INVESTIGATING DYNAMICS GREENHOUSE GAS FROM GOSAT IN TROPICAL PEATLAND, CENTRAL KALIMANTAN (A COMPARISION OF EMPIRICAL ESTIMATION AND GOSAT SATELLITE)

A Darmawan, A Sulaiman, N Setyaningrum, H Prayogi
Center of Technology for Regional Resources Development,
the Agency for the Assessment and Application of Technology (BPPT)
Jl. MH. Thamrin No 8 Jakarta 10340, Indonesia

E-mail: arief.darmawan@bppt.go.id

Abstract. Spatial dynamics of Greenhouse gases, CO_2 will be investigated by comparing the carbon flux estimation using empirical models with satellite GOSAT data. This study was based on the research result which is showed a correlation between the lowest monthly average of GWL and Net Ecosystem Exchange (NEE) on peatlands in Central Kalimantan. The NEE value is representing the CO_2 emitted from the decomposition process of Peatland due to decreasing of groundwater level which caused by land-use change and land fires. The empirical estimation of carbon emission calculation is based on empirical relationship between soil water moisture, groundwater level and net ecosystem exchange (NEE) that measured by eddy covariance. The comparison this result with GOSAT data show that the empirical relationship between GWL with NEE for each type of peat (UF NEE DF and NEE DB) showed a very strong correlation with a correlation coefficient value of 0.984). This is understandable because the value of GWL for each grid of 0.5 deg estimated from empirical calculation of the value of soil moisture and three data GWL representing all three types of peat with Krigging interpolation. On the other hand, the correlation between CO_2 data GOSAT with NEE values did not show any correlation even the correlation coefficient between NEE and CO_2 GOSAT data is worth the negative (which is supposed to be positive) correlation value of -0.68.

Keywords: GOSAT, global warming, peatland, Ground Water Level, Net Ecosystem Exchange, Eddy Covariance

1. Introduction

Indonesia made commitment to reduce greenhouse gases (GHG) emission by 26% (0.767 GTon CO_2e) in 2020 from the business as usual (BAU) level with its own efforts and reach 41% reduction (additional 0.477 GTon CO_2e) if it secures international support. To implement this commitment, the Government of Indonesia formulate a National Action Plan for GHG Emission Reduction (RAN-GRK) to provide a policy framework for the central government, local governments, private sectors, and other key stakeholders in implementing actions related to GHG reduction effort during the period of 2010-2020. The RAN-GRK proposes mitigation actions in five priority sectors (agriculture, forestry and peatland, energy and transportation, industry, waste management) as well as other supporting actions that are integral parts to the national development planning which support the principle of economic growth, poverty alleviation and sustainable development. The initiative action is needed to achieve emission cut based on the platform RAN-GRK, in particular for sectors agriculture, forest and peatland even if other sectors hold important contribution too. Based on this fact the initiative action is developed to execute the project plan of "reduction of GHG emissions from sectors in Indonesia" that covers various sites and sources.

Observation and monitoring of carbon stock estimations for tropical countries are still considered limited. In Indonesia with frequent episodes of forest fire and deforestation, it is important to estimate carbon storage capabilities of tropical vegetation. The researchin this area involve field, modeling, remote sensing methods and laboratory measurements in selected locations to represent the diverse regions in Indonesia. The aim is to understand the impact of global warming for natural resources inventory especially forest and peatland. The information will be useful as an incentive for rehabilitation and conservation programs, which correspond with REDD+ objective. Information on carbon sink capability of tropical region is important to support efforts of climate change mitigation.

Indonesian maritime continent is one of the most convectively active areas in the tropic. This area have strong latent heating accompanies cumulus convection and heavy rainfall and strongly modulated by the Madden Julian Oscillation (MJ), the El-Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). Indonesian Maritime Continent is the region where trace gas distributions in the troposphere is strongly influenced by deep convection, frequent lightning and biomass burning (Ishida et al 2011, Kodama et al 2006). Due to the winds are moderate and generally predictable, with usually blowing in from the south and east in June through September and from the northwest in December through March and temperature or air pressure is less varies then the strong variability associated with trace gas is rainfall. This condition, with variation of topography, make Indonesia spatially complex and interest to be analysed.

One of the factors that influence the decomposition rate of peat is groundwater level. When groundwater level decreases, the surface layer of peat will be exposed to the air which provides opportunities for peat decomposition. This will then increase the carbon emissions level into the air (Sundari et al 2012). The research results conducted by Hirano et al. (2012)showed a correlation between the lowest monthly average GWL and Net Ecosystem Exchange (NEE) on peatlands in Central Kalimantan. NEE value in a peatlands can be considered as a CO_2value emitted from the decomposition process. Therefore, the observed GWL data or estimated GWL data from satellite can be used to estimate the CO_2 emissions frompeatlands. Thus the carbon emission of tropical peatland can be estimated by using groundwater level data. The aim of the study is to observe dynamics spatial variation of carbon emission of peatland forest in Central Kalimantan using GOSAT data and comparing it with empirical carbon emission estimation. The empirical estimation is carbon emission calculation based on empirical relationship between soil water moisture, groundwater level and net ecosystem exchange (NEE) measured by eddy covariance. CO_2 movement or CO_2 flux between the soil and the atmosphere is the primary function of soil respiration. Soil respiration returns substantial amounts of carbon to the atmosphere and is a majorcomponent of CO_2 emissions or NEE.

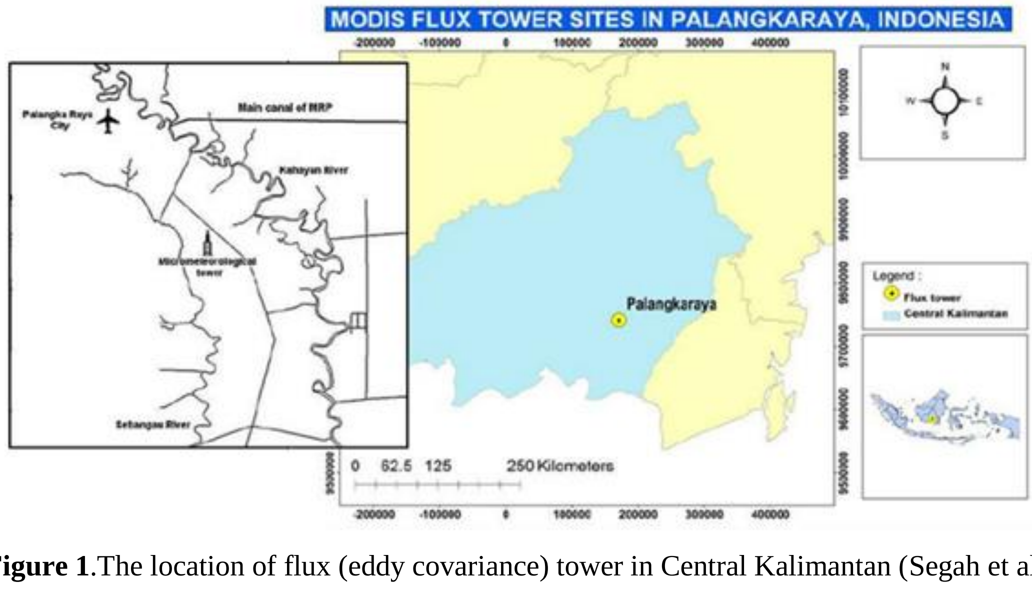

Figure 1.The location of flux (eddy covariance) tower in Central Kalimantan (Segah et al. 2010)

The paper is organized as follow;the data and methodology will be presented in detail in Sec-2, the result of the research and its discussion will be described in Sec-3 and it will be ended by a summary.

2. Data and Metodology

2.1 GOSAT Data

The L3 global CO_2 distribution (SWIR) product provides information on the monthly average of the CO_2 column abundances of every 2.5-degree lattice across the globe, with is retrieved by interpolating with the monthly total of L2 CO_2 column abundances (SWIR). In order to obtain more detail data over Indonesian area, the grid map of GOSAT data over Indonesia (0.5 deg. x 0.5 deg) was developed. The footprint is depicted in Fig.2.

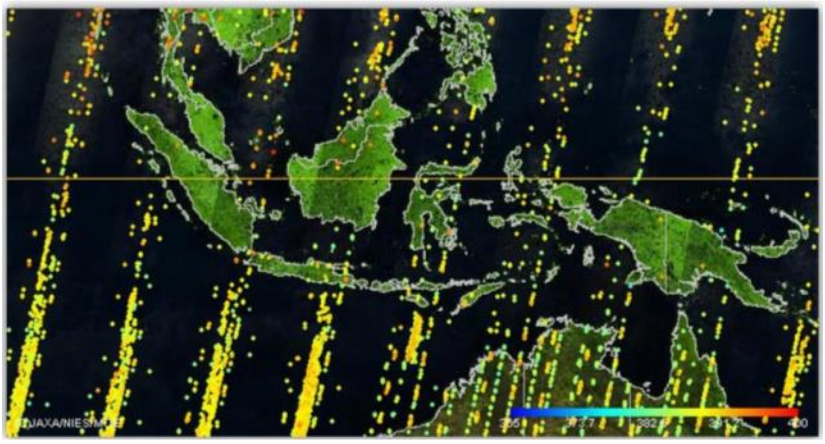

Figure 2.The GOSAT footprint over Indonesia region.

The L3 data sets somehow on specific grids and time have empty data (value of -999). Data downloaded were the data level-3 (L3) which was further processed into data level-4 (L4). The L4 data was built from GOSAT L3 dataset that has been through the process of nested for increasing spatial resolution to 0.5 degrees then the data was interpolated and extrapolated using Krigging method. The process was carried out with:

1. Convert the mixing ratio data of CO_2 manually. Mask information of XCO_2Mask which contain information about the availability of data from each point of the data. Number 1 indicates no data while the number 0 indicates the data was available then save geo-location information (latitude and longitude) as text (.txt) file.
2. Compile information from the first process into a single layer,
3. Remove no data which has a value of -999
4. Increasing the spatial resolution of 2.5 degree to 0.5 degree with Krigging method.
5. Change the data format which generated from the previous process into a format that can be interpreted in software's used.

2.2 Empirical Calculation Carbon Emission

To complement the GOSAT data which are notobserved in central Kalimantan then we will use the empirical model to estimate carbon emissions.This model based on the soil moisture data obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) and empirical models is calculated based on groundwater level data and flux tower (Hamada et al 2015). First is determine peatland and land cover of the area of interest. This can be done by collecting data from peatland map and various remote sensing data. Then the grid 0.5 deg. x 0.5 deg. are made for covering the Central Kalimantan area.

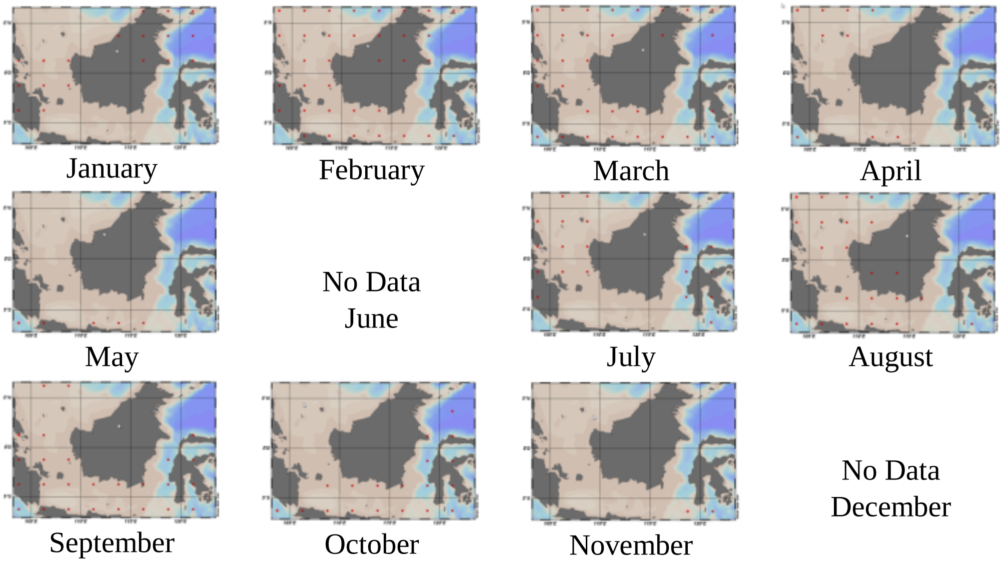

Figure 3. The availability GOSAT data (shown with red dots) in 2014

The peatland maps are obtained from Indonesia ministry of agriculture and weatland International. In this study, the peatlandarea are categorized into three different type: 1) Undrained Forest/UF; 2) Drained Forest/DF; and 3) Drained Burn Forest/DB). The next step is find the surface soil moisture data of this area from the ECMWF daily time series. The soil moisture data are collected for three type of peatland catagory for daily times series for 2014. For each station we should measure the groundwater level data. The coordinate of groundwater measurement of three type of peatland catagory are -2.323614694, 113.9043575 for UF, -2.346070697, 114.036408 for DF and -2.340796006, 114.0378994 for DB. We calculate empirical linear regresion between soilwater moisture and groundwater level. The repeatation procedure for all peatland type should be done for 32 grids. We have 32 groundwater level data for all grids and for all peatland type. Calculate monthly average groundwater at each grids and find the lowest groundwater value. Finally the Net Ecosystem Exchange were obtained by using Hirano's model as follow (Hirano 2012),

$$\psi_{df} = -665.00x - 68.74 \tag{1}$$

where $\psi_{df}$is the NEE for Undrained Forest (UF) and Drained Forest (DF) and$x$ is the lowest monthly groundwater level data (meter). For the Burn Forest (DB) the NEE is given by,

$$\psi_{df} = -420.56x + 397.46 \tag{2}$$

where ψ_{df} is the NEE for DB. The total of NEE yields,

$$Total \quad NEE = \sum_{n} A_n \times \left[\alpha_n \Gamma_n + \beta_n \Pi_n + \gamma_n \mathrm{B}_n\right] \tag{3}$$

where A_n is total area of peatland for each grid, α_n is ratio of UF forest area, Γ_n is the NEE of UF, $\beta_n$is the ratio of DF area, Π_n is the NEE of DF, $\gamma_n$is the ratio of DB area and B_n is the NEE of DB.

3. Result and Discussion

The study area is depicted in Figure 4. Tropical peatlands in Central Kalimantan Province is distributed mainly along the southern coastal area of Kalimantan Island. The width of the peatland zone reaches nearly 200 km from the coast at maximum, wider in the eastern area relative to the western area. The total area of peatland in Central Kalimantan is 2,664,438 ha, about 17.4% of the total area of the Province. The low to medium frequency (0.00-0.50) are catagorized by UF, medium high to high frequency (0.50-1.00) are catagorized by DF and canopy loss and unclassified are catagorized by DB.

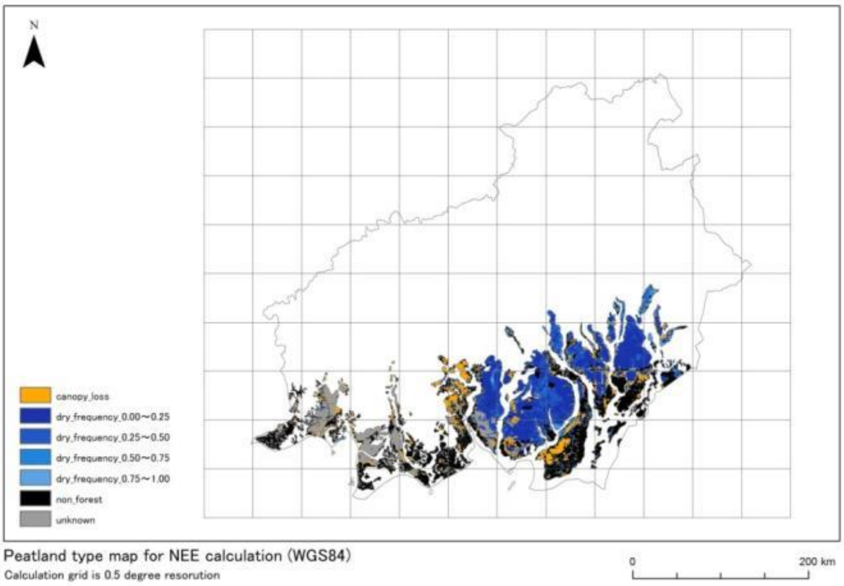

Figure 4. The 0.5 x 0.5 degree grids are used to cover the Central Kalimantan area. Seventy-four cells actually cover the area of the Province, and only 32 grids contain the area of tropical peatlands. The legend show a distribution of forest type and dry frequency of peat swamp forest in the tropical peatland of Central Kalimantan in 2014 .

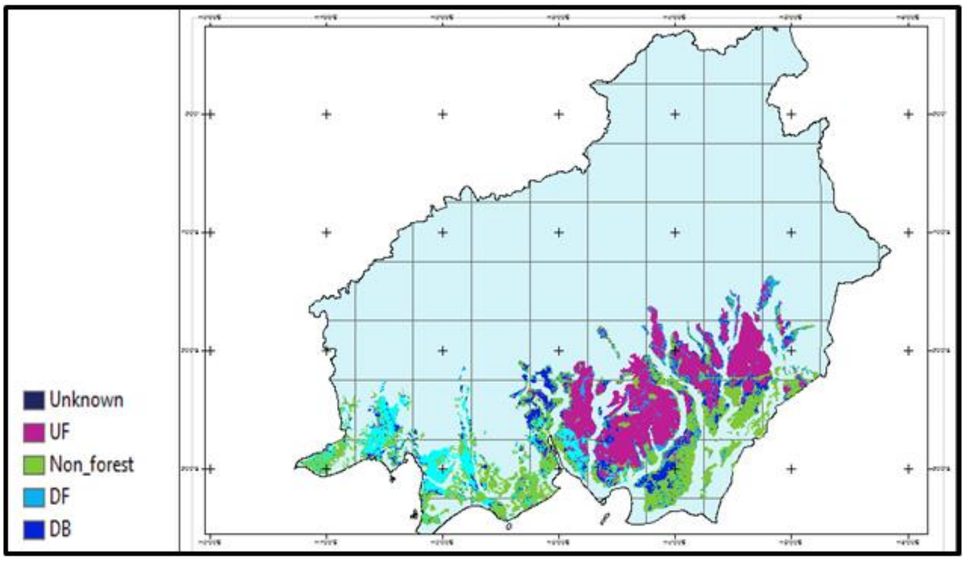

Figure 5. The map in three type of peatland catagorize in 2014.

The peatland type in Central Kalimantan is dominated by UF, DF and then DB. The non forest area is also large and dominated close to the coastaline. In this study, the non-forest area was excluded from the calculation, and the result suggests that the total area of peat swamp forest was 15,826 km^2. Nearly two-thirds of that area was classified as UF (64%). The remaining area was categorized as DB (19%) and DF (17%).

The soilwater moisture daily time series in 2014 were collected from ECMWF for each grids. The groundwater level data for one site which are represent three type of peatland catagories compare with soil moisture data. The linear regresion of soil moisture and groundwater level is depicted in Fig 6.

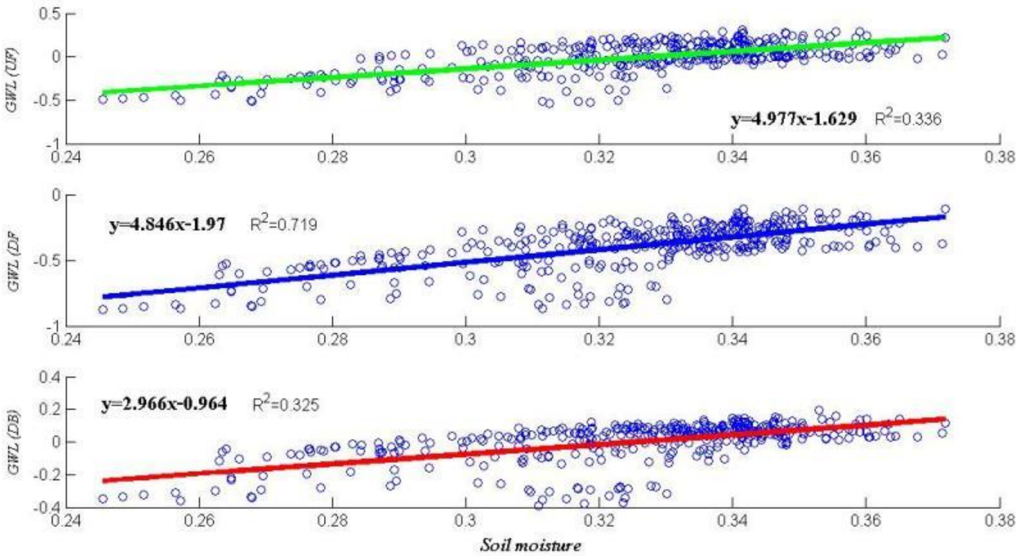

Figure 6. The linear regresion between soil moisture and groundwater level for three type of peatland

By using the empirical formulation, the groundwater level for each grid was obtained. The groundwater level estimation based on the empirical formulation is depicted in Fig-6. The groundwater level is decrease in the region with the density of peatland is high. The lowest groundwater level dominant in the UF region and in grid number 70. In this grids is dominant by DB catagory where the ex-MegaRice Project (MRP) take place. The most of peatland in the ex-MRP area was classified as non-forest and canopy loss, since these areas were mainly developed and deforested during the ex-MRP (1997-98) and devastated after the following big peat fire. Areas with less dry frequencies were generally distributed in the upstream area of the big canal extended eastward from Beren Bengkel, Sebangau National Park, and the basin of KatinganRiver.

The NEE is depicted in Fig-8. In the figure, NEE value was being normalized with the greatest value that previously had units of grams of carbon per year. Regions with large emission values situated on the grid where the peatland is dominant either type of UF, DF or DB. These conditions are also correlated with the area where the groundwater level is low, except in the ex-MRP. For ex-MRP grid where there is little peatland, percentage of non-peatland is not taken into account in the calculation of NEE. By constructing the grid becomes less likely to make the relationship between groundwater level and NEE be more consistent spatially.

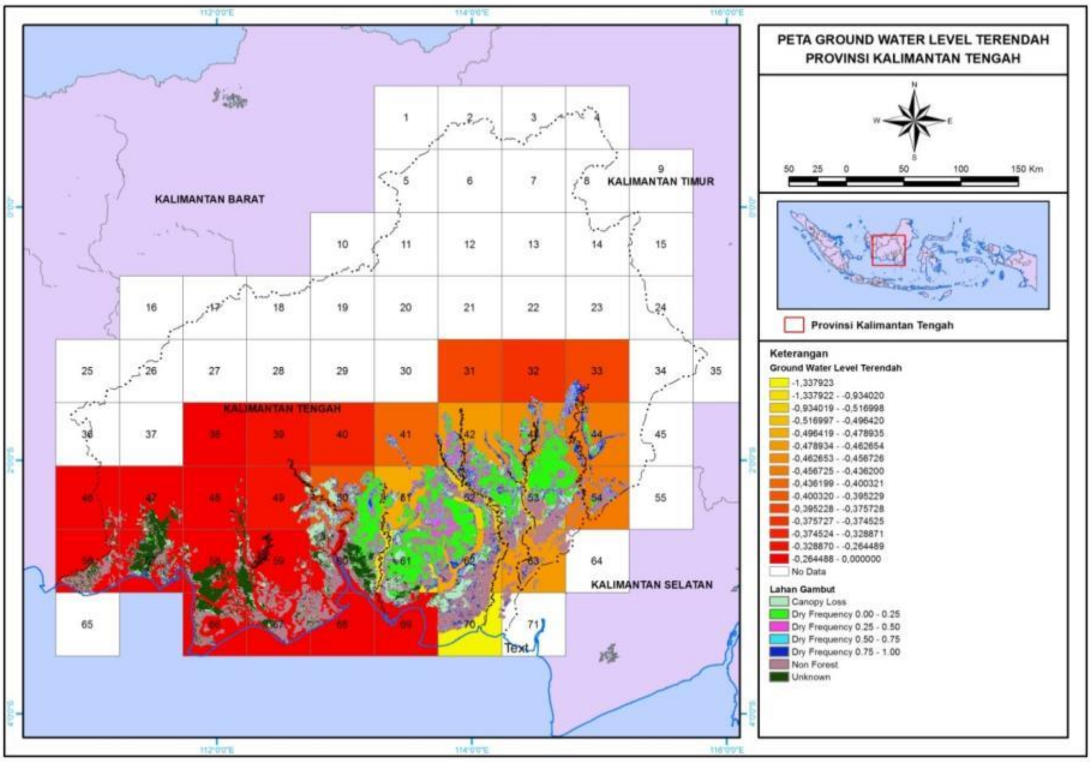

Figure 7. The groundwater level (meter) estimation for three type of peatlands.

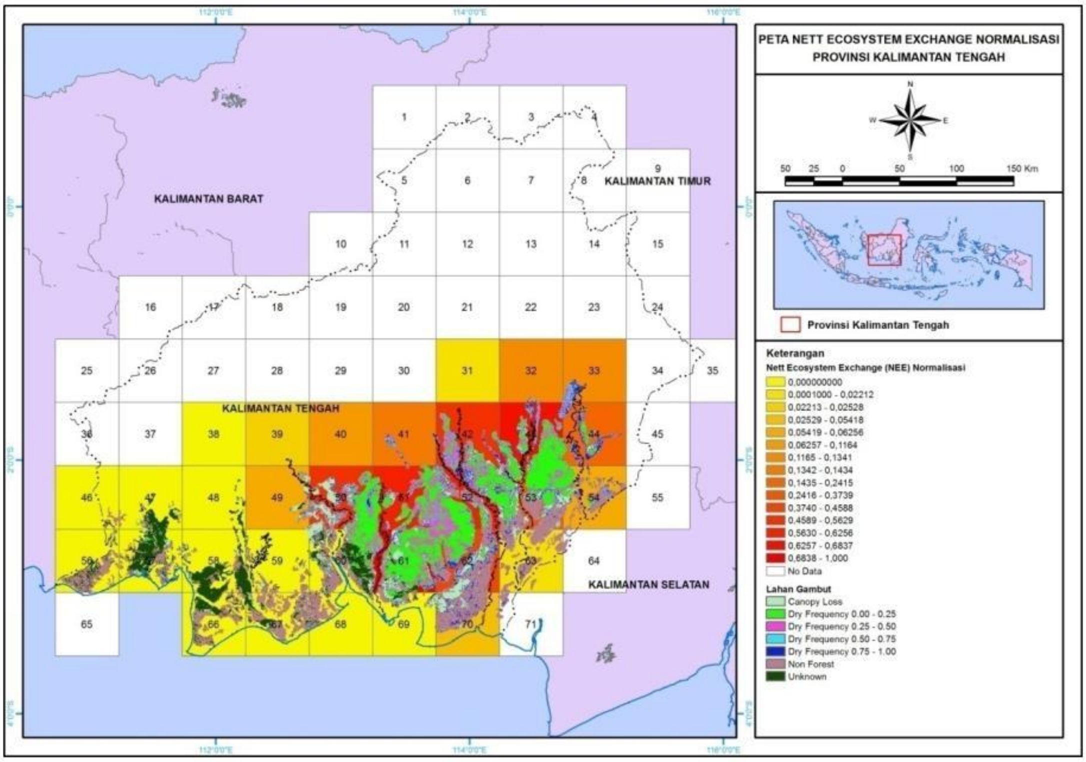

Figure 8. The Net Ecosystem Exchange estimationsfor three type of peatland and its value has been normalized.

The carbon flux is highly correlated with the Hot spot. Hotspot is an indicator of fire that detects a location that has a relatively high temperature than the surrounding temperature.The term of hotspot and fire can be identified from statistically calculation of confidence level.Confidence levels vary from 5% to 100%. Although fire is not necessarily identified with high confidence level (> 80%), generally it is very a few detected that small confidence level value (<80%) as a fire.

Table 1. Fire-pixel confidence classes associated with the computed confidence level (C) for each fire pixel

Range	Confidence Class
0% ≤ C < 30%	Low
30% ≤ C < 80%	Nominal
80% ≤ C < 100%	High

Source: http://www.fao.org/fileadmin/templates/gfims/docs/MODIS_Fire_Users_Guide_2.4.pdf

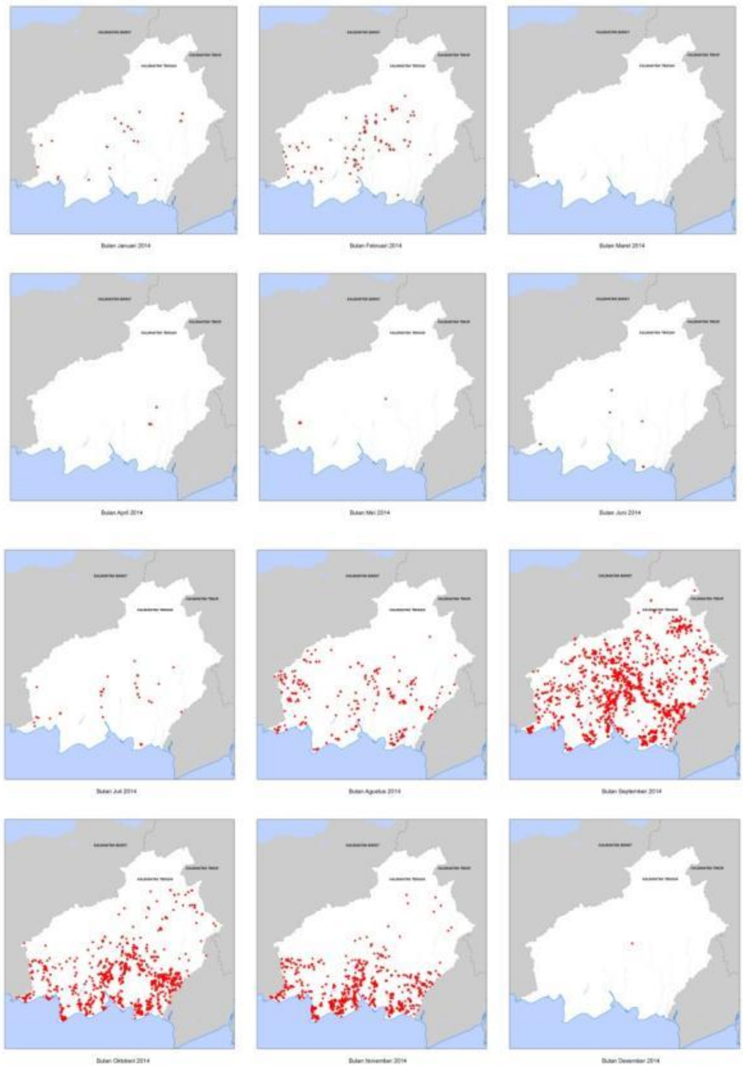

Figure 9. Hotspot MODIS Terra/ Aqua MCD14DL monthly occurrence in 2014 (https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data)

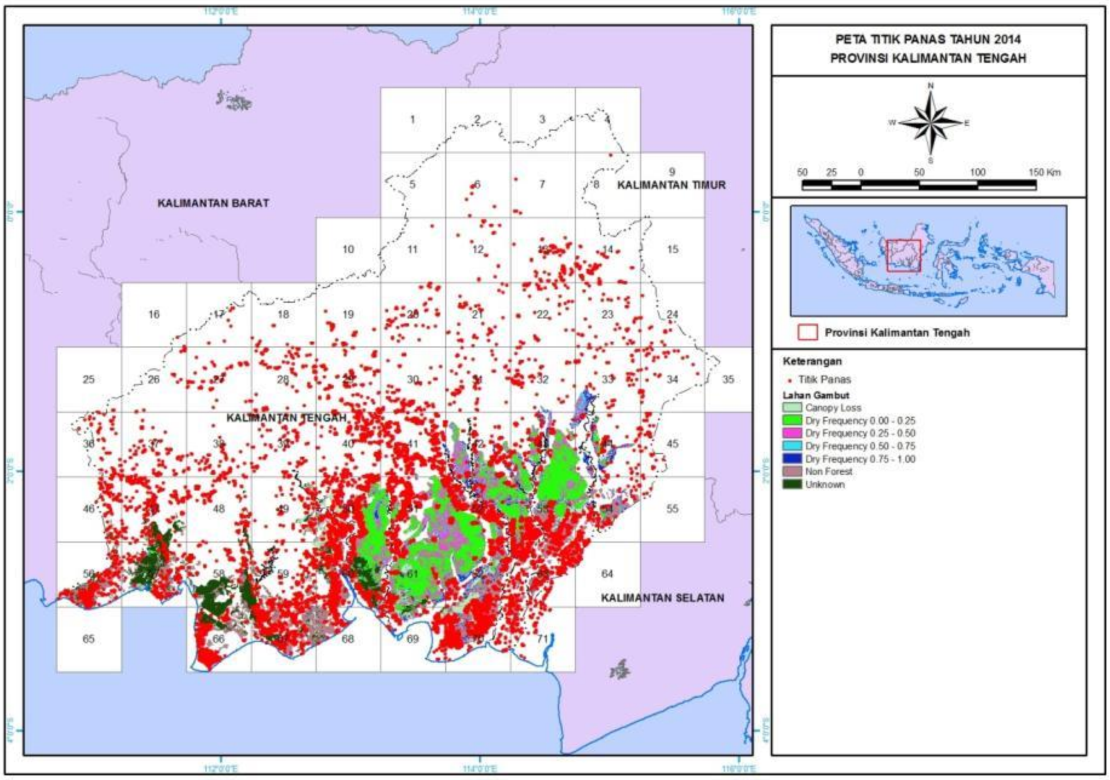

Figure 10. Composited Hotspot MODIS Terra/ Aqua MCD14DL occurrence in 2014 (https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data)

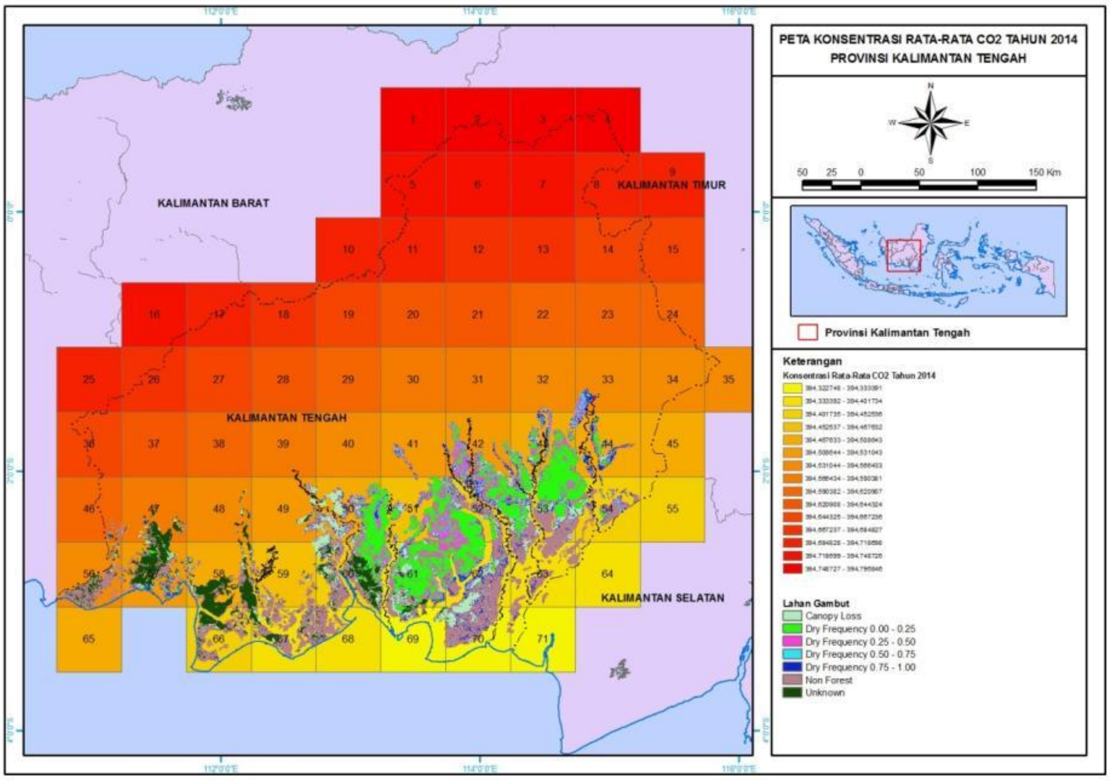

Figure 11. Averaged CO_2 mixing ratio in 2014 for three types of peatland from GOSAT data

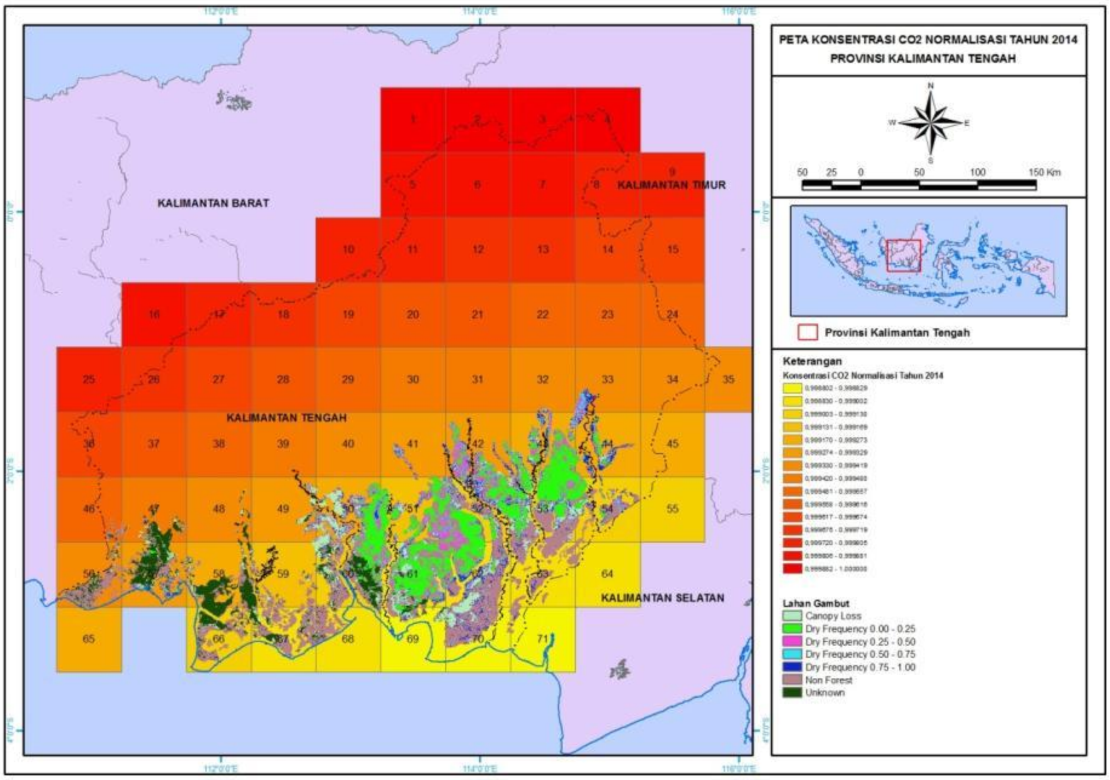

Figure 12. Normalized CO_2 mixing ratio in 2014 for three types of peatland from GOSAT data

From the calculation shows that the empirical relationship between GWL with NEE for each type of peat (UF NEE DF and NEE DB) showed a very strong correlation with a correlation coefficient value of 0.984). This is understandable because the value of GWL for each grid of 0.5 deg estimated from empirical calculation of the value of soil moisture and three data GWL representing all three types of peat with Krigging interpolation. On the other hand, the correlation between CO_2 data GOSAT with NEE values did not show any correlation even the correlation coefficient between NEE and CO_2 GOSAT data is worth the negative (which is supposed to be positive) correlation value of -0.68. The GOSAT CO_2 data in 2014 in the study area is very spread unevenly (see Fig. 3). GOSAT data availability in 2014 for the study area only in August although only 2 spots data and the remaining distribution of the data was outside Kalimantan Island. Thus, the value of CO_2 for each grid of the results Krigging was not representing actual concentration of CO_2.

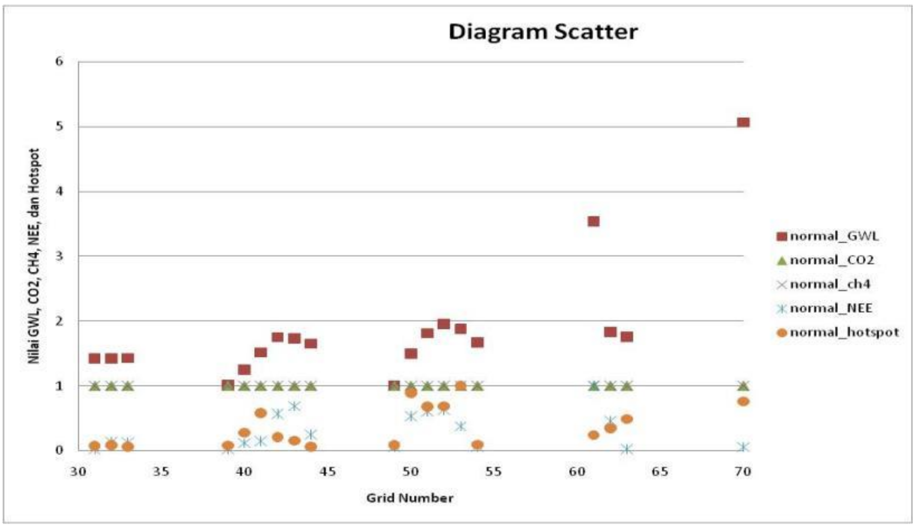

Figure 13. Scattered diagram

Table 2. Correlation Coefficient (r)

	normal of Lowest_GWL	normal of ave_mixCO	normal of NEE	normal of NEE_UF	normal of NEE_DF	normal of NEE_DB	Count hotsp ot
normal of Lowest_GWL	1						
normal of ave_mixCO	-0.756	1					
normal of NEE	0.244	-0.275	1				
normal of NEE_UF	0.992	-0.684	0.198	1			
normal of NEE_DF	0.992	-0.684	0.198	1	1		
normal of NEE_DB	0.992	-0.684	0.198	1	1	1	
count_hotspot	0.355	-0.515	0.256	0.287	0.287	0.287	1

This study can be concluded that the data GOSAT is a representation of global condition of CO_2 and CH_4 so if applied to the local conditions (i.e. province region) the result would bias coupled with inanition or very limited data on the region of study. The main factor is due to errors data as a effect of the presence of atmospheric disturbances i.e. high convective cloud coverage especially in the tropical region.

4. Conclusion

Comparison of the GOSAT data of Carbon flux with empirical estimation is investigated. The relation with the hot spot os also investigate. From the study, it was uphill work to estimate the condition of greenhouse gases such as CO_2 and CH_4 from GOSAT data in the local area (after applying Krigging's method with grid 0.5 deg). It is coupled with data inanition or data is very limited. We conclude that there is a low correlation between empirical estimation the hot spot and GOSAT data. This bias may caused by the limited GOSAT data in the equatorial region especially in Kalimantan.

Acknowledgement

We acknowledge the support by GOSAT RA (Research Announcement) initiative. This research is part of international collaborative initiatives under coordination the Ministry of Environment (MOE) Japan and the Japan Aerospace and Exploration (JAXA). Here we also would like to thanks to IJ-REDD+ for supporting and making a guidance of carbon estimation using empirical model.

References

H. Ishida, T.Y. Nakjima, T. Yokota, N. Kikuchi, and H. Watanabe 2011 Investigation of GOSAT TANSO-CAI Cloud Screening Ability through an Intersatellite Compariso*J. Applied Meteorology and Climatology***50** 1571

Y.M. Kodama, M. Tokuda, and F. Murata 2006 Convective Activity Over the Indonesian Maritime Continent During CPEA-I as Evaluated by Lightning Activity and Q1 and Q2 Profiles *J. Meteo. Soc. Japan***84A**, 133-149.

D. L. Ermak 1977 An analytical model for air pollutant transport and deposition from a point source*Atmos. Environ*.**11**(3): 231–237.

A. Sulaiman and M. Sadly 2014Integration of Smoke Dispersion Modeling with Earth's Surface Images*International Conference on Advanced Computer Science and Information Systems. Proc. IEEE Indonesia section*

Sundari,S., T. Hirano., H. Hamada., K. Kusin., and S. Limin 2012 Effect of groundwater level on soil respiration in tropical peat swamp forest J. *Agric. Meteorl*. **68** (2) 121-134.

Hirano,T, T Krug, K. Tanabe, N. Srivastara, B. Jamsranjav, M. Fukuda and T. Troxler 2013 Methodology Guidance on Lands with Wet and Drained Soils and Constructed Wetlands for Wastewater Treatment*Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: Wetlands

Hamada, Y., N. Tsuji., Y. Kojima., M.A. Qirom., A. Sulaiman., Firmanto., Y. Jagau., D. Irawan., R. Naito., and E.N.N. Sari 2015*Guidebook for Estimating Carbon Emissions from Tropical Peatlands in Indonesia*, IJ-REDD+ Project, Jakarta.

Osaki., M and N, Tsuji 2015 *Tropical Peatland Ecosystem*(Springer Verlag, Berlin)