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Local knowledge on landscape sustainable-hydrological management reduces soil CO_2 emission, fire risk and biomass loss in West Kalimantan Peatland, Indonesia

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Abstract. *Astiani D, Taherzadeh MJ, Gusmayanti E, Widiastuti T, Burhanuddin. 2019. Local knowledge on landscape sustainable-hydrological management reduces soil CO_2 emission, fire risk and biomass loss in West Kalimantan Peatland, Indonesia. Biodiversitas 20: 725-731.* Local knowledge in managing peatlands, especially in the area of peat hydrology, has been practiced through generations to manage peatlands for agriculture and small scale gardens. Farmers in West Kalimantan have developed the way to conserve water by making simple dams using soil or woody plants to hold water from the peat upstream areas on small channels or rivers. To reduce puddles during rain or tides, people make small trenches, so-called *parit cacing* in the middle of the larger channel. The trench cross-section size is ~30-40 cm^2. This channel can maintain the peat water level to the extent of the depth of the channel. These channels, at the same time, are useful, for a clear, easy land ownership border for one farmer family land. The results of CO_2 emissions assessment at various water levels on the peatland landscape demonstrate that the landscape which surrounded by the *parit cacing* trenches can maintain lower CO_2 emissions compared to the one that has deeper water levels. The knowledge to develop this channel has also reduced the risk of peatland fire hazard and the amount of peat biomass loss on a fire event. An assessment on the effect of water level on the loss of peat biomass when burned, reduce 30-78% loss risks if compared to water table depth of 60-80cm, which is assumed as general practices on peatland recently. The practices of the knowledge on peatlands hydrology management can reduce the risk of peatland soil CO_2 emission as well as loss of peat mass through decomposition and during peat fires.

Keywords: Local knowledge, *parit cacing*, peat biomass loss, peat CO_2 emission, peatland hydrology

INTRODUCTION

Peatland traditional farmers in West Kalimantan basically already have provisions to manage peatlands. Various local wisdom handed down from generation to generation become a reference for farmers in processing peatlands. For a long time, people in the area have used peatlands to fulfill their various subsistence needs. The existing peatland management practices are then passed on to the next generation through oral tradition, so that there should be a document on the local wisdom of Kalimantan farmers in managing peatlands. The need for distributing the wisdom is so that in the future peatlands can be maintained properly and in accordance with the knowledge possessed by farmers. Another goal is that this cultural heritage is not lost but can be known by many parties and can be taken into consideration in taking a policy related to peatland development.

Peatland development and management to become agricultural land not as easy as other lands management. In the course of various problems encountered in utilizing peatlands. This happens because peatlands have characteristics that are a lot different from rice fields and other farmlands that are commonly found in Indonesia. It takes some time to be able to change the peatlands into productive land suitable land for agricultural activities. In the beginning, especially, it needs a variety of improvement and treatments so that vegetables, seasonal crops, annual crops, and fruit can thrive in the peatland area. Appropriate handling is needed because due to its functions as an environmental buffer, peatland development and land cover change should be made in proper manners (Dariah dan Nurzakiah 2014). Otherwise, the peatland development and land cover change from forest to other land uses could decompose its organic matter layers faster than it used to be.

The increased of peat organic matter decomposition, concomitantly increasing the CO_2 emission to atmosphere. Astiani et al. (2018) show that peatland water table condition has significant impact on the rate of CO_2 emission from tropical peatlands. agricultural development-both industrial plantations and smallholder farmers-logging, mining, and peatland land clearing and drainage for infrastructure have affected tropical peatlands (Carlson et al. 2013). These activities have resulted in an enormous loss of biomass, and thus carbon gas emissions, peat oxidation and also combustion (Page et al. 2002; Hooijer et al. 2010).

Another problem that arises is the rejection of peatland forest cover changes issued by the government by farmers in West Kalimantan. These issues happen because the direction of government policy regarding the development of peatland is contrary to the knowledge and local wisdom of farmers (Sutanto 2002). As a result, there are a lot of complain and rejection in the management of peatlands. Government awareness is needed to observe that there are various kinds of local wisdom practices that farmers have in West Kalimantan. This local wisdom can be a strategy in managing peatland so that its potential can be used optimally.

Scientific assessments were held to justify some local wisdom on peatland development. One of the local wisdom practiced is in managing hydrology on agriculture. Non-developed peatland area covered by forests or shrubs some time inundated by water both due to rainwater or tide. Farmer mostly develops *parit cacing*, small trenches of 30-40 cm depth are built on each farmer land margin, to reduce puddles during high water levels. At the same time, the trenches also are used as their land marker. Why this practice has been applied throughout generations should be scientifically discussed. The objective of this study is to search the scientific facts about the *parit cacing* on its role to peat soil CO_2 emission and fire risks accident. The results could be scientific proof.

MATERIALS AND METHODS

Study site and land general description

The study has been executed on Kubu Raya Distrik peatland area of West Kalimantan, Indonesia, which focused on Kuala Dua Village, especially on Dusun (Hamlet) Karya 2. The hamlet was developed in year 2002, when communities, most of them traditional farmers, were moved to this area from Sambas District. The hamlet is 2-6 m depth peatland area, covered partially by degraded forest, shrub, and open, non-cultivated areas. Each family was granted 2 ha land by local government for their living. Since then each family processed the land into arable land. They plant many kinds of mixed crops such as corn, sweet potato, cassava, pineapple, ginger, and some vegetables. There was no government interference when they first moved there. Therefore, at the beginning of their inhabitant in the area, they relied on traditional farming knowledge from their area of origin to cultivate the land.

To ensure their survival in their new settlement, each family cultivate almost all of their 2 hectares land into agricultural land. Before the farmer open and cultivate their land, each farmer develops small trenches with the size of 30-40cm in width, and similar size fo the depth manually using hoes and digger, their conventional farming tools (Figure 1.A-B). The goals from making the trench are not only being used as their land boundary markers between farmers, but it also lowered water table level, so it provides space for plant roots to grow and develop properly, therefore, but their agricultural land can also be cultivated with some crops and vegetables.

However, in 2015, the peatland area of Dusun Karya 2 was affected by construction of canals planned by local government. Larger canals with 5m width and 3m depth were built and split farmers lands. This construction had some impacts on farmer lands. The peatland landscape water levels were drastically lowered and dried up the land (Figure 2). Since then the farmer could not cultivate crops anymore within the impact area, because the peat has been dried permanently that it caused problem for crops to grow.

CO_2 emission assessment on peatland agriculture lands

Post thirteen years of opening the peatland landscape for agricultural purposes, the intensive assessment had been conducted to measure the CO_2 emission rate on the cultivated lands that covered by some crops and vegetables (Astiani et al. 2015). The soil CO_2 emission was measured with a carry-on device called: 'A 20 cm diameter Li-Cor 8100 Automated soil CO_2 flux system'. The Li-Cor 8100 contains an infrared gas analyzer that simultaneously can detect soil surface relative humidity, CO_2 and H_2O concentrations. This equipment measures spatial and/or temporal variability of soil CO_2 emission. The device of Licor 8100 system also attached with soil temperature with a temperature probe (p/n 8100-201) at 10 cm peat depth. The device was seated on permanent collars, which were set up of 6 collars on each site. On 2015-2017, CO_2 emission assessment was executed not only on the former site but also included the larger canals impacted areas.

Laboratory scale fire experiment

Recently some fire experiment has been conducted to explore peat hydrology condition (i.e., water table levels) impacts on water content and biomass loss. Soil sampling has been conducted on open peatland area in Dusun Karya 2, Kubu Raya, West Kalimantan, Indonesia. Peatland drought testing was conducted at Soil Laboratory, Faculty of Agriculture, Tanjungpura University (Untan), Pontianak, West Kalimantan, Indonesia.

The materials used were undisturbed soil samples, rectangular with size 30cm x 30 cm x 30 cm as much as 48 soil samples. The tools used is a 30cm x 30cm x 30 cm peat sampler, small boards for removing soil samples from molds, machetes/knives, aluminum plates and cardboard boxes to bring soil samples from the field to the soil laboratory at Untan, and 0.0 g weight scale. Data was taken directly in the field include peat water levels at the time of soil sampling, soil temperature, and soil moisture around the soil sampling.

Prior to soil sampling, the peat site where the bulk soil sample was watered up to water saturation (field capacity condition). This treatment was to manipulate the condition of peat soil as soon after rainy day. The soil samples then were placed on an aluminum plate, wrapped in transparent plastic, labeled, and inserted into cardboard to be brought to the soil laboratory at Untan (~ 25 km). Plastic cover soil samples were expected to avoid changes in water content during transportation. The data collected in the laboratory included baseline moisture content in weekly (week 1-8) of measurement of peat water content on each 10cm the soil sample depth. The length of experiment of 8 weeks was used based on the most extended dry season in El-Nino event experienced in West Kalimantan.

Upon the weighing and water content assessment, the peat soil samples were plastic wrapped and kept for laboratory-scale fire experiment. When each weekly water content assessment was done, 4 soil samples were used for burning experiment. The experiment tests how peat-surface water content ignite the fire. However, a 100g dry litter each will be used to start the fire on each peat sample (Figure 3). Before the fire ignition, peat samples were weighted and water-content measured. After the fire extinguished, the soil samples were re-weighing for biomass and water losses.

Figure 1. A. The process of building 30-40 cm width and depth trenches, and B. Planting crops and vegetables by traditional farmer on peatland

Figure 2. Large canals developed on peatland lowered water table level till the depth of the canals and dried up surface peat material

Figure 3. Peatland fire experiment: impact of water content on biomass loss

Data analysis

Throughout the estimation of soil CO_2 emission, soil water content upon the drought experiment, and biomass losses, data are presented as mean and SEs. The relationship between water content and biomass loss, water table level and soil CO_2 emission were analyzed using Systat 11.2 and shape will be presented in a regression between the two variable.

RESULTS AND DISCUSSION

CO_2 emission on peatland agriculture lands

Assessment results indicate that mean water level <35 cm resulted in lower CO_2 emission compared to higher ones over 35 cm. When farmers cultivated corn and pineapple which manage soil water table level less than 40cm, the emission rate was lower than fern area cover, which mean water level further below peat surface will increase peat CO_2 emission. Linear regression between peat water table level and CO_2 emission demonstrates that lowered water level within the landscape will significantly increase the emission (Figure 4.A-C). The linear regression equation is as follows: CO_2 Emission =-35,297 + (1.829 * Water Table Level), N = 143, R = 0.777, Rsqr = 0.603.

Those results justify that the hydrology management such as practice by West Kalimantan farmers on peatland resulted in low CO_2 emission which has mean under 27 ton ha^{-1} y^{-1}. This mean value is much lower compared to Astiani (2014) that assessed CO_2 emission under oil palm plantation on peatland, where the hydrological management maintains water table level ~60-70cm below peat surface. The emission rate in oil palm plantation ranges between 45,6-61,9 ton ha^{-1} y^{-1}.

Precipitation in this peatland is an important factor because it alters the water table, although precipitation alone is not sufficient to predict peat CO_2 emission. Peat CO_2 emission increased ~ 27% during the dry season compared with the rainy season. Dry and rainy season comparison displayed significant differences. The amount of precipitation had an indirect influence on peat CO_2 emission due to water level is not far from peat surface. Our data analyses indicate that peat water level was moderately correlated with amount of rainfall (R =-0.44), the increase of 100 mm monthly precipitation reduced the distance of water table level (~3.6 cm) from peat surface. This evidence also in line with the habits of farmer who started their farming activities at the beginning of rainy season. thus the land preparation could reduce peatland CO_2 emission

Together with other site conditions, increasing water level will reduce peat CO_2 respiration rates. Because this peatland area solely depends on water supplied through rainfall, the amount of monthly precipitation also influences water table levels, but is rather weakly correlated with other site conditions: peat temperature, peat CO_2 concentration, and peat relative humidity and only moderately correlated with ambient temperature.

Water table level on peat fire risks

As mention above that larger canals with 5m width and 3m depth were built and split farmers lands in 2015. It was drastically lowered water level in the landscape especially the site that was adjacent to the canal. Water table levels distribution on the peatlands area were assessed for several weeks since February 2018. Mean distribution of water table was 1.09 m with ranges from the lowest of 0.56m to the highest of 1,46m. There were two large canals that had been established in the area for community agriculture-land severals years ago. Since then wildfire has frequently affected these areas. The last large fire events were in 2015, found scattered within this peatland landscape (Figure 5.A-C). In long drought years, wildfire events occurred and caused large impact on surrounding communities and environment.

Before large canal development, fire events did not occur in the site. The water table position close to peat surface, keep the peat surface moist, make it difficult to start fire. As generally known that a fire event will start when there are available fuel sources, oxygen and heat. Therefore, when upper peat soil is moist, both intentional and escaped fire event is rarely started.

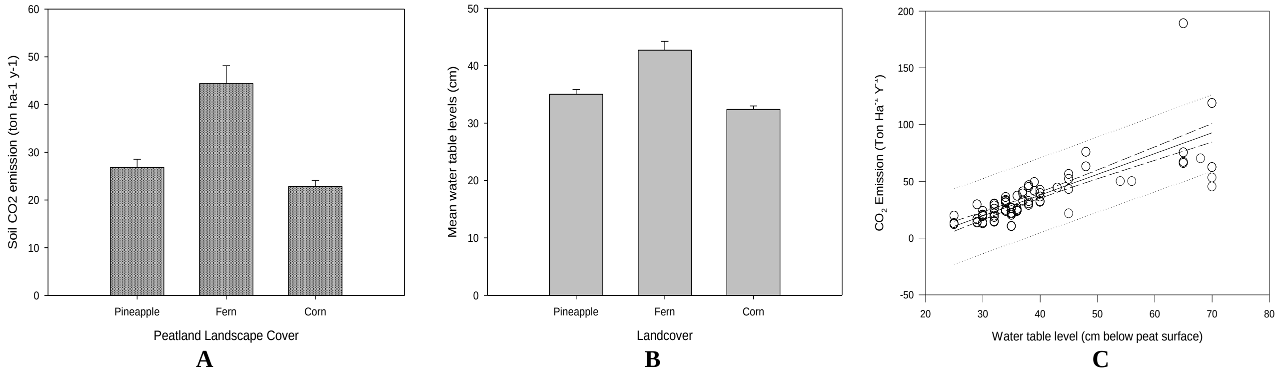


Figure 4. A. Mean CO_2 emission from peat landscape with some crops cover, B. Mean water table level on peat landscape with some crops cover, C. Linear regression between water table level and peat CO_2 emission

A B C

Figure 5. A. Fire affected peatland forest, B. shrub, and C. open area which impacted the surrounding communities and environment

Drought impact on peat water contents

Drought experiment had been conducted to explore how no rain days on peatland affect their water contents. After 8 week measurement, the water contents on 30 cm depth of peat described in Figure 5. The first 10 cm depth was reduced the highest loss of % water content, it lost 198% within eight weeks of no rain. It is also discovered the deeper part of peat loss less water content. The 10-20cm depth peat layer lost its water content 178%, followed by 20-30 peat depth which lost 174%. This laboratory scaled experiment controlled the loss of water from side part with plastic layer. Therefore the measurement shows the loss of water content to the atmosphere in laboratory ambient condition (mean temperature 28-29°C and mean moisture 67%). Weekly dynamics of water content in laboratory experiment were demonstrated in Figure 6. When farmer set up their land with 30-40 cm water level, with similar losses of water portion on evaporation, the water content could be higher due to capillary movement of soil water from lower peat layer. The capillary movement in peat soil may reach 20-30 cm above peat water table level (Hooijer et al. 2010).

Peat biomass loss on fire

Lab scale experiment using our blocks of 30x30x30cm had been accomplished each week for two months. Soil biomass was measured before and post-fire, to explore how soil water content influence carbon loss in room ambient temperature, while other environmental factors are controlled. Results show that days with no rain (drought) season which reducing water content of peat, dictating biomass loss on peat fire events. On Figure 6 demonstrate that critical peat water content (200% of dry weight based) which start fire easily on peat surface was reach on the 2-3 week dry season. This critical time may be shorter on field-based measurement when other environments/weather factors also taking parts such as wind, ambient temperature and humidity, soil temperature and humidity, air density, and aboveground fuel sources, and other factors involved. The increasing days of no rain subsequently increase the amount of fuel loss from peat burning (Figure 7).

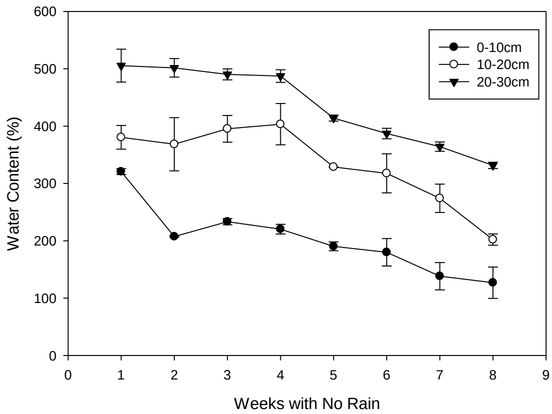
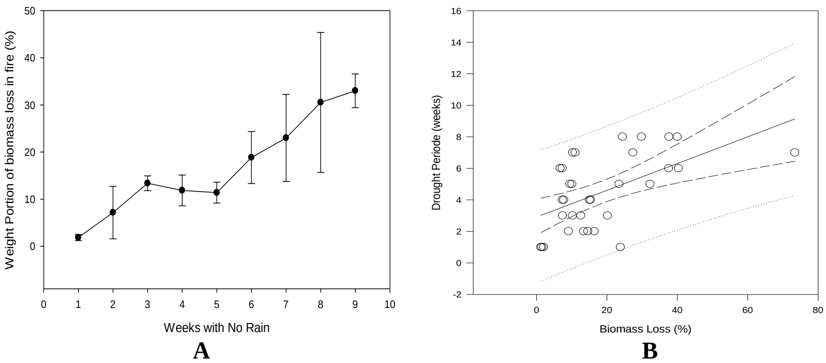


Figure 6. Weekly distribution of water content on each peat depth range of 10 cm within eight weeks of assessment



A B

Figure 7. A Biomass losses along the weeks of no rains, and B. Linear regression on length of drought (weeks) period and % biomass/ carbon loss. The longer days with no rain increase proportion of biomass loss. Both variables with positive correlation coefficients and P < 0,050 tend to increase together. Linear Regression of the both variables is % of Biomass Loss = 2.91 + (0.085 * Weeks of Drought) N = 32; R = 0.55; Rsqr = 0.31.

It is recorded that prior to massive land use change and the increase in population densities in Kalimantan, severe fires on peatland was rarely occurred (Field et al. 2009). Generally, climate condition, land cover variety, and accuracy in land management are some of the drivers of fire event in Indonesia which are interactive of one another. Moreover, El Niño events that happen every 2-4 years in the area enhance drought and dryer condition of peatland surface, that has more vulnerable impacts due to fuel sources sensitivity (Goldammer 2007). El Niño conditions increase the potential for peatland to burn by drying fuels material on peatland surface. Drought condition moves fire pollution and particles which increase regional haze development (Heil et al. 2007).

The experiences indicate one or two weeks with no rain has significant impact to increase intensify fire events, especially if there are El Niño conditions (Gaveau et al. 2014). Many farmers start to produce ashes for increasing peat reaction and peatland crop productivities. For the farmers, controlled burning is also considered to be a cheap and effective method to facilitate land clearing and could shortly increase productivity at the beginning of agricultural and plantation development (Simorangkir 2007). However, when drought is too severe, it is potential to lose in biodiversity, decrease in carbon storage, cultivated land damage, and increase severe air pollution and particulate materials in surrounding communities. (Reddington et al. 2014; Kim et al. 2015).

Rainfall patterns in equatorial land of Indonesia (e.g., West Kalimantan) predicted to be shifted due to climate change impacts (Li et al. 2007). The shift of rainfall amount and frequency will have negative impacts on peatland ecosystems, because the precipitation is the predominant factor on ecosystem processes such as nutrient cycle, net primary production, flowering and fruiting season, and water cycle (Churkina and Running 1998; Knapp and Smith 2001; Astiani 2016; Astiani et al. 2017) and exchange of carbon dioxide from the peatlands (Davidson and Janssens 2006; Astiani et al. 2018). The process of decomposition, relatively lower in compared to lowland mineral soil where anaerobic conditions frequently persist. However, prolonged drought and lowering water table could change the rate of decomposition or emission as well as peatland risk to fires. Fluctuations of the frequency and intensity of precipitation, such as the local water table lowering during droughts, may contribute to some significant consequence on soil CO_2 fluxes and fire event risks.

In conclusion, the use of *parit cacing* on peatlands as hydrology regulators of irrigation and land boundaries between farmers for generations proves that this method provides great benefits to farmers. These hydrological arrangements are scientifically proven to provide environmental risks such as lower emissions, better fire prevention, and fewer biomass losses. The management and conservation of peatlands is a central issue today. Considering that peatland is an alternative answer to the problem of lack in agricultural land in Indonesia. Peatlands are potential to be utilized by farmers to cultivate crop and vegetable farming activities. However, the difficulty in managing peatlands is also a problem in itself. Therefore, local wisdom in the management of peat hydrology greatly contributes to the sustainability of peatlands in the future.

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