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RESEARCH OF INDONESIAN GHG EMISSION ASSESSMENT FROM FOREST AND LAND FIRES

(*Penelitian Penilaian Emisi GRK di Indonesia dari Kebakaran Hutan dan Lahan*)

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ABSTRACT

Previous research has confirmed that efforts to control forest and land fires in Indonesia are not optimal so that fires still occur at a high escalation rate. This happens because very few research results are used to solve the problem of forest and land fires, so that useful information becomes useless. Research activities continue, which do not cover only technical issues of controlling forest and land fires but also the negative implications as a result, namely the production of GHG emissions, especially on peat land because it is one of the main sources of significant GHG emissions. What is also not important is the procedure for calculating GHG emissions, which based on this research actually results in overestimation of emissions from what should be produced. Of course, this needs to be straightened out so that Indonesia is not harmed just because it follows an inappropriate calculation.

Keywords: Greenhouse gases, forest and land fires, research, peat, fire control

ABSTRAK

Penelitian sebelumnya telah mengkonfirmasi bahwa upaya pengendalian kebakaran hutan dan lahan di Indonesia belum optimal sehingga kebakaran masih terjadi dengan tingkat eskalasi yang tinggi. Hal ini terjadi karena sangat sedikitnya hasil penelitian yang digunakan untuk memecahkan masalah kebakaran hutan dan lahan, sehingga informasi yang bermanfaat menjadi tidak berguna. Kegiatan penelitian terus berlanjut, yang tidak hanya mencakup masalah teknis pengendalian kebakaran hutan dan lahan tetapi juga implikasi negatif yang ditimbulkannya, yaitu produksi emisi GRK khususnya di lahan gambut karena merupakan salah satu sumber utama emisi GRK yang signifikan. Yang juga tidak kalah pentingnya adalah prosedur penghitungan emisi GRK, yang berdasarkan penelitian ini justru menghasilkan estimasi emisi yang terlalu tinggi dari yang seharusnya dihasilkan. Tentu hal ini perlu diluruskan agar Indonesia tidak dirugikan hanya karena mengikuti perhitungan yang tidak tepat.

Kata kunci: Gas rumah kaca, kebakaran hutan dan lahan, penelitian, gambut, pengendalian kebakaran

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INTRODUCTION

Fires in humid tropical forests, both natural and anthropogenic in origin, have been a source of disturbance over millennia (e.g., Goldammer, 1990), but large, intense fires have been relatively infrequent prior to anthropogenic land use change. Fires in Indonesia have consequences from the local to global scale, including burning forest that is home to endemic and endangered flora and fauna, emitting haze that compromises human health and impacts economies across the region, and converting peatlands from a major carbon sink to a major source of CO_2 (Cattaua *et al*., 2016). Identifying the sources of fire ignitions and LULC classes associated with fire ignitions is a key factor for reducing fire on this landscape, as this will allow us to more pointedly target management and policy interventions (Cattaua *et al*., 2016).

The problem of forest fires cannot be observed merely from a single viewpoint. It must be seen expansively in various contexts. Forest land areas, which are supposedly designated as green zones by the state, are being misused by local actors (Purnomo *et al*, 2021). Thus, a key component to understand changing fire regimes in the tropics is to identify the sources of fire ignitions and the land use/land cover (LULC) classes associated with fire ignitions (Cattaua *et al*., 2016).

Fire prevention is the most important activity in fire control and is a work that must be done continuously. Often fire prevention is a more economical way to reduce fire damage and losses, without having to use expensive equipment. Forest fire prevention strategies consist of: fuel reduction, which reduces the ease with which fuel can ignite (fuel flammability), Reduction of risk sources of fire (risk reduction), which reduces the possibility of sources of fire that can create opportunities for fires to occur. In other words, a fire prevention strategy is to reduce the chance of a fire occurring by separating the source of the fire (risk) from the fuel (fuels). Fire prevention will always deal with the sources of fire and fuel that are always changing from time to time, and the opportunities for association.

As a country that is vulnerable to the adverse impact of climate change and contributes to global greenhouse gas emission, Indonesia is highly committed to reduce GHG emission. In the First Nationally Determined Contribution (NDC), Indonesia has unconditional target of 29% and conditional target up to 41% compared to business as usual in 2030 (MoEF, 2021). Through Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR) 2050, Indonesia will increase ambition on GHGa reduction by achieving the peaking of national GHG emissions in 2030 with net- sink of forest and land-use sector, reaching 540 M ton CO2 e by 2050, and with further exploring opportunity to rapidly progress towards net-zero emission in 2060 or sooner.

GREENHOUSE GAS EMISSION FROM FOREST AND LAND FIRES

The Copernicus Atmosphere Monitoring Service (CAMS) reported that increasing of GHG emissions from Indonesia in 2019 was mainly due to carbon-rich peatlands burning. About 1.65 million ha were burnt and a half million ha of peat were burned in devastating fire events in 2019, yet GHG (greenhouse gas) emissions released was almost nearly compared to the 2015 fires where 2.6 million ha areas were burnt. Thousands of acres of ecologically significant land were burned, resulting in toxic haze which threatening human health as well as disrupting natural forests and wildlife habitat (Saharjo and Novita, 2021).

Mark Parrington, ECMWF Senior Scientist at the Copernicus Atmosphere Monitoring Service (CAMS), comments: "*We closely monitor the intensity of fires and the smoke they emit. Approximately half of the local fire season having passed, it is clear that these*

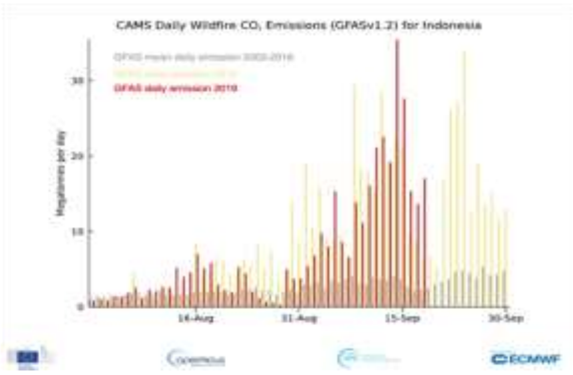

Figure 1 Daily total estimated CO_2 equivalent emissions, comparing 2019 (in red) with 2015 (in yellow) and the 2003-2018 mean (in grey), showing the comparability of recent emissions to the same days in 2015. Credit: CAMS/ECMWF

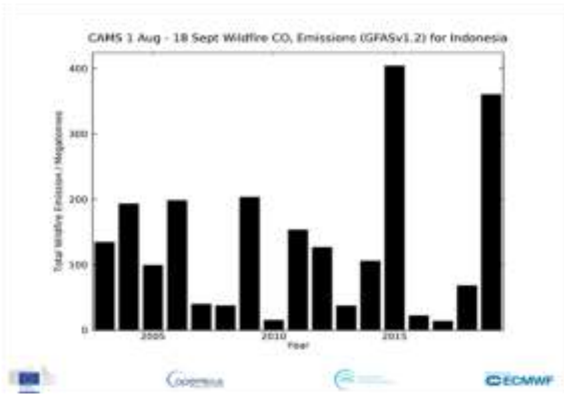

Figure 2 Total estimated CO_2 equivalent emissions calculated for Indonesia between 1 August and 18 September for all years between 2003 and 2019. Credit: CAMS/ECMWF

fires are unusual and are causing significant concern. In Indonesia, burning peat, which can smolder at low temperatures and underground, is the most significant concern as it is releasing carbon which has been stored for tens or thousands of years. Some of this carbon will be taken up again by the biosphere, but this is difficult to estimate in near-real-time. The very high and persistent levels of pollution in Indonesia and the Maritime continent that CAMS forecasts and monitors are undoubtedly a threat to human health, flora and fauna."

GHG EMISSION REDUCTIONS

Peatlands consists of decomposed organic matter, and peat degradation will produce significant amount of GHG emissions, especially when the areas are burnt. The lowering ground water level (GWL) on peatlands will increase the sensitivity to the fires because of the drier condition of peat surface. The restoration efforts implemented in degraded peat ecosystem (i.e.: rewetting and revegetation) seem like the best solution, if and if the fire prevention management activities are really well implemented. Fire suppression has high potential to reduce GHG emissions resulted from peat fires into the atmosphere. The success of peatland fire suppression will depend on the skill of fire brigades, strategy, and the availability of equipment, direct and indirectly in the ground. Lack of knowledge and experience to combat peat fires will spread more fires and potentially out of control fire break outs. Finally, this condition will produce significant amount of GHG emissions as dry peat burnt is difficult to control (Saharjo and Novita, 2021).

Efforts to significantly reduce the emission of this sector and turn it into net sink by 2050 under CPOS (Current Policy Scenario), and by 2030 under LCCP (Low Carbon Scenario Compatible with Paris Agreement target) depends primarily on the success of the following actions (MoEF, 2021): (i) reducing emission from deforestation and peatland (peat decomposition and peat fire); (ii) increasing the capacity of natural forest in sequestering carbon (by reducing degradation and enhancing the regeneration); (iii) restoring peatland, (iv) implementing forest restoration (enrichment planting/sink enhancement), (v) adopting sustainable forest management practices; and (vi) maximizing the use of unproductive lands (idle lands) for the establishment of forest and agriculture plantations

Significant amount of greenhouse gas emissions has been released from the use of peatland through decomposition and peat fire (MoEF, 2021). At present emission from these sources contribute to about 50% of the total emission from AFOLU (Agriculture, Forestry and Other Land Use) sector. Indonesia has issued a number of key policies to protect peatland and improve its management. Under Presidential Instruction No. 5/2019, there will not be any new permit for the use of peatland. In addition, the Ministerial Regulation No. 15/2017 (Minister for Environment and Forestry) mandates private sector and local governments to improve the use of peatland and water management (MoEF, 2021).

Under CPOS it is expected that the improvement of peatland and water management by 2030 and 2050 reaches 0.86 Mha and 1.04 Mha consecutively, while under LCCP it should reach 0.95 Mha by 2030 and 1.04 Mha by 2050. For peatland restoration, CPOS figures the area of degraded peatland being restored should reach 1.03 Mha by 2030 and 1.7 Mha by 2050. While under LCCP, the target will be increased to 2.7 Mha by 2030 and 4.2 Mha by 2050 (MoEF, 2021).

Considering the significance of Indonesia's peatlands for the environment as well as for the livelihoods of the communities surrounding the area, Indonesia has prioritized it environ mental strategy to restoring degraded peatland, conserving the remaining good peatland and providing alternative livelihood for communities living inside and surrounding peatland. Several measures were taken including issuing policy and regulations reflecting the commitment for better peatland management, developing institutional arrangements to deal with problems in peatland management, conducting research and development to better manage Indonesia's peatland, and providing incentives for conservation and sustainable management of peatland (MoEF, 2018).

The restoration of degraded peatland has been conducted through (MoEF, 2018): 1. Application of peat restoration techniques that include water management on site level (operational scale); 2. Construction, operation and maintenance works, including the arrangement of canal blocking installation (rewetting infrastructure); 3. Application of cultivation according to local wisdom; and/or 4. Research and development, taking into account and adhering to the development of science and lessons learnt from international perspectives.

The importance of peat restoration is also related to the prevention of peat fire that may lead to a huge amount of carbon released to the atmosphere. To deal with the fire problem, a Grand Design of Forest, Estate and Land Fire (Karhutbunla) Prevention in 2017-2019 has been developed by the Coordinating Ministry for Economic Affairs, National Development Planning Agency and Ministry of Environment and Forestry to improve coordination, synergy and harmonization between central and regional governments and increase the participation of other sectors. The scenario of the reduction of karhutbunla in the grand design uses two approaches comprising: (1) Ensuring that the 2.4 million hectares of peat land area under Peatland Restoration Agency are not burnt; and (2) Ensuring that 731 villages identified by MoEF as fire-prone villages are not burnt (MoEF, 2018).

Rewetting of drained organic soils may reduce GHG emissions and waterborne C losses. Given the development of global climate policy and the high emissions associated with drained organic soils, it has been argued that rewetting and restoration of these soils should be included in mitigation strategies (Joosten *et al*. 2012, IPCC 2014).

Rewetting is the deliberate action of raising the water table in soils that have previously been drained for forestry, agriculture (crop production and grazing), water supply, peat extraction and other human-related activities, in order to re-establish and maintain water saturated conditions, e.g., by blocking drainage ditches, construction of bunds or disabling drainage pump facilities.

Rewetting can have several objectives such as nature conservation, GHG emission reductions and the promotion of leisure activities or paludiculture on saturated organic soils (Wilson *et al*. 2016).

GHG fluxes in rewetted organic soils are controlled by a wide range of external and internal factors, which include the prevailing climate, nutrient status, water table position, previous land use history, time since rewetting, absence or presence of vegetation and vegetation composition (Wilson *et al*. 2016).

One more thing that is often forgotten is the role of the community in efforts to control forest and land fires, which is actually very significant. Fire control for the community is actually not only keeping them away from excessive use of fire (because indigenous or traditional communities are still justified in using fire for land clearing as long as the fire does not jump to non-target land), but in fact it is also an increase in income for them and at the same time reduce greenhouse gas emissions.

There are many things they can do starting from what has been mentioned above, namely making compost, making charcoal or charcoal briquettes, making wood vinegar, also being able to take advantage of the land with a higher value such as planting purple taro which can be harvested for 7 months with a harvest per hectare of approx. Rp.15,000,000 per month not to mention the harvest of other commodities. You can also grow coffee and produce high quality coffee, plant pineapples, harvest honey and so on. Meanwhile, for logs scattered on the surface of plantation land that have been burned and produce extraordinary smoke and GHG and damage peat or soil, it can be used as a blower material for biomass power plants with low GHG emissions and the opportunity to get carbon trade as it happened before.

Figure 3 Pineapple (left) in Siak, Riau and small planting management in Mempawah, West Kalimantan

GHG EMISSIONS CALCULATION

GHG emissions from fires that burn above-ground fuels are reasonably well understood, but are very different in character to peat fires that are very poorly understood (KFCP, 2014). Smoldering peat fires produce more CO relative to CO_2, and there can be significant loss of C as other volatile compounds. In an excellent study in which the smoldering of blocks of peat was realistically achieved under a range of moisture contents, Rein *et al*., (2009) found that only 60% of the C in combusted peat was emitted as $CO+CO_2$ (i.e., there were emissions of many other volatile C compounds). This contrasts with about 95% of combusted C released as CO_2 + CO for surface fires.

In undisturbed peat forests, peat C stocks are relatively stable. Disturbance, especially drainage, greatly increases CO_2 emissions from biological

Figure 4 Log and branches (left) use as blower for biomass electric power plant (right)

oxidation (decomposition) of peat because a larger volume of peat and litter is exposed to toxic conditions (KFCP, 2014). Enhanced release of CO_2 from biological oxidation is often the major source of GHG following the disturbance of forests on peat. The rate of CO_2 emissions depends on the quality of decomposable substrate for microorganisms and thus the rate may change over time. CO_2 emissions can continue for many decades until all the aerated peat is decomposed (KFCP, 2014).

When peat forests are disturbed, the peat typically begins to subside (KFCP, 2014). The subsidence rate is correlated, to some extent, with drainage depth (depth of the water table) across a wide range of environmental conditions, suggesting that it may be a useful proxy for the rate of peat decomposition. However, a range of other factors such as vegetation cover and prior fire disturbance also affect subsidence, although their effects are difficult to quantify. Couwenberg *et al.*, (2009) in their survey of the literature found a linear relationship between subsidence rate and water depth for Southeast Asian tropical peat soils, with subsidence increasing by 0.9 cm a-1 for each 10 cm of additional drainage depth. This is substantially more than in other parts of the world (Hooijer *et al.*, 2006; Couwenberg *et al.*, 2009).

Emission factors for CO_2, CO, and other C compounds from peat fires are very poorly understood and result in very large uncertainties in GHG emissions from peat fires (KFCP, 2014). There are very few measurements of GHG emissions from burning peat. It is critical to get more robust data on the effects of peat type (chemistry) and burning conditions (especially variations in moisture content) on the nature of GHG emissions, so as to be able to establish more reliable emission factors.

To calculate annual CO_2-C and Non-CO_2 emissions from organic soil fire using these equations (Krisnawati *et al*, 2015):

Equation 2.8 (IPCC, 2014)

Annual CO_2-C and Non-CO_2 Emission from Organic Soil Fire

$$L_{fire} = A \text{ x } MB \text{ x } C_f \text{ x } G_{ef} \text{ x } 10^{-3}$$

Where:
$Lfire$ = amount of CO_2 or non-CO_2 emissions, e.g., CH_4 from fire, tonnes
A = total area burnt annually, ha
MB = mass of fuel available for combustion, t ha^{-1}
Cf = combustion factor, dimensionless
Gef = emission factor for each gas, g kg^{-1} dry matter burnt

Mass of fuel available for combustion = burn area (m2) x burnt depth (m) x bulk density (t m-3)

Table 1 shown that parameters input, fuel mass available for burning depend on the calculation and CO_2-C, CO dan CH_4 emissions in Ton ha^{-1} resulted from three types of fuels in the site. Yearly emission calculated through multiplicating yearly burnt area with emission released from each species gases (Krisnawati *et al*, 2015).

Indonesian National Carbon Accounting System (INCAS) (Krisnawati *et al.*, 2015) has followed the model used by IPCC (IPCC 2013) to estimate carbon

Table 1 Paramaters input and Parameter input dan CO_2-C, CO dan CH_4 emissions ha^{-1} for fires in the organic soils (Krisnawati *et al*, 2015)

Peat fire EF calculation	**First fire**	**Second fire**	**Third fire**
Burned depth (m)	18	11	4
Area (ha)	1	1	1
Buld density (gcm^{-3})	0.121	0.121	0.121
Combustion factor	1	1	1
FE CO_2-C (g kg^{-1})	464	464	464
FE CO (g kg^{-1})	210	210	210
FE CH_4 (g kg^{-1})	21	21	21
Mass of fuel available for combustion (t dm ha^{-1})	217.8	133.1	48.4
Emisi CO (t CO ha^{-1})	45.7	28.0	10.2
Emisi CH_4 (t CH_4 ha^{-1})	4.6	2.8	1.0
Emisi CO_2-C (t C ha^{-1})	101.1	61.8	22.5
Emisi CO-C (t C ha^{-1})	19.6	12.0	4.4
Emisi CH_4-C (t C ha^{-1})	3.4	2.1	0.8
Emisi C Total (t C ha^{-1})	124.1	75.8	27.6

Source of CO_2-C, CO, CH_4 emission using Tabel 2.7 IPCC (2013)
Source of burnt depth, buld density, and combustion factor is Page *et al.*, (2014)
Note: Emissions factor for N2O dan Nox is not given by IPCC at Tier due to lack of data on of N_2O dan NOx fires emission in organic soils

emission from the forest and peat fire as follows (Setyawati and Suwarsono, 2018):

$$E = a \text{ x } F1 \text{ x } C_f \text{ x } E_f \text{ x } 10^{-3}$$

Where:
E is amount of CO_2 or non-CO_2 emission (ton), a is total area burned annually (ha),
Fl is dry fuel mass available for combustion (ton/ha),
Cf is a dimensionless combustion factor EF refers to emission factor for each gas (g/kg dry mass burned).
Dry fuel mass available for combustion (ton/ha) is calculated by multiplying depth of burned peat (m) with bulk density (ton/m^3).

CO_2 emission from Peat Fire could be calculated as follow (Budiharto, 2019):

$$E_k = A_k \text{ x } h_k \text{ x } BD \text{ x } CF \text{ x } C_{org} \text{ x } 3.67$$

Where:
A_k area of burnt peat (ha),
h_k is depth of burnt peat (m),
BD is peat bulk density (t/m^3), and
CF is Combustion Factor
C_{org} is peat C content (weight basis)

- Similar to peat decomposition, the component of h_k*BD*CF*C_{org}*3.67 can be converted to emission factor of 923.1 tCO_2 with assumption h_k is about 0.33 m and BD is 0.153 t/m^3 CF is 1
- The EF of 923.1 t/ha may change if we have field measurement data including h_k and BD

Table 2 Emission and their corresponding variables for peat fire in 2015 (Setyawati and Suwarsono, 2015)

No	Descriptions		Sumatera	Kalimantan	Papua	Total
1	Total peat area burned (ha)		270.691	320.756	31.857	623.304
2	Dry fuel mass available for combustion (ton/ha)		0.0069	0.0092	0.0092	
3	Combustion factor (dimensionless)		0.8 [11]	0.7 [13]	0.7	
4	Emission factor (g/kg dry fuel burned)	CO_2	1.703 [11]	1.677 [13]	1.111	
		CO	210.3 [11]	221 [13]		
		CH_4	20.80 [11]	13.1 [13]		
5	Emission CO_2 (million ton)		2.545	3.464	0.228	6.237
6	Emission CO (million ton)		0.314	0.457	0.035	0.806
7	Emission CH_4 (million ton)		0.031	0.027	0.007	0.065
8	Emission CO_2 eq. (million ton)		2.756	3.765	0.253	6.774
9	Emission C (million ton)		0.752	1.027	0.069	1.848

Table 3 Emission Factor for CO_2, CO, CH_4

Refferences	Location	Method	CO_2 (g/kg)	CO (g/kg)	CH_4 (g/kg)
Christian *et al*,. (2004)	Sumatera	Lab	1703	210.3	20.8
Wooster *et al*,. (2018)	Kalimantan & Sumatera	In Situ	1775	279	7.9
Stockwell *et al*,. (2016)	Central Kalimantan	In Situ	1564	291	9.51
Stockwell *et al*,. (2015)	Central Kalimantan	Lab	1507.2	224.66	11.69
Narra *et al*,. (2017)	Sumatera	In Situ	1663	205	7.6
Huijnen *et al*,. (2016)	South Kalimantan	In Situ	1625	234	7.8
Setyawati *et al*,. (2017)	West Kalimantan	Lab	1831	138	17
Average			1693.5	229.4	17

Table 4. Values for peat burn depth and peat density found in previous studies and the average value across studies. All studies were based in Kalimantan, Indonesia (Kiely *et al*., 2019)

	Burn depth (m)	Peat density (g cm^{-3})
Page *et al*., (2002)	0.51	
Ballhorn *et al*., (2009)	0.33	
Center for International co-operation in measurement for tropical peatlands (from Ballhorn *et al*., 2009)	0.3	
Usup *et al*., (2004)	0.35	
Stockwell *et al*., (2016)	0.34	
Neuzil *et al*., (1997)		0.093
Driessen and Rochimah (1976)		0.11
Warren *et al*., (2012)		0.127
Shimada *et al*., (2001)		0.112
Konecny *et al*., (2016		0.121
Average	0.37	0.11

Dry fuel mass available for combustion is a product of depth of burned peat and bulk density (Krisnawati *et al*., 2015). For depth of burned peat, INCAS recommends using 0.18 m for newly burned peat and 0.11 m and 0.04 m for peat burned two and more than two times, respectively (Krisnawati *et al*., 2015). Bulk density used for Sumatera (Wahyunto *et al*., 2003; Hikmatullah and Sukarman, 2014), Kalimantan (Setyawati, 2017) and Papua (Wahyunto *et al*., 2006) peats are 0.1716, 0.23 and 0.23, respectively (Setyawati and Suwarsono, 2018).

Although INCAS recommends using 1 as the combustion factor, which means peat fire is a complete combustion, but in this study, we used 0.8 for Sumatera and 0.7 for Kalimantan and Papua peat fires (Christian *et al*., 2003; Stockwell *et al*., 2016). It was because peat fire mostly was dominated by smoldering combustion (Setyawati and Suwarsono, 2018), a type of combustion when no flame is visually observed but apparent thin or thick smokes (Setyawati, 2017).

Data in Table 3 shown emission Factor for CO_2, CO, CH_4 taken from the results of the research being conducted in the peatland area in Sumata and Kalimantan that use for calculating GHG emission from peat fires.

Data in Table 4 shown the compilation data for peat depth burn and Bulk Density that used for calculating GHG emission's taken from the results of research from many research's that had been done.

Based on the results of the research that we conducted in Central Kalimantan in 2015 in collaboration with several Universities in USA and funded by NASA, whose research results were published in the International Journal in 2016, it was quite surprising, because some species of GHG emissions are actually overestimated and some are even reached 86%. This is of course not good news for Indonesia, which is on its way to achieving its 29% emission reduction target by 2030. This happened because some of the GHG emission calculation parameters used did not originate or did not originate from the location where the fire occurred. For example, if there is a fire in Central Kalimantan, then at least data sourced from Central Kalimantan will be used and not data from other places. However, in fact, this is not the case, because in one calculation using the IPCC equation, the calculation parameters used actually come from several data originating from several research results that are not sourced from the same research location.

One more fatal thing that occurs from using the IPCC equation to calculate greenhouse gas emissions from peat fires is the inability to distinguish between fires on the surface of peatlands and peat fires that are actually different. This difference results in a difference in using the Combustion Factor (CF) number, because the CF used is 1 and not less than one, because if CF = 1 it means that all the peat is burned and nothing is left like burned dry grass. Whereas peat is not like that, because it is wet or valley so that even if it burns to a certain depth, that is, until the surface is relatively wet or moist so that it cannot burn. If things like this are not straightened out, Indonesia will forever be at a loss. Our field data strongly suggest revisions to previously recommended IPCC's EFs for most gases that were based on a limited amount of lab measurements.

CONCLUSION

- Most of the fires occurred in the tropical rain forest done by human being that comes from arsons or carelessness
- Previous research shown that Indonesian forest fire management lacked useful data rooted in the forest fire research, making effective action against forest fires very weak.
- The problem of forest and land fires that lead to an increase in greenhouse gas emissions is sometimes

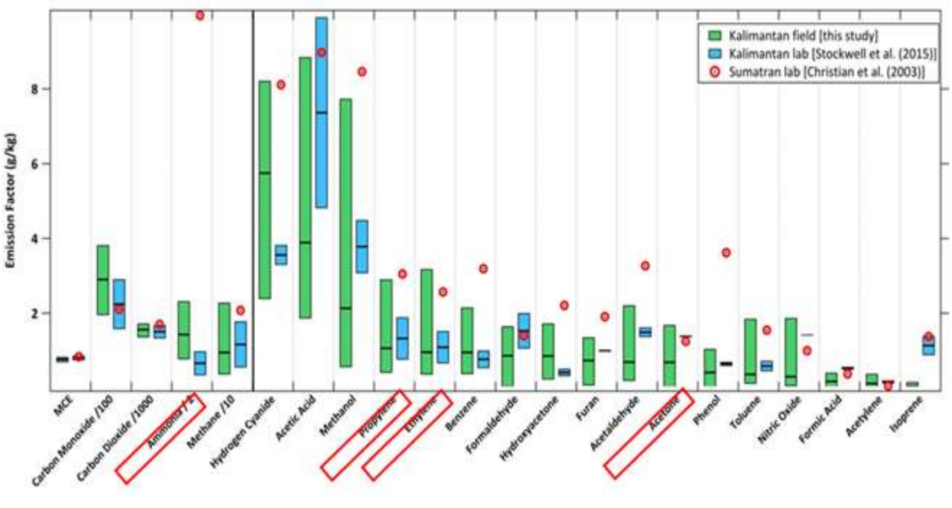

Figure 5 Result of research shown that **CO_2 (-8%): CH_4 (-55%): NH_3 (-86%): CO (+39%)** (Stockwell *et al.*, 2016)

uncontrollable which sources from various problems that occur in it.

- It is impossible to only control in one way, but must be integrated with various aspects, including the political will of the government itself and also not just directly translated from other countries experiences without any adjustments

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