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Climate Change Mitigation Through Forest Fire Prevention and Peatland Rewetting Programs in Central Kalimantan Indonesia

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ABSTRACT

Peat forest plays a principal role in climate change mitigation in Indonesia. Considering the potential releases of GHGs from a forest fire and degraded peatland, it is important to conserve peatland forests. Besides being essential for ecological balancing, the role of peatland forest expands to the economic and social aspects. The purpose of this research was to calculate CO_2 emissions that can be avoided by the community-based fire prevention and rewetting program. This research utilized spatial analysis to calculated avoided CO_2 emissions in six villages in Central Kalimantan. Data and information for the calculation were generated from field observations, interviews, and desk study. Spatial analysis using Arc GIS 10.5 was applied to compute the incombustible areas. The result from the analysis found that fire prevention and rewetting programs managed to prevent approximately 1 million Mg C or equivalent to 3.7 million CO_2. The program managed to prevent emission from the vulnerable area including swamp shrubs, plantations and dry land agriculture. The finding of this study suggests that community-based fire prevention and peatland rewetting programs could become a strategic program in climate change mitigation in Indonesia.

Keywords: climate change mitigation, fire prevention, peatland rewetting, community based program

INTRODUCTION

Global communities demonstrate rising concern toward increasing Green House Gases (GHGs) emission that causes catastrophic effects including climate change, disturbing ecosystem balance, and even threaten human existence. Considering the disastrous impacts of GHGs, Indonesia's government participated in mitigate of climate change that manifested in act No. 16 2016. This policy furthermore translated into more technical strategies by enacted Nationally Determined Contribution (NDC) that contain the Indonesian target of emission reduction as big as 29% for Business as Usual (BAU) scenario and 41% with International contributions. Emission reduction in Indonesia is focusing on land use and land-use change sector as these two sectors are the main emission contributors. More specifically, GHGs emissions in Indonesia are sourced from timber extraction, deforestation for the expansion of agriculture and plantation, and forest fire (MoEF, 2015).

Peat forest plays a principal role in climate change mitigation in Indonesia (Hatano, 2019). Indonesia covers a significant amount of world peatland, approximately 47% of the total global tropical peatland. Thus Peatland becomes an important carbon pool. Peatland in Indonesia is generally formed in lowland areas where usually flooded and has poor drainage (Dommain et al., 2014). In natural conditions and undisturbed where the ecological condition functioning well, peat forest is capable to absorb carbon dioxide from the atmosphere and store in the form of plant biomass, litter, and peat (Loisel et al., 2014; Yu, 2011). Peatlands store carbon as much as twice of carbon stock in tropical forests. Peatland in general contains 2000 Mg C/ha and in very thick peatland (>12 m) could reach 7500 Mg C/ha (Jaenicke et al., 2008; Murdiyarso et al., 2010; Warren et al., 2012).

Despite the crucial function of peatland, peatland in South East Asia keep experiencing deforestation, dried, and forest fire at an alarming rate. The main drivers of peatland degradation include expansion of large-scale oil palm plantations *(Elaeis guineensis)*, timber plantations and illegal logging (Langner et al., 2007; Miettinen and Liew, 2010; Margono et al., 2014).

On contrary, degraded peatland forests become a source of CO_2 emission (Wilson et al., 2016; Veber et al., 2017; Leifeld and Menichetti, 2018). It estimated over a period 2000–2010 Sumatera island disappearance its forests approximately 41.3% meanwhile Kalimantan Island decrease its forest by 24.8% (Miettinen et al., 2011). When peatland forest cleared and experiencing over drainage, peatland naturally decomposed and released CO_2, NO_2, and methane in considerable amounts (Hiraishi et al., 2014; Wilson et al., 2016). Drop of water table by 74 cm for instance resulted 60–100 ton CO_2/ha/year (Hooijer et al., 2012).

In that condition, peatland forests become the subject of a forest fire that generated paramount CO_2 emissions (Hiraishi et al., 2014; Wilson et al., 2016). For example, forest fires in 2015 generated 1.74 Gigaton CO_2. Emission from peatland or peat forest depending on the degree of the degradation. CO2 emission from degraded peat ranging from 1.3 Gt CO_{2eq} /year until 1.91 Gt CO_{2eq} yr^{-1} (Joosten, 2010; Leifeld and Menichetti, 2018; Leifeld et al., 2019).

One of the areas in Indonesia that are prone to forest fire is Mantangai Sub-District, Kapuas District, Central Kalimantan. The majority of peatland in this area is degraded due to Mega Rice Project (MRP) started in 1995 (Anon, 1995). The MRP project aims to create a large-scale paddy field by clearing the forest and creating drainage canals. As a result, peatland in this area was highly degraded and burn repeatedly in the dry season (Jaya et al., 2008; Thoha et al., 2019).

Considering the amount of C stock and potential releases of GHGs, it is important to conserve peatland forests. Besides being essential for ecological balancing, the role of peatland forest expands to the economic and social aspects. Peatland generates numerous ecosystem services including providing habitat for numerous endemic animals, supply various products both timber and non-timber forest product as well (Cheyne and Macdonald 2011; Posa et al., 2011; Nowak, 2013).

Forest fire prevention and climate mitigation of tropical peatland have gained global concern as large CO_2 emissions can be avoided or reduce (Murdiyarso et al., 2010). Furthermore, peatland rehabilitation could bring multiple co-benefits including habitat conservation, maintenance of ecosystem services, and support local community's livelihood. Multiple benefits of peatland conservation provide an incentive to manage and restore peatland (Page et al., 2009).

Indonesia Climate Change Trust Fund (ICCTF) is one of the conservation projects conducted in Mantangai Sub-Regency. Receiving fund support from the United Kingdom Climate Change Unit (UKCCU), ICCTF aim to reduce GHGs emission through management of forest and peatland. This program applies the 3R principle namely Rewetting, Revegetation, and Revitalization. Rewetting focuses on rehabilitate hydrological conditions through canal blocking and backfilling. Meanwhile, the revegetation was conducted by planting trees on degraded peatland. Revitalization is intended to improve the economy and prosperity of local communities by providing sustainable livelihood. Besides that fire prevention is also an important part of this project.

Assessment of avoiding GHGs emissions resulted from community-base fire prevention and rewetting program is a necessary step as part to measure project performance. By measuring the emission that can be avoided, the contribution of the ICCTF program to national targets can be determined. The information from the assessment also can be used to develop a further strategy in peatland conservation.

The objective of this research was to measure CO_2 emission that can be mitigated by the community-based fire prevention and rewetting program. Information from this program also can be seen as an effective indicator of the program in restoring hydrological conditions and managing forest fire.

METODOLOGY

This research was carried in six villages in Mantangai sub-distric, Kapuas Distric Central Kalimantan Indonesia. Those six villages namely Kalumpang, Mantangai Hulu, Mantangai Tengah, Mantangai Hilir, Pulau Kaladan dan Lamunti. The six villages were chosen because the ICCTF program was conducted in that villages. Besides that, the peatland area in those villages has degraded massively. This research was conducted for three months from January – March 2019. The activities encompassed preparation, data collection, analysis and reporting.

This study used primary data and secondary data. Primary data were obtained from field observations and interviews with the community in six villages. Observation intended to check the condition of land cover in some selected points. Meanwhile, interviews were applied to obtain information about the ICCTF program and forest fire in their area. Secondary data included land cover data of 2017 issued by the Directorate of Inventory and Monitoring of Forest Resources, KLHK. Maps of the burn area of 2019 were obtained from sentinel images recorded on October 23, 2019, as well as the coordinates of deep wells obtained from P2KLH (Forest Fire Prevention And Land Rehabilitation Palangka Raya University).

The analysis in this study included spatial analysis, intersect process, and attribute data processing. There are four main stages in this analysis. namely the analysis of the distribution of deep well canal blocking, field observations, interviews, spatial analysis, and calculation the emissions that can be avoided.

The analysis of the distribution of deep wells, canal blocking, backfilling and surveillance tower aims to determine the GPS location. In this way, the extent of the area covered by the program can be determined. The information on the distribution of GPS location will then be used as a basis for field checks and interviews. Of all the deep wells and canal blocking that have been built, 18 points were selected to be checked in the field, 3 points for each village. Some considerations for selecting observation samples are (1) characteristics of different environmental conditions, (2) has access either by land or by river/drainage channel. Some parameters observed were the type of vegetation around the deep well and canal blocking, the condition of the canal blocking/deep well, the presence or absence of water in the drainage canal.

Once all the information was obtained, then a spatial analysis was carried out using Arc GIS 10.5 software to determine the distribution of deep wells and canal blocking. In detail, the analysis step was as follow:

1. GPS points of deep wells and canal blocking are mapped to determine the area covered by the program
2. The area covered by the program then overlayed with a land cover map to determine the types of land cover at the site. The land cover map used was the 2017 land cover map issued by The Directorate of Forest Resources Inventory and Monitoring, KLHK.
3. The area covered by the program was then also overlayed with the 2019 fire map to generate the total area that was burned. Fire map obtained from sentinel imagery recorded on October 23, 2019.
4. It is assumed that the incombustible areas in 2019 were areas where CO_2 emissions have been prevented by the implementation of the ICCTF program. The amount of emission that can be prevented is adjusted to the type of land cover. The amount of carbon content in each type of land cover used in emission calculation was sourced from the Director General of Forest Planology (2015) and Hairiah (2007).

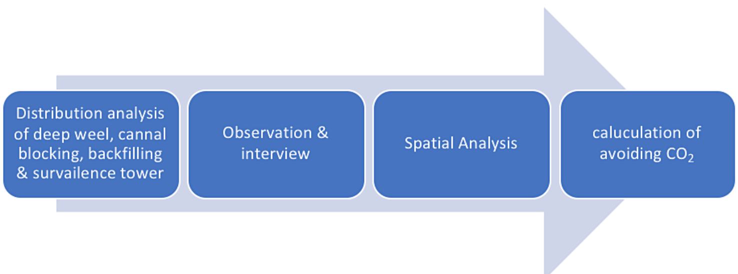

Figure 1. Research flowchart

RESULT

Study site description

The six villages where the ICCTF project was implemented are located in the former PLG area, an agricultural land development project in the year of peat covering an area of one million hectares. Interviews with the community revealed that the PLG Project caused this area to degrade and burned frequently. To develop the rice production area, the first forest in this area is cleared and then drainage canals were built as part of the irrigation system. However, this project failed and left the peat area open and drained. As consequence, this area became prone to fire and emit significant amounts of CO_2. Degraded peat ecosystem also impacted local community livelihood. For example, fish stock decrease rapidly and nontimber forest product (NTFP) become hard to find.

The population in the study area is dominated by the Ngaju Dayak tribe, the rest are from the Banjar and Javanese tribes. To meet their daily needs, most of the community manages rubber plantations, farms, manages rattan gardens, fishing, and collecting non-timber forest products. Only a small part of the community works in the service sector such as manage grocery stalls and artisans.

The interview also revealed that the community has suffered a lot of losses from repeated fires. Almost in every long dry season fires occur. Many rubber plantations, fields, and community rubber plantations were burned, in addition, health, economic and educational activities were disrupted due to the thick smoke that surrounded the village for months.

Community-base fire prevention and peatland rewetting programs

Community-based pograms funded by ICCTF was focusing on restoring the hydrological condition of peatlands as well as preventing and controlling forest fires. The hydrology of peatlands was restored by blocking canals and backfilling. Blocking canals was established to reduce the rate of water from peatlands and to keep peatlands flooded which could maintain the function of peatland. Efforts to prevent and control fires were carried out by constructing deep wells and surveillance towers.

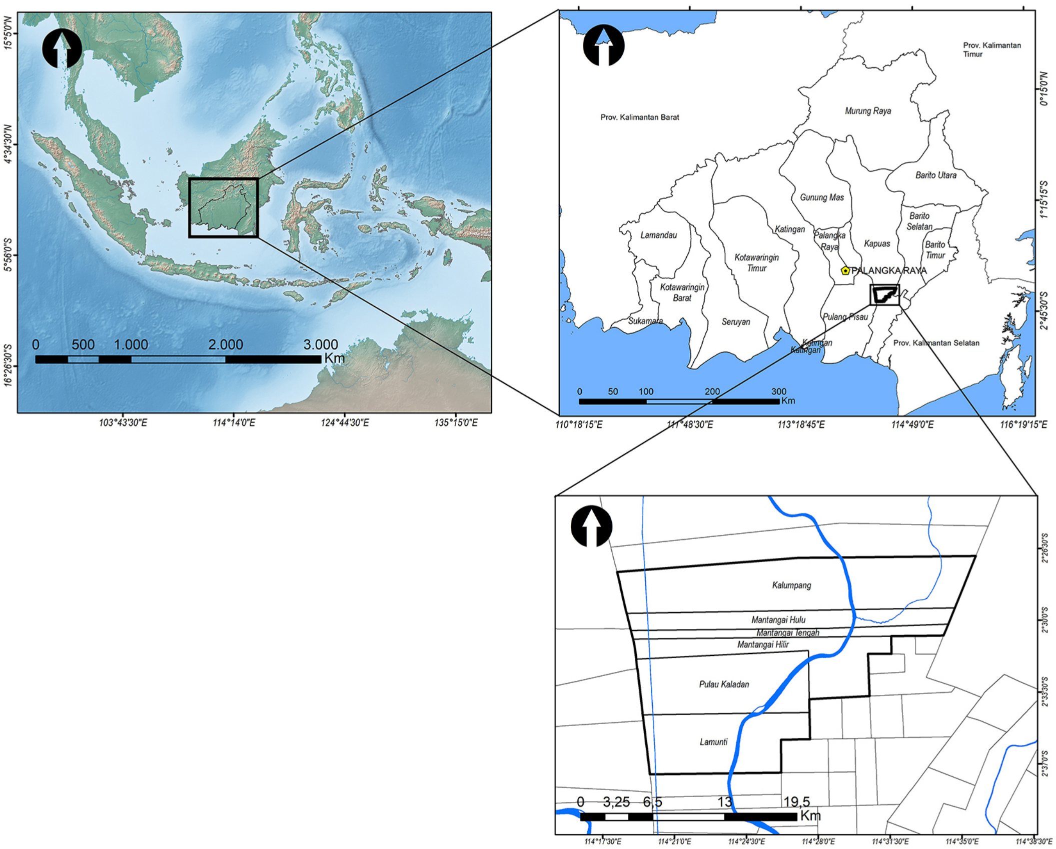

Figure 2. Map of research location

Construction of deep wells was expected to be a source of water for fire fighting. It is estimated that one deep well can prevent fires of 4–8 Ha. The determination of the deep well point was carried out through a deliberation process by the community, P2KLH and village officials. Deep wells are built in locations where fires usually occur and also at vulnerable points where fires from outside the village are usually spread to the village area. In addition to these considerations, the village community also pays attention to access to the points where the deep wells will be built. To optimize the utilization, deep wells must be placed in areas that are accessible to the public either by road or by water. In each village, 50 deep wells were built so that a total of 300 deep wells were built.

Canal blocking is one of Rewetting's priority activities to restore the ecological function of peatlands. Canal blocking is made on drainage canals that are no longer used by the community. A total of 33 canal blocks have been constructed in five villages, namely Kalumpang, Mantangai Hulu, Mantangai Tengah, Mantangai Hilir and Kaladan Island.

The fire surveillance tower was built as part of the early warning of forest and land fires. With the existence of this surveillance tower, the fires that occur in the surrounding village area can be quickly identified. The program built two surveillance towers located in Mantangai Hilir and Mantangai Hulu village.

All the programs were established by put forward participation approach. Local communities actively involve in every step of the programs start from planning, implementing and until monitoring. As community based program it is essential to make the community as the main actor. This approach was selected because local community possessed the knowledge regarding the forest fire including areas that are vulnerable to forest fire, the obstacle in combating forest fire and the loss that they have to face.

Land cover

Based on the 2017 land cover map, the study area is covered by ten types of land cover, namely: secondary swamp forest, open land, plantations, dryland agriculture, dry mixed bush agriculture, swamps, rice fields, shrubs, swamp shrubs, and water bodies.

The dominant land cover types in the study area are swamp shrubs and plantations. Swamp shrubs are mostly formed through natural succession on the burned area. Based on field observations, the dominant vegetation in the scrub is kelakai *(Stenochlaena palutris)*, fern (*Diplazium*

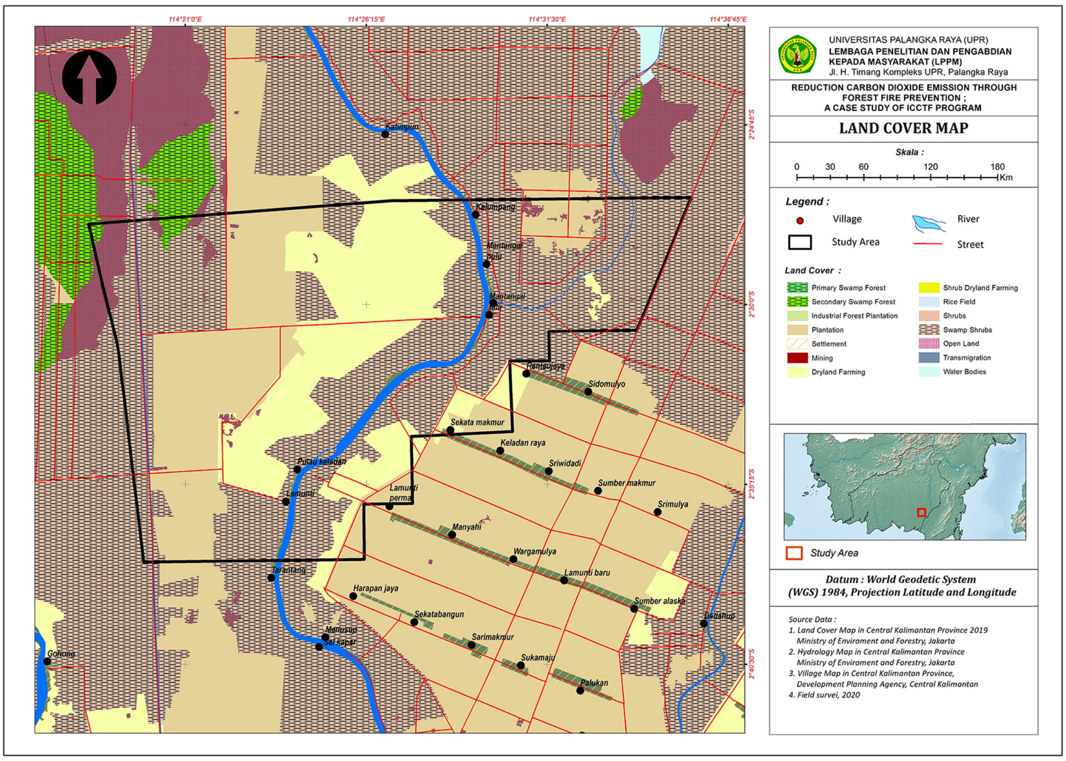

Figure 3. Land use type of block A Mantangai Sub District

esculentum), karamunting *(Melastoma malabathricum)*, rasau *(Pandanus helicopus)*, gerungang *(Cratoxylon arborescens)* and galam *(Melaleuca leucadendra)*. These plants are pioneer species that can grow well on peatlands. During the long dry season, peat, grass, and shrubs become very dry and become abundant fuel for forest and land fires.

Based on the main commodity, there were four types of plantations, namely rubber plantations, oil palm *(Elaeis guineensis)* plantations, sengon *(Albazia falcataria)* plantations and mixed fruit gardens. The plantations managed by the local communities are typically small-scale, and located near the settlement. People's plantations are mostly managed in a traditional way, using a mixed cropping pattern, low input, and using traditional tools. Traditional communities have been managing rubber plantations and for centuries as their main income. On contrary, plantations managed by companies are usually at a large scale, employed monoculture systems and palm oil as the main commodity.

Dryland agriculture is usually land managed by the community to grow rice, vegetables, and fruits. This type of farming uses traditional methods. Forest land is usually cleared by felling and clearing, following by burning the wood and shrub and after three to four weeks the seed of paddy or vegetables could be planted. After two or three rotations (2–3 years) of dryland farming is no longer productive and then farmers started planting it with rubber, fruit, and rattan.

Details of the type of land cover in Block A can be seen in the following picture

Avoided CO_2 emissions

By connecting all GPS points of deep wells and canal blocking, the ICCTF program area can be computed. The total area covered by the ICCTF program is 40,099 Ha which comprises six villages in the Mantangai District. Analysis of the 2019 forest and land fire map showed that 18% (7,381 ha) of the total area was burned. Meanwhile, the incombustible area was 32,178 ha or 82%. By overlaying the burned area with the land cover map, we can expose that previously the burned area was mostly shrub, dryland agriculture, and plantations. In detail, previous land covers of burned area are plantation area 1554 ha, open land 5 ha, secondary swamp forest 2 ha, swamp scrub 3622 Ha, and dryland agriculture 2198 Ha.

Swamp shrubs and peatlands during the dry season become dry and prone to fire, so this type of land cover becomes very vulnerable. The second-largest proportion of areas that burned was

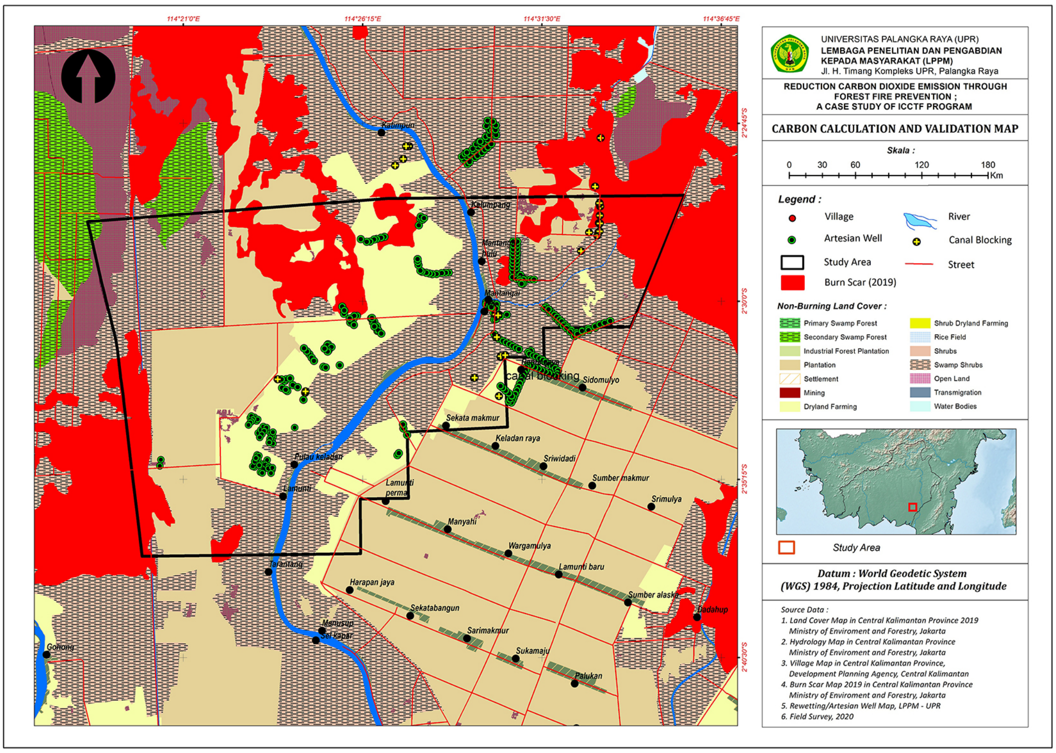

Figure 4. Map of land and forest fire 2019 at research location

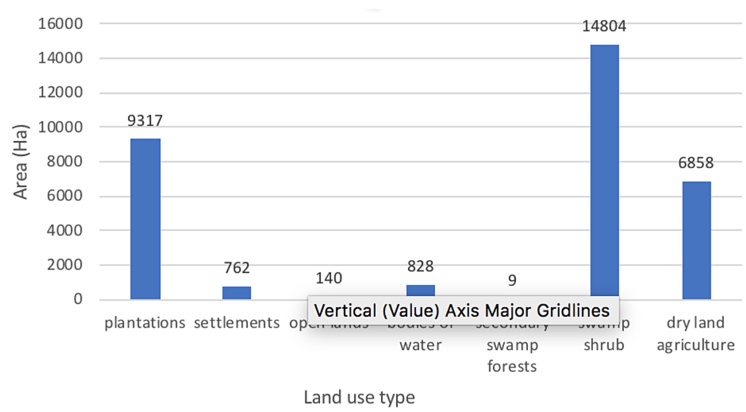

Figure 5. Incombustible area base on land use type

dry land agriculture with 30% and plantations with 21%. Productive land becomes an area that is prone to be burn because fire is often used as a tool to clear land. This method is considered to be the easiest, cheapest, and most effective way. This finding is in accordance with the research of Van Butsic, Kelly M and Moritz MA (2015) and Taconi (2003) that found that forest and land fires often occur in forested areas, shrubs and grasslands as well as plantation areas. Furthermore, peat areas are areas that can experience repeated fires.

It is assumed that the incombustible area is the result of the prevention and mitigation efforts carried out by the program. This incombustible area then becomes the basis for calculating the amount of CO_2 emissions that can be prevented. Based on spatial analysis, the total unburnt area was 32,718 Ha which was divided into seven land cover categories, namely plantations, settlements, open lands, bodies of water, secondary swamp forests, swamp shrub, and dryland agriculture. The categorization of the unburnt area into land cover types is intended to determine the appropriate carbon stock.

Calculation of the total carbon stock in all types of land cover shows that the carbon stock in the incombustible area is approximately 1 million Mg C. This amount is equivalent to 3.7 million Mg CO_2e emissions that could be prevented.

Shrubs area is the most vulnerable area to forest fire. However, the incombustible shrubs in 2019 relatively high. Of the total 18426 ha shrub area in study area, only 18.26 % burnt during the 2019 forest fire and the rest (80.34%) could save from the forest fire. This data indicate that the deep wells and canal blocking are effective to prevent and suppress forest fire. For plantation areas, 9317 ha had saved from the fire disaster.

CONCLUSIONS

This study found that peatland rewetting and forest fire prevention program could prevent 3.7 million Mg CO_{2e} from the 2019 forest fire event. This finding indicates that community based peatland rehabilitation program contribute significantly to climate change mitigation in

Tabel 1. Carbon stock calculation of incombustible area

Land Use	Cover area (Ha)	C stock (Mg/Ha)	C total (Mg)	Reference
Plantation	9 317	52.7	491 005.9	Setiawan et al., 2016
Settlement	762	0	0	Hairiah, 2007
Open Area	140	2.5	350	Directorate General Forest Inventory, 2015
Water body	828	0	0	Directorate General Forest Inventory, 2015
Secondary peat swamp forest	9	79.67	717.03	Directorate General Forest Inventory, 2015
Swamp shrubs	14 804	30	444 120	Directorate General Forest Inventory, 2015
Dry land cultivation	6 858	10	68 580	Directorate General Forest Inventory, 2015
Total			1 004 772.9	

Indonesia. One of the biggest obstacles to controlling fires on peatlands is the lack of operational fund of community fire brigade. The fund is required to fund transportation cost, fuel for the pomp machine and deep well maintaining cost. Thus fire community bridge needs to find a financing scheme, either in the form of a productive business that can be managed by them or financing from other schemes. Most of the burned areas are degraded areas in the form of swamp scrub, open areas, dry land agriculture and plantations. Rewetting efforts need to be followed by efforts to restore vegetation in areas prone to fire.

Acknowledgements

This study is part of the ICCTF project, specifically part of monitoring and evaluation. This study help ICCTF to measure their achievement to mitigate GHGs emission. However, this study is free from bias and conflict of interest. All the analysis and data collection were conducted objectively using valid methodology.

REFERENCES

1. Anon. 1995. Keputusan Presiden Republik Indonesia No. 82 Tahun 1995 Tentang Pengembangan Lahan Gambut Untuk Pertanian Tanaman Pangan Di Kalimantan Tengah (Presidential Decree of Republic Indonesia No. 82 of 1995 on Peatland Development for Food Crops Agricluture in Central Kalimantan). Presidential Office of Republic Indonesia, Jakarta.
2. Cheyne S.M., Macdonald D.W. 2011. Wild Felid Diversity and Activity Patterns in Sabangau Peat-Swamp Forest, Indonesian Borneo. Oryx. 45(1), 119–124.
3. Directorate General Forest Planology and Environment Management, Ministry of Forestry and Environment of Indonesia. 2015. Book of Activity, Carbon Sink and Emission. Jakarta
4. Dommain R., Couwenberg J., Glaser P.H., et al. 2014. Carbon Storage and Release in Indonesian Peatlands Since The Last Deglaciation. Quat Sci Rev, 97, 1–32
5. Hairiah K., dan Subekti R. 2007. Pengukuran Karbon Tersimpan di Berbagai Macam Penggunaan Lahan. World Agroforestry Centre. Bogor.
6. Hatano R. 2019. Impact of Land Use Change on Greenhouse Gases Emissions in Peatland: A Review. International. Agrophysics., 33, 167–173. https://doi.org/10.31545/intagr/109238
7. Hiraishi T., Krug T., Tanabe K., Srivastava N., Baasansuren J., Fukuda M., Troxler T.G. 2014. Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Switzerland: IPCC) www.ipcc-nggip.iges.or.jp/public/wetlands/
8. Humpenöder F., Karstens K., Lotze-Campen H., Leifeld J., Menichetti L., Barthelmes A., Popp A. 2020. Peatland protection and restoration are key for climate change mitigation. Environmental Research Letter, 15, 104093. https://doi.org/10.1088/1748–9326/abae2a
9. Eggleston H.S., Buendia L., Miwa K., et al. 2006. In: IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan.
10. Jaya I.N.S., Boer R., Samsuri, Fathurakhman. 2008. Development of Wildfire Vulnerability Index in Central Kalimantan. Research Report. CARE Indonesia, Bogor.
11. Jaenicke J., Rieley J.O., Mott C. 2008. Determination of The Amount of Carbon Stored in Indonesian Peatlands. Geoderma, 147, 151–158.
12. Langner A., Miettinen J., Siegert F. 2007. Land Cover Change 2002–2005 in Borneo and the Role of Fire Derived from MODIS Imagery. Glob Chang Biol, 13, 2329–2340.
13. Leifeld J., Menichetti L. 2018. The Underappreciated Potential of Peatlands in Global Climate Change Mitigation Strategies. Nature Communications, 9, 1071.
14. Leifeld J., Wüst-Galley C., Page S. 2019. Intact and Managed Peatland Soils as a Source and Sink Of GHGs From 1850 to 2100. Nature Climate Change, 9, 945–947.
15. Loisel J., Yu Z., Beilman D.W., et al. 2014. A Database and Synthesis of Northern Peatland Soil Properties and Holocene Carbon and Nitrogen Accumulation. The Holocene, 24(9), 1028–1042. https://doi.org/10.1177/0959683614538073
16. Margono B.A., Potapov P.V., Turubanova S., et al. 2014. Primary Forest Cover Loss in Indonesia Over 2000–2012. Nat Clim Chang, 4, 730–735.
17. Miettinen J., Liew S.C. 2010. Degradation and Development of Peatlands in Peninsular Malaysia and in The Islands of Sumatra and Borneo Since 1990. Land Degrad Dev, 21, 285–296.
18. Miettinen J., Shi C., Liew S.C. 2011. Influence of Peatland and Land Cover Distribution on Fire Regimes in Insular Southeast Asia. Reg Environ Chang, 11, 191–201.
19. Ministry of Environment and Forestry. 2015. Intended Nationally Determined Contribution Republic of Indonesia. Jakarta.
20. Murdiyarso D., Hergoualc'h K., Verchot L.V. 2010.

Opportunities for Reducing Greenhouse Gas Emissions in Tropical Peatlands. Proc Natl Acad Sci, 107, 19655–19660.

21. Nowak K. 2013. Mangrove and peat swamp forests: refuge habitats for primates and felids. Folia Primatol, 83, 361–376.
22. Page S., Hoscilo A., Wösten H., et al. 2009. Restoration Ecology of Lowland Tropical Peatlands in Southeast Asia: Current Knowledge and Future Research Directions. Ecosystems, 12, 888–905.
23. Posa M.R.C., Lahiru S., Wijedasa L.S., Corlett R.T. 2011. Biodiversity and Conservation of Tropical Peat Swamp Forests. BioScience, 61(1), 49–57.
24. Setiawan G., Syaufina L., dan Puspaningsih N. 2016. Estimation of Carbon Stock Loss from Land Use Changes in Bogor Regency. Jurnal Silvikultur Tropika, 7(2), 79–85.
25. Syahza A., Suwondo, Bakce D., Nasrul B., Mustofa R. 2020. Utilization of Peatlands Based on Local Wisdom and Community Welfare in Riau Province, Indonesia. International Journal of Sustainable Development and Planning, 15(7), 119–1126. https://doi.org/10.18280/ijsdp.150716
26. Thoha A.S., Saharjo B.H., Rizaldi Boer R., Muhammad Ardiansyah M. 2019. Characteristics and Causes of Forest and Land Fires in Kapuas District, Central Kalimantan Province, Indonesia. Biodiversitas, 20(1), 110–117. https://doi.org/10.13057/biodiv/d200113
27. Veber G., Kull A., Villa J.A., Maddison M., Paal J., Oja T., Iturraspe R., Pärn J., Teemusk A., Mander Ü. 2017. Greenhouse gas emissions in natural and managed peatlands of America: case studies along a latitudinal gradient. Ecol. Eng. https://doi.org/10.1016/j.ecoleng.2017.06.068.
28. Warren M.W., Kauffman J.B., Murdiyarso D., et al. 2012. A Cost-Efficient Method to Assess Carbon Stocks in Tropical Peat Soil. Biogeosciences, 9, 4477–4485.
29. Wijaya A., Chrysolite H., Mengpin G., Wibowo C., Almo Pradana A., Utami A., Austin K. 2017. How Can Indonesia Achieve Its Climate Change Mitigation Goal? An Analysis Of Potential Emissions Reductions From Energy And Land-Use Policies. World Resources Institute. Working Paper.
30. Wilson D., Blain D., Couwenberg J. 2016. Greenhouse Gas Emission Factors Associated With Rewetting of Organic Soils. Mires Peat, 17, 4–28.
31. Yu Z. 2011. Holocene carbon flux histories of the world's peatlands: Global carbon-cycle implications. The Holocene, 21(5), 761–774. https://doi.org/10.1177/0959683610386982