Water management for hydrological restoration and fire prevention in tropical peatland

S Sutikno, R Rinaldi, E Saputra, M Kusairi, B H Saharjo and E I Putra

1 Civil Engineering Department, Universitas Riau, Pekanbaru, Indonesia
2 Faculty of Forestry, Institut Pertanian Bogor, Bogor, Indonesia

Corresponding e-mail: ssutiknoyk@yahoo.com

Abstract. Water management is an important aspect of hydrological restoration and fire prevention in tropical peatland because the availability of water is not well distributed in the dry and rainy seasons. The degraded peatlands with massive canalization are very vulnerable against peat fire especially in the dry season. A pilot project for water management was conducted at Tanjung Leban, Bengkalis Regency, Riau Province with the purpose not only for hydrological restoration but also for fire prevention. In 2013, 2014, and 2015, the big peat fires occurred at Tanjung Leban and many peatland areas in Riau which caused a haze disaster. Peatland restoration and peat fire prevention efforts have been continuously undertaken by Peatland Restoration Agency and stakeholders at Tanjung Leban and many peatland areas in Riau. The rewetting, revegetation, and revitalization of livelihood were the integrated approaches that were carried out to support the peatland restoration. The aim of this research is to monitor the hydrological condition as the impact of rewetting activities using canal blocking at Tanjung Leban. Forty dip wells in four transects and an automatic rainfall record equipment were set up in the research area to monitor the groundwater level (GWL) and the rainfall event as the impact of rewetting activities. The result shows that the rewetting activity using canal blocking has a significant impact on the rewetting effort so that the risk of peat fire can be minimized. The historical evidence shows that the peatland restoration has been improving after the peatland areas were kept in always wet conditions.

1. Introduction

Peatlands are wetland ecosystems that occur as a result of the accumulation of organic material called "peat," which comes from the dead plant material and decays under water-saturated conditions [1]. Peatland ecosystems are the most efficient carbon sinks on the earth because peatland plants capture CO2 that is released naturally from peat to maintain the balance of nature. The Peatlands only cover about 3% of the earth's surface, but they are able to store up to 30% of carbon on earth in the form of peat or organic matter [2]. Peatlands are one type of wetland which is the most valuable ecosystem on earth. They are very important for conserving global biodiversity, providing safe drinking water, minimizing the risk of flooding, and helping to tackle climate change. Basic characteristics of peatlands are in extreme conditions high water and low oxygen content, toxic elements, and low nutrient availability [3]. Peatland now becomes the global topic concerning massive utilization for various purposes that can cause environmental problems including land fires, declining massive ecosystem functions, and increasing carbon emission [4]. Severe peatland fires are very difficult to be extinguished.
because the incidence of peatland fires occurs below the surface that can only be extinguished in the presence of rain or artificial rain [5].

Indonesia holds the largest tropical peatland area, comprising approximately 50% of the world’s total tropical peatlands. The area of peatland in Indonesia is estimated to range from 14.91 million hectares spread over Sumatra Island 6.44 million hectares (43%), on Kalimantan Island 4.78 million hectares (32%), and 3.69 million hectares in Papua Island (25%) [6]. Recently, large areas of those peatlands have already been cleared and drained for food crops and cash crops such as palm oil and other plantations. However, large-scale drainage of peatlands for those purposes has often generated mayor problems of subsidence, fire, flooding, and deterioration in soil quality [7-9]. Indonesian Government trough Peatland Restoration Agency (BRG) and stakeholders have been continuously undertaking peatlands restoration and peat fire prevention efforts on those degraded peatlands using 3R approach, such as Rewetting, Revegetation, and Revitalization of livelihood [10-11].

The key important factor for the restoration of tropical peatlands is how to keep the peat always wet [12]. Water management is an important aspect of hydrological restoration in tropical peatland due to the availability of water is not well distributed in the dry and rainy seasons [13]. The degraded peatlands with massive canalization are very vulnerable against peat fire especially in the dry season due to over-drained. A pilot project for water management was conducted at a research area of Tanjung Leban Village, Bengkalis Regency, Riau Province, Indonesia with the purpose not only for hydrological restoration but also for fire prevention. Tanjung Leban Village is a very vulnerable area against peat fire in Riau. In 2013, 2014 and 2015, the big peat fires occurred at Tanjung Leban Village and many peatland areas in Riau which caused haze disaster for about two months.

This disaster produces the sickening and deadly cloud of smoky pollution, which threatens not only the nation but also neighboring countries. Peatland restoration and peat fire prevention efforts have been continuously undertaken by Peatland Restoration Agency (BRG), Republic of Indonesia and stakeholders at Tanjung Leban Village and many peatland areas in Riau. The rewetting, revegetation, and revitalization of livelihood were the integrated approaches that were carried out to support the peatland restoration. The aim of this research is to present the hydrological condition as the impact of rewetting activities at Tanjung Leban village for hydrological restoration and fire prevention. Forty dip wells in the four transects and an automatic rainfall record equipment were set up in the research area to monitor the groundwater level fluctuation and the rainfall event as the impact of rewetting activities.

2. Methodology

This study is located at Tanjung Leban Village, Bengkalis Regency, Riau Province, Indonesia, as shown in Fig. 1. The village and many peatland areas in Riau suffered big peat fires in 2013, 2014 and 2015 that caused a haze disaster as presented in Fig. 1b. As shown in the figure, a lot of hotspots were detected at those villages in 2013, 2014 and 2015 which the worst fire was in 2014. This disaster produces the sickening and deadly cloud of smoky pollution which threatens not only the nation but also neighboring countries. The research about water management for hydrological restoration and fire prevention was carried out at a series of canal blocks of about 5 km canal at Tanjung Leban Village (See Fig. 1c). There are two canals at the study area which are located at the right and left side of the road, as shown in Fig. 1e. There are two canal blocks at the downstream area of the right canal and a canal block at the upstream area of the left canal. The topographic map (Fig. 1d) shows that the ground surface along the canal is lower than that of in peatland area.

Forty dip wells were set around the canal with four transects, as presented in figure 1c for monitoring the fluctuations of GWL as the impact of water management. Six dip wells were set up with the distance of 2 m, 52 m, 102 m, 202 m, 302 m, and 502 m from the canal for each Transect-1, Transect-2 and Transect-3 and four dip wells for the Transect-4 with the distance of 2 m, 52 m, 102 m and 202 m. The Transect-1 is located in the most upstream of the canal and the Transect-4 is in the most downstream of the canal. There are three canal blocks in the study site that were constructed in 2009, 2018, and 2019, respectively. The first and the second canal block are located in the right-side canal which is about 10 m in the downstream side and 10 m in the upstream side of Transect-4 respectively. The third one is
located about 10 m upstream side of Transect-2. 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 every 10 minutes recorded by the SESAME (Sensory Data Transmission Service Assisted by Midori Engineering) system.

3. Results and discussion

3.1. Impact of rewetting using canal blocking

To understand the impact of rewetting using canal block, the recorded data of the GWL fluctuation before and after canal blocking are mapped as presented in Fig. 2. The third canal block which was the last construction, was constructed on August 26th, 2018. Fig. 2 presents the maps of GWL before (July 20th, 2018) and after (January 10th, February 5th and April 23rd, 2019) canal block construction. The maps show that the GWL in the peatland around the Transect-1 and Transect-2 was about 5.5-6.0 m and 6.0-6.5 m respectively on July 20th, 2018 (before canal blocking), as presented in Fig. 2(a). It raised after canal blocking on August 26th, 2018 about 6.0-6.5 m and 6.5-7.0 m in Transect-1 and Transect-2 respectively as presented in GWL map on January 10th, 2019 (Fig. 2b), February 5th, 2019 (Fig. 2c) and April 23rd, 2019 (Fig. 2d). The raised of GWL as the impact of canal blocking for peatland rewetting was also
presented in Fig. 3. The figure shows the cross-section of GWL at Transect-1 (10 m downstream side of canal block (Fig. 3a)) and Transect-2 (400 m upstream side of canal block (Fig. 3b) as the impact of canal blocking on at Tanjung Leban, Bengkalis Regency, Riau Province. It clearly shows the raised of GWL as the impact of canal blocking which was about 0.5 m for the left side of the canal. However, the peatland in the right-side canal was not raised because it was not blocked.

Figure 2. Map of GWL before canal blocking on July 20th, 2018 (a) and after canal blocking on January 10th, 2019 (b), February 5th, 2019 (c), April 23rd, 2019 (d) at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.

Figure 3. Cross-section of GWL at Transect-1, 10 m downstream side of canal block (a) and Transect-2, 400 m upstream side of canal block (b) as the impact of canal blocking on at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.

In order to investigate the impact of canal blocking, continuous monitoring of GWL in the Transect-2 has also been recorded daily using water loggers from August 1st (before blocking) to October 22nd (after blocking). Fig. 4 presents the daily water level fluctuation at the canal and GWL fluctuation of two dip wells with a distance of 60 m and 210 m perpendicular to the canal because of canal blocking and precipitation from August to October 2018. Minimum water level at canal before canal blocking was about 5.8 m. It raised significantly after canal blocking on August 26th, 2018, and the minimum water level after canal blocking was 6.5 m. It means that the raised water level at the canal after canal
blocking was 0.7 m. The 0.7 m raised the water level at the canal caused raised of GWL about 0.3 m and 0.2 m at the peatland with a distance of 60 m and 210 m to the canal respectively. However, the heavy rainfall that was occurred on October 11th, 2018, has a big impact on raising water level not only at the canal but also at the peatland. The existence of the canal block can keep the water level for a long time because the drainage flow can be slowed down.

Figure 4. Daily water level fluctuation at the canal and GWL fluctuation of two dipwells with the distance of 60 m and 210 m perpendicular to the canal because of canal blocking and precipitation from August to October 2018.

3.2. Impact of water management on peat fire risk

To analyze the impact of water management on peat fire risk, the maps of groundwater depth were developed. To develop the map of peat fire risk, we classified the level of peat fire risk base on the groundwater depth, such as 0-0.25 m depth is safe, 0.26-0.40 is fire alert, and more than 0.4 is in danger status [14]. The maps of peat fire risk before and after canal blocking is presented in Fig. 5. Before canal blocking, all of the area in the dry season was in danger status (Fig. 5.a), but after canal blocking is reduced about 6% for construction of a canal block (Fig. 5b). For the larger area of reducing the peat fire risk area, it should be added more canal blocking in this area with the shorter distance between each canal block.

Figure 5. Map of peat fire risk before canal blocking on July 20th, 2018 (a) and after canal blocking on January 15th, 2019 (b), at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.
3.3. Impact of water sharing

Water management in the peatland should be considered in terms of the hole water management in the one peatland hydrological unit (PHU). In a PHU consist of many ownership and management, which usually in the upstream areas are managed by plantation companies and in the downstream areas are managed by local communities. The basic concept for water management is how to save the water as long as possible in the peatland in order to keep peatland always wet. The peat domes that are usually in the upstream area and under the company concession should be designed for the water reservoir to save the water from the rainy season and still available in the dry season. The water flows from peat dome trough canals are blocked to reduce the velocity and to save them in the canals. The water in the canals is supposed to infiltrate to the peatland, and the exceeded water flow is drained to the sea to prevent flooding.

The Tanjung Leban area which is located in downstream of the PHU, is supposed to get more additional water from the upstream reservoir managed by the company concession especially in the dry season as the application of water sharing. Fig. 6 presented the GWL fluctuation at each transect before and after water-sharing application at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia. The figure shows that the application of water sharing in the right-side canal could raise the GWL about 0.5 m, 0.4 m, 0.3 m and 0.55 m in Transect-1, Transect-2, Transect-3 and Transect-4 respectively. It also has an impact on reducing the level of peat fire risk up to 10% for setting a canal blocking, as presented in Fig. 7. The more canal blocking, the wider area of peatland will reduce against peat fire risk in case of water sharing application.

![Figure 6. GWL fluctuation at Transect-1 (a), Transect-2 (b), Transect-3 (c) and Transect-4 (d) before and after water-sharing applied at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.](image)

3.4. Impact of water management on peatland restoration

The impact of rewetting using canal blocking in the peatland restoration for a long-term period is presented historically in Fig. 8. Those areas are located in the Transect-4, which are in high GWL as presented in Fig 7b. Previously, those areas were burnt severely but after canal block construction in 2009, there was no more peat fire. After canal blocking, the peatland areas are kept always wet that make those areas free from fire and the plantation growing very well. In 2017, those areas were assessed as one of the successful areas for tropical restoration exercises according to many scientists who visited here.

4. Conclusion

This research monitors the hydrological condition as the impact of rewetting activities using canal blocking at Tanjung Leban village. Forty dip wells in the four transects and an automatic rainfall record equipment were set up in the research area to monitor the GWL and the rainfall event as the impact of
rewetting activities. The result shows that the rewetting activity using canal blocking has a significant impact on the rewetting effort so that the risk of peat fire can be minimized. The canal blocking could raise the water level at the canal about 0.7 m that could raise GWL about 0.3 m and 0.2 m at the peatland with a distance of 60 m and 210 m to the canal respectively. The canal blocking also could reduce the level of peat fire risk area about 6% for the construction of a canal block. For the larger area of reducing peat fire risk, it should be added more canal block in this area with the shorter distance between them. The application of the water sharing system could raise the GWL about 0.3-0.55 m in the peatland area, which can reduce the level of peat fire risk up to 10% for setting a canal blocking. The more canal blocking, the wider area of peatland will reduce against peat fire risk in case of water sharing application. The historical evidence shows that the peatland restoration has been improving after the peatland areas were kept in always wet conditions.

Figure 7. Map of peat fire risk before and after water-sharing application at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.

Figure 8. The timeline history of tropical peatland restoration as the impact of rewetting using canal blocking at Tanjung Leban, Bengkalis Regency, Riau Province, Indonesia.
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