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Case Study Paper

HYDRAULIC INTERVENTION IMPACT ON SUBSIDENCE AND CARBON EMISSIONS IN PEATLAND AS A DISASTER MITIGATION EFFORT

(CASE STUDY : SEI AHAS - CENTRAL KALIMANTAN)

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Abstract

The objective of this research in Sei Ahas is to know the effect of ground water elevation in the form of peat thickness against peat subsidence and carbon emissions. Furthermore, the effect of intervention applied on degraded peat lands towards the rate, speed and time of subsidence have been considered as well. The hydraulic intervention is carried out by canal blockings to keep water run out of the peat and simultaneously raise the water level in the canal and land. Subsidence and carbon emissions on peatlands can be correlated directly proportional to the depth of the ground water table. The correlation shows that the lower the ground water table will result in the higher rate of land subsidence and higher carbon emissions. Controlling the ground water level in peatlands is the key to prevent degradation of peatland and some problems, such as floods, fires and carbon emissions. The results of this research confirmed the hypothesis that the amount of carbon emissions depend on ground water table in peatlands. Furthermore, can be proved that speed and time of subsidence is determined by the height of the ground water table. Type of interventions applied on peatlands also determine the rate and duration of subsidence. This research proves that by building canal blockings and reforestation, giving much smaller subsidence rate and carbon emissions (Acacia plantations) compare with no intervention.

Keywords: peat, carbon emissions, ground water table, subsidence

INTRODUCTION

General Background

Peatland is conserve carbon and the carbon will not be lost and stable in their natural state. When peatlands drained for various purposes, such as land clearing for agriculture and plantations or for timber, the peat will subsidence (flooding) and release carbon into the atmosphere through the process of oxidation.

More than half of the content of the world's tropical peatlands are in Southeast Asia (24.8 Mha), especially in Indonesia and Malaysia (Page et al., 2011). Assuming peat thickness (average of > 5 m) in the two countries, then they have 77% of all deposits of peat carbon (Page et al., 2011).

In PEAT-CO2 project (Hooijer et al, 2006), found the present and future emissions from drained peatlands were quantified using the data on peat extent and depth. It was found that likely current CO_2 emissions caused by decomposition of drained peatlands amounts to 632 Mt/y (between 355 and 874 Mt/y). This emission will increase in coming decades unless land management practices and peatland development plans are changed, and will continue as well beyond the 21^{st} century. In addition, over 1997-2006 an estimated average of 1400 Mt/y in CO_2 emissions was caused by peatland fires that are also associated with drainage and degradation. To avoid the above problems, that had a very large negative impact, then the control of ground water level in peatlands is the key to prevent defound gradation, floods, fires and reduced carbon emissions.

Calculation of subsidence rate and time in this study are based on the average height of the groundwater table, while the carbon emission calculations are based on the volume of peat above the water table (which can be oxidized). All calculations are done using GIS software (QGIS).

A study on carbon emissions in peatlands also has been done by Firmansyah from Balai Pengkajian Teknologi Pertanian, Central Kalimantan in 2011. This research and the research of Anang Firman, have the same concern, i.e. carbon emissions from peat decomposition.

Location

The research activities are located in Block A, in ex PLG at Sei Ahas village, Kuala Kapuas district, Central Kalimantan with area of ± 28,6 km^2 or 28.600 hectares. Sei Ahas village is ± 160 km (follow the flow of the river) from the Kapuas River estuary. To obtain a clearer picture, see **Figure 1**.

Problems

Many peatlands in Indonesia are currently experiencing degradation due to water mismanagement in the past. Most peatlands drained for various purposes, such as land clearing for agriculture and plantations (i.e. oil palm) or for timber. Further, the peat will decrease (subsidence) and and release carbon into the atmosphere through the process of oxidation. While use of peatland is still continues unwisely in some places, the degradation of peatlands occur more severe.

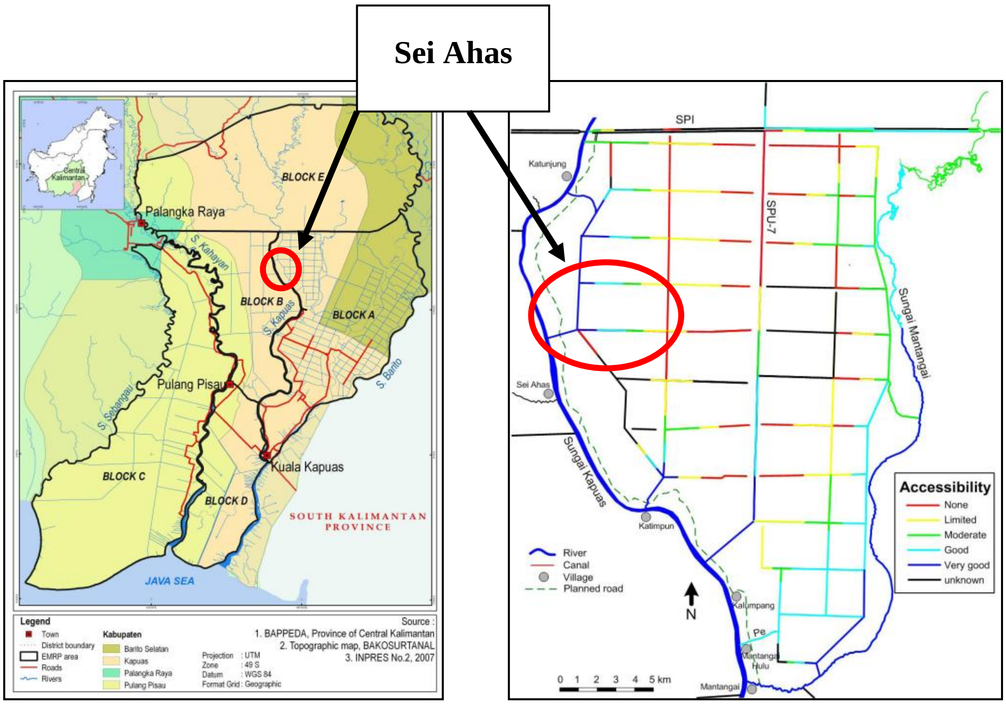

Figure 1 Location of Sei Ahas (Source, KFCP-2009)

Scope of The Research

This research is limited to the shallow peatland area with a depth of about 3 m or less in the adaptive management zone. Subsidence and carbon emission calculations are based on the empirical approach and some of the following assumptions: Land conditions studied are natural forests and plantations ; Bulk Density based on values that are generally accepted or standard ; oxidation values taken by the general provisions, amount to 80% ; Value for shallow peat carbon content was also taken under the general provisions, amount to 50% and 55% ; the increase of ground water level due to canal blocking was taken at 20 cm ; drainage Limit is assumed to have a slope of 20 cm/km, and assumed of every 1 point fires, the peat decrease by 10 cm/year.

Objective

The objective of this research is to know the effect of ground water elevation in the form of peat thickness against peat subsidence (speed and duration) and carbon emissions. Furthermore, the effect of intervention types applied on degraded peat lands toward the rate, speed and duration of subsidence have been considered as well.

Design of the study

The hydraulic intervention is carried out by creating a canal blocking to keep the water does not flow out of the peat and simultaneously raise the water level in the canal and land. Calculation of the rate, speed, and duration of peat subsidence through 4 (four) scenarios as follow: **without** canal blocking and **without** reforesting (actual condition); w**ith** canal blocking and **without** reforesting ; **with** canal blocking and **with** reforesting, and **without** canal blocking, **without** reforesting and **fires.**

Literature Study

Carbon storage in peatlands will be stable if peatland is not drained through the darinage process. In this case, to control ground water level is the main key to carbon do not released into the air. Moreover, subsidence on peatlands can be correlated directly proportional to the depth of the water table. The lower the ground water table will result in the higher rate of land subsidence (Hooijer et al., 2012b). According to research by Hooijer et al. (2012a), at a depth of 0.7 m water level, "acacia estates" and "natural forests" have the same rate of subsidence

(**Figure 2**) and a linear line "acacia estates" can be used for drained natural peatlands when the depth of the water table average below 0.7 m (Hooijer et al., 2012a). This number on average which is presently the norm in relatively well managed plantations in Indonesia (Hooijer et al., 2012b)

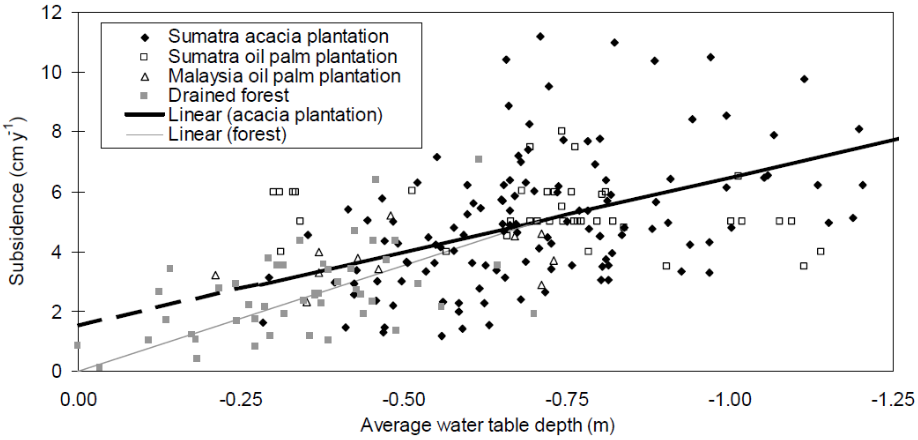

Figure 2 The relation between subsidence and average wayter table depth

Figure 2 also shows that land use affects the rate of land subsidence. The subsidence rate of agricultural land is higher than the natural forest.

Based on the relationship of water table elevation and carbon emissions per year by the height of average ground water table around 0.4 m, can be expected to produce carbon emissions (CO2) per year of approximately 50 tons per hectare (Hooijer et al., 2012a).

Not all of total peat volume will be oxidized, most of the volume will still be stored as carbon at peat under the ground water level or below the Drainage Limit. In this research, drainage limit line is assumed to have a slope of 20 cm/km from water level in the river (Hooijer, et al, 2012b).

Methodology of Study

In this study, peat volume was calculated based on the elevation maps generated from LIDAR, i.e. sensing using laser technology (KFCP Project, processed by Deltares) and peat depth distribution data. Peat depth data were obtained from Puslitanak (1992), KFCP (2011), and Research Centre of Water Resources, Experimental Station of swamps (2011-2012). In this case, the peat volume is a dry peat volume above the water table (which can be oxidized). Calculations were performed using GIS software (Quantum GIS).

Calculation of the oxidized peat volume were carried out by multiplying the peat thickness above the ground water table with the oxidation percent value (taken 80% for Sei Ahas) and the land area.

Calculation of the existing carbon deposits from the total dry peat weight can be determined by multiplying the peat volume that can be oxidized with Bulk Density values and carbon content factors of 50-55% (Hooijer et al., 2012a). Further, carbon deposits can be converted into CO2 equivalents.

Hooijer et al. (2012a) makes a linear equation that links between peatland subsidence rate with the average groundwater levels for natural forest and acacia plantations. The equation is used in this study and it is described as follows.

Acacia plantations : S = 1,5 - 4,98 * WD .... (1)

Natural forest : S = 0,69 – 5,98 * WD .... (2)

where S, is annual subsidence of the peat surface (cm yr^{-1}) dan WD is average water table depth below the peat surface (−m; negative). Accordance with the measurement data, the value taken for WD is - 0.4 m for the whole year (Research Centre for Water Resources, Experimental Station for Swamps, 2012). If there are canal blockings, subsidence rate is calculated with the reduce WD value, assumed by 50%, which is 0.2 m.

When reforestation is carried out then the value of the subsidence rate is calculated by the equation:

S = 7,06 * WD .... (3)

Time of subsidence (year) can be calculated from peat thickness (cm) divided by subsidence rate (cm/year).

Peat forest fires consideration was calculated based on a distribution of peatland fires map in Sei Ahas in 2001-2009. From the map, it was found that there are 54 hotspots in the 27 regions in Sei Ahas. So, on average over a 2.19 hotspots per region (2.19 fires/cells) for 9 years (0.243 fires/cells year). Furthermore it is assumed every 1 (one) hotspots, peat decreased by 10 cm/year (Tansey et al, 2008). Thus subsidence rate can be calculated from the formula:

$$S = 1,5 - 4,98 * WD \quad + \text{annual average fires} \qquad .... (4)$$

HYPOTHESIS

The Canal Blocking will increase the water level in the channel and soil, thus the peat becomes wet, then subsidence and carbon emissions can be reduced. The amount and duration of subsidence and carbon emissions numbers depend on the depth of the ground water level. The lower ground water elevation, will result a longer and larger subsidence, and a higher carbon emissions as well. In addition, interventions/actions taken on peatlands will have an impact on the rate, speed and duration of subsidence. These things will be proven in this study.

RESULTS AND DISCUSSION

From this research, results are obtained which are support the hypothesis as follow.

The amount of carbon emissions depend on ground water table or peat thickness above gound water table in peatlands. To get a clearer picture, these correlations are presented in **Table 1**.

Tabel 1. Peat Volume, Carbon, and Carbon Emissions at Sei Ahas

PEAT THICKNES	PEAT VOLUME (Mm^3)	OXIDIZED PEAT VOLUME (Mm^3)	DRY PEAT MATERIAL (Mton)	CARBON VOLUME (Mton)		CARBON EMISSION (Mton)	
				CARBON CONTENT SHALLOW PEAT (50%)	CARBON CONTENT SHALLOW PEAT (55%)	CARBON CONTENT SHALLOW PEAT (50%)	CARBON CONTENT SHALLOW PEAT (55%)
Total Peat (above peat bottom)	36.07	28.86	2.78	1.39	1.53	5.09	5.60
Peat above river water level in dry season	32.07	25.65	2.48	1.24	1.37	4.55	5.00
Peat above drainage limit in dry season	27.08	21.66	2.11	1.06	1.16	3.87	4.26
Peat above river flood water level	27.88	22.30	2.16	1.08	1.19	4.00	4.35
Peat above drainage limit in wet season	21.63	17.30	1.677	0.84	0.92	3.08	3.38

Dry season water level number in river was taken from measurement data on 1st to 2nd October 2012 (dry season), i.e. + 1.1 m. And for flood water level number was in May-June 2012 (rainy season), i.e. + 1.59 m (Research Centre for Water Resources, Experimental Station for Swamp, 2012)

The above calculation is carried out on Sei Ahas region with an area of approximately 19 hectare area, at a depth of peat varies between 0 m to 6 m and an average depth of 1.88 m.

From **Table 1** can be seen :

1. For smaller carbon content (depending on the type of peat), will obtain a smaller carbon emission too. On all peat thickness, carbon content of 50% give a smaller carbon emission compared with 55% of carbon content.
2. Total peat depth provide the greatest carbon emissions of all peat thickness. This happens because the water table is at its lowest level, approaching the bottom peat. This condition is the most extreme conditions and is the most pessimistic outlook in the carbon emissions estimation.
3. In the dry peat thickness during dry season, the value of carbon emissions (4.55 Mton and 5,00 Mton) is greater than in the rainy season (4.00 Mton and 4,35 Mton). Thus, the lower the ground water level, the greater the carbon emissions.
4. Peat above the Drainage Limit (both, in the dry and the rainy season), showing the peat above the drainage boundary line assumptions (see Literature Study). For more details, an overview of the "drainage limit" can be seen in **Figure 5** below.

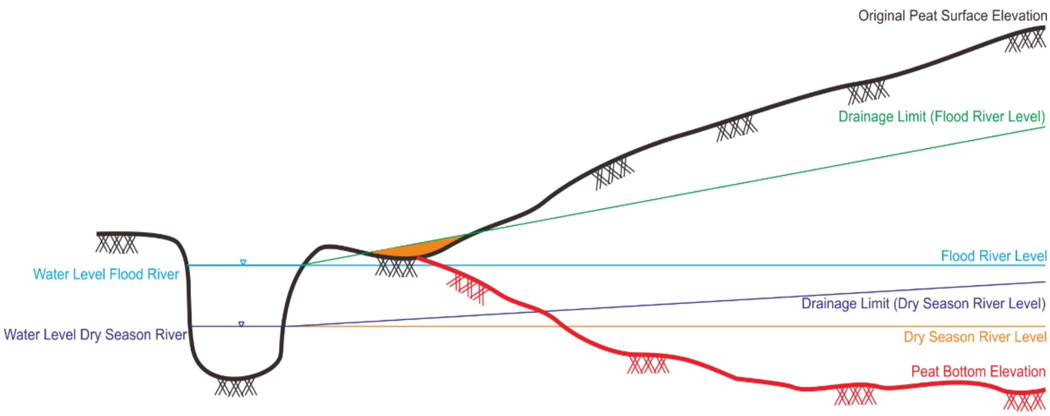

Figure 5 Drainage Limit

From **Table 1** above, can be seen that peat above the drainage limit in dry season provides greater carbon emissions from the peat above the drainage limit in the rainy season. This behavior is the same as item number 3 above.

Furthermore, can be proved that speed and duration (time) of subsidence are determined by the height of the ground water table and the type of interventions applied in peatlands. In **Table 2,** presented the effects of different ground water level (dry peat thickness) and type of intervention toward a speed and time of subsidence.

Tabel 2. Speed and Time of Subsidence (year) for Each Hydraulic Intervention

PEAT THICKNES	*ACTUAL CONDITION; SUBSIDENCE RATE 3,5 CM/YEAR*		*DAM; NO REFORESTATION; SUBSIDENCE RATE 2,5 CM/YEAR*		*DAM; REFORESTATION; SUBSIDENCE RATE 1,6 CM/YEAR*		*NO DAM; NO REFORESTATION ; FIRES; SUBSIDENCE RATE 5,9 CM/YEAR*	
	SPEED OF SUBSIDENCE (Cm/year)	TIME OF SUBSIDENCE (Year)	SPEED OF SUBSIDENCE (Cm/year)	TIME OF SUBSIDENCE (Year)	SPEED OF SUBSIDENCE (Cm/year)	TIME OF SUBSIDENCE (Year)	SPEED OF SUBSIDENCE (Cm/year)	TIME OF SUBSIDENCE (Year)
Total Peat (above peat bottom)	3.49	54	2.50	75	1.62	116	5.92	32
Peat above river water level in dry season	3.49	48	2.50	67	1.62	103	5.92	28
Peat above drainage limit in dry season	3.49	40	2.50	56	1.62	87	5.92	24
Peat above river flood water level	3.49	41	2.50	58	1.62	89	5.92	24
Peat above drainage limit in wet season	3.49	32	2.50	45	1.62	69	5.92	19

Furthermore, from **Table 2** above can be seen :

1. The greater dry peat thickness (or the lower the ground water elevation), the longer time of subsidence.
2. Total peat, giving time of subsidence the longest of all conditions because the ground water table is at its lowest level (approaching the bottom peat). Thus the potentially subsidence of peat is the total peat thick.
3. Time of subsidence of dry peat in the dry season is longer than in the rainy season in all forms of intervention, as potentially peat subsidence is thicker in the dry seasons well .
4. The reason and behavior of subsidence time on peat thickness above the drainage limit is the same as point 2 above. In the dry season, time of subsidence is longer than in the rainy season.
5. In case of dam (canal blockings) and reforestation, time of subsidence is twice longer compared to the actual condition (no canal blockings and reforestation). Even when compared with the actual condition and fire situation, then the time increase an average of 3-4 times longer.
6. All values of speed of subsidence in the range of peat thickness have the same value, as the value of speed does not depend on the thickness of the peat and only depend on the depth of the ground water (see equations 1 and 2).
7. Speed of subsidence on the actual condition is greater when compared to the intervention situation, but when coupled with fires, then the speed of subsidence is more increasing.
8. All forms of interventions provide speed of subsidence is smaller when compared with the absence of any intervention, especially when compared with no intervention and fires condition.
9. Speed of subsidence of the dam (canal blockings) and reforesting condition is slower than simply dams (canal blockings) alone. Speed of subsidence of

dam (canal blockings) and reforesting, worth only about 46% (1.6 cm/year) when compared with the actual condition (3.5 cm/year). But the speed of subsidence of the dam plus fires just stay by 27% when compared with the actual condition (no dams and no reforestation) with fires (5.9 cm/year).

10. From the above figures can be drawn a conclusion that the actual condition with fires (business as usual) provides speed and time of subsidence is very high with a very adverse impact.

This study and Firmansyah (2011), talking about the same thing, namely carbon emissions from peat decomposition. Both studies also used the same approach, ie estimating carbon emissions based on characteristics of the peat soil. Difference of these two studies is that if this research focuses on degraded peat land in Central Kalimantan Sei Ahas, the research of Firmansyah talking about peatlands in general.

CONCLUSION AND RECOMMENDATION

As a specific conclussion, can be concluded that the height of the ground water table is crucial to reduce subsidence and to reduce the amount of carbon emissions in peatlands. Subsidence and carbon emissions will be larger with the lower of the peat ground water surface.
Types of intervention applied on peatlands also determine the rate, speed, and duration of subsidence. This research proves that by building canal blockings and reforestation, the amount of subsidence rate and carbon emissions (Acacia plantations), much smaller than without any intervention.
Furthermore, actual condition combined with fires generate the greatest subsidence and carbon emissions.

Meanwhile, as a general conclusion, can be concluded that although this research and Firmansyah`s research different in locus and time, those research have a same topic and approach.

From the results of the above study, it can be suggested that further control the water level needs to be done to reduce the degradation of peatlands that have been opened and has been degraded. Construction of canal blockings or dams are a very effective way to raise the water level so that subsidence and carbon emissions can be reduced

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