.51 m and from 0.1 m to 0.41 m that caused groundwater depth from 0.67 m to 0.34 m and from 0.62 m to 0.31 m respectively (Figure 4.a and Table-1). This means that the rewetting efforts could fulfill the groundwater depth based on the Indonesian regulation (0.4 m) if the
raise of GWL at the canal (from monitoring data at 1 m distance from the canal dipwells) minimum of 0.6 m. The raise of GWL at the Transect-2 because of canal blocking has similar phenomena with the situation in the Transect-1. However, The transect-3 has no impact on rewetting because of canal blockings in this research area.

Table 1. The impact of canal blocking on the raise of GWL at each transect

| Raise of GWL D 1-1 (m) | Raise of GWL D 1-101 (m) | Groundwater Depth (m) | Raise of GWL D 1-201 (m) | Groundwater Depth (m) |
|------------------------|--------------------------|-----------------------|--------------------------|-----------------------|
| 0.45                   | 0.19                     | 0.67                  | 0.10                     | 0.62                  |
| 0.50                   | 0.25                     | 0.60                  | 0.16                     | 0.56                  |
| 0.55                   | 0.36                     | 0.50                  | 0.26                     | 0.46                  |
| 0.60                   | 0.51                     | 0.34                  | 0.41                     | 0.31                  |

| Raise of GWL D 2-1 (m) | Raise of GWL D 2-101 (m) | Groundwater Depth (m) | Raise of GWL D 2-201 (m) | Groundwater Depth (m) |
|------------------------|--------------------------|-----------------------|--------------------------|-----------------------|
| 0.45                   | 0.11                     | 0.63                  | 0.12                     | 0.57                  |
| 0.50                   | 0.17                     | 0.58                  | 0.18                     | 0.51                  |
| 0.55                   | 0.25                     | 0.49                  | 0.28                     | 0.41                  |
| 0.60                   | 0.38                     | 0.36                  | 0.43                     | 0.26                  |
4. Conclusion

This research investigated the impact of canal blocking on the fluctuation of groundwater level in peatland ecosystems. Groundwater level fluctuation as the impact of canal blocking was monitored using eight dipwells that were set with a distance of 1 m, 51 m, 101 m, and 201 m from the canal for each transect of the three transects. The result of this study showed that the canal blocking has a good impact for keeping groundwater elevation and keeping peatland on always wet condition until 400 m distance to the upstream area from canal block and about 1 m distance perpendicular to the canal. The canal blockings will have a good impact on rewetting at the peatland area up to 201 m distance perpendicular to the canal if the rise of water level at the canal is more than 0.45 m. However, at least it needs about 0.6 m of raise water level at the canal to fulfill the groundwater depth in the peatland area to satisfy the Indonesian regulation (0.4 m) for peatland restoration.
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