

Annex 22

GHG Assessment

to the GCF Funding Proposal

*Land-based mitigation and adaptation through a Jurisdictional
Approach in West-Kalimantan*

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Annex 22. GHG Emission and Mitigation Impacts for West Kalimantan GCF Project

The estimated overall mitigation impact of the GCF REDD+ project in West Kalimantan is 16.05 million tCO₂e of emission reduction (with an annual average of 2.3 million tCO₂e (Table A22-1). These potential emission reduction is expected to be the results of the project activities in reducing deforestation and forest degradation, as well as enhancement of forest carbon stock. Emission reduction from reduced deforestation contributes the largest with total reduction of 15.3 million tCO₂e (96% of total absolute emission reductions). Total reduced emissions from reduced forest degradation and enhancement of forest carbon stock are expected to be 0.4 million tCO₂e and 0.3 million tCO₂e, respectively. The total 6-years emission reduction is equal to 54.2% of the annual forest reference level (2nd FRL), which has nett emission baseline of 29,6 million tCO₂e. The baseline emissions from deforestation, forest degradation and enhancement of forest carbon stock in West Kalimantan are 29.4 million tCO₂e, 0.8 million tCO₂e and -0.7 million tCO₂e, respectively.

Table 1: Summary of the estimated emission reduction for the REDD+ project of West Kalimantan

GHG Source	Reference Level ¹	Projected Emissions	Expected Net Benefit (tCO ₂ /year)	Total Net Benefit (tCO ₂ /year)
Deforestation	29,423,698	27,237,069	2,186,629	15,306,401
Forest Degradation	825,041	765,850	59,191	414,336
EFCS (removal)	(639,758)	(684,616)	44,858	314,005
EFCS (peat emission)	22,070	20,468	1,602	11,213
Total Emission (FREL)	30,270,809	28,002,919	2,245,820	15,731,950
Total removal (FRL)	(639,758)	(684,616)	44,858	314,005
Total net emission (FREL/FRL)	29,631,051	27,318,303	2,290,678	16,045,955

Table 2: Cost and GHG performance of the project

	Component 1: Institutional & Regulatory Frameworks	Component 2: Sustainable commodity production and social forestry	Component 3: Management, protection and rehabilitation of forest and peatland ecosystems	Total
Total project financing (mill EUR) (excluding M&E, cont., PMC)	30.93	23.94	33.98	88.85

¹ 2nd FRL of West Kalimantan Province, published in 2023.

GCF Financing (mill EUR) (excluding M&E, cont., PMC)	13.1	16.25	23.94	53.29
Emission reduction (Million tCO₂e)	7,620,237	3,965,633	4,460,086	16,045,955
Cost per tCO₂e ER (total project fund- EUR /tCO₂e)	4.1	6.1	7.6	5.5
Cost per tCO₂e ER (GCF fund- EUR/tCO₂e)	1.7	4.1	6.4	3.3

The seven years project is expected to have total funds of 88.85 million Euro (without M&E, contingencies and PMC), with GCF contributions of 53.29 million Euro (without M&E, contingencies and PMC). With the expected GHG emission reduction performance, this results in an estimated cost per tCO₂e of 5.5 Euro per tCO₂e with reference to total financing (see Table A22-2). Component 1 has the lowest total cost ratio per ER of 4.1 Euro per tCO₂e, while Component 2 and Component 3 are higher with cost ratio of 6.1 Euro/ tCO₂e and 7.6 Euro/ tCO₂e, respectively. In addition to the cost ratio of total fund, a ratio cost of 3.3 Euro/ tCO₂e is estimated with reference to total GCF funding (excluding the non-GCF funding).²

Table 3: Cumulative GHG emission reduction by project activity

	Output	Total Expected ER (tCO₂e)
Component 1		7,620,237
	Output 1.1	6,489,490
	Output 1.2	1,041,467
	Output 1.3	89,279
Component 2		3,965,633
	Activity 2.1	3,965,633
Component 3		4,460,086
	Activity 3.1	2,797,814
	Activity 3.2	1,662,271
Total		16,045,956

The largest contribution of the expected emission reduction is from Component 1, with total expected ER of 7.6 Million tCO₂e in 7 years, mainly generated by Output 1.1 with almost 6.5 Million tCO₂e total expected ER in 7 years.

Table 4: Expected impacted areas (in hectares) for each project activity and REDD+ activity in 7 years

	Effectiveness factor			Reduced activity data due to effectiveness factor (ha)		
REDD+ Activities	Component 1	Component 2	Component 3	Component 1	Component 2	Component 3
Deforestation						
Deforestation Emission - Biomass	27%	13%	15%	18,120	8,752	9,874

² No distinction is made between adaptation and mitigation finance. If only the 50% mitigation finance figures would be taken into account, the cost per ER would be further reduced.

	Effectiveness factor			Reduced activity data due to effectiveness factor (ha)		
REDD+ Activities	Component 1	Component 2	Component 3	Component 1	Component 2	Component 3
Peat Decomposition Emission (in deforested area)	32%	11%	13%	8,162	2,903	3,382
Peat fire emission	32%	11%	13%	2,328	828	965
AGB+DOM fire emission (in deforested area)	27%	13%	15%	136	66	74
Mangrove soil emissions (in deforested area)	30%	12%	27%	64	27	59
Forest Degradation						
Forest degradation emission - Biomass	25%	15%	14%	974	594	562
Peat Decomposition Emission (in forest degraded area)	0%	0%	0%	-	-	-
AGB+DOM fire emission (in forest degraded area)	25%	15%	14%	1	1	1
Enhancement of Forest Carbon Stock						
Enhance of forest carbon stock (EFCS) - Biomass	38%	8%	7%	683	135	121
Peat Decomposition Emission (in EFCS area)	42%	8%	4%	223	42	22

Table 5: Expected impacted areas (in hectares) for each REDD+ activity in seven years of GCF project lifetime.

REDD+ Activities	Annual AD (ha)	Total effectiveness factor	Total reduced activity data due to effectiveness factor (ha)	Implied Emission Factors (tCO ₂ e/ha)
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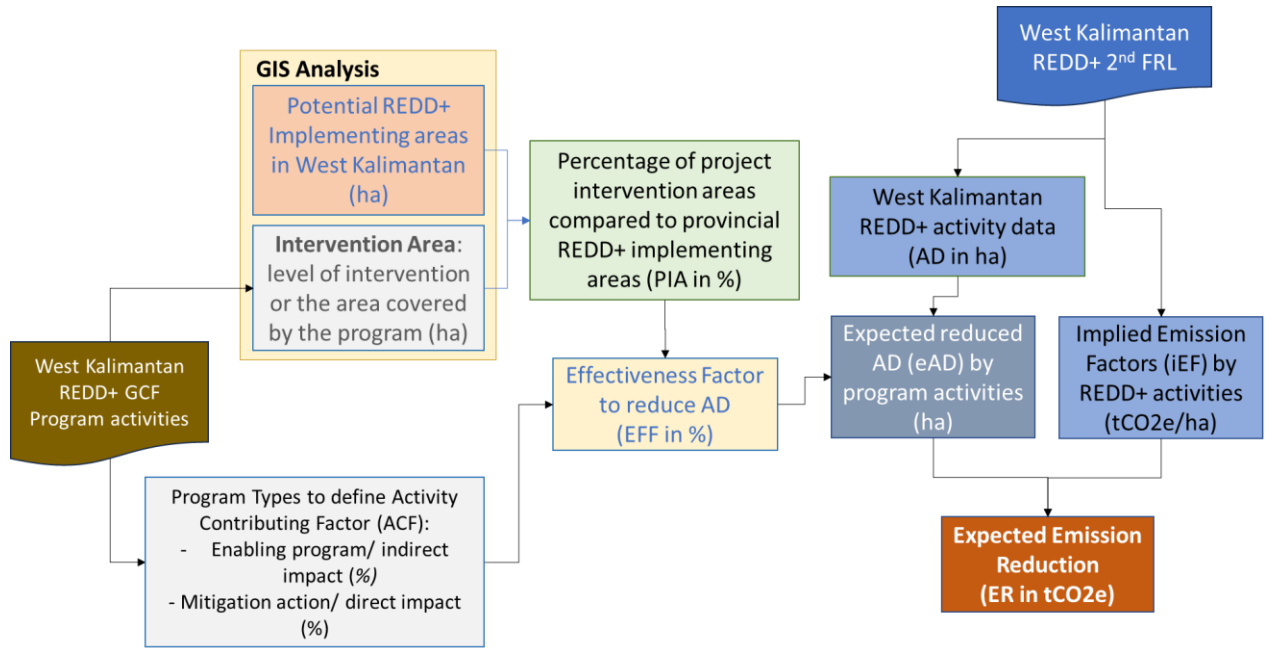
Deforestation				
Deforestation Emission - Biomass	66,475	55%	36,746	372.1
Peat Decomposition Emission (in deforested area)	25,443	57%	14,447	37.7
Peat fire emission	7,258	57%	4,121	509.0
AGB+DOM fire emission (in deforested area)	500	55%	276	50.3
Mangrove soil emissions (in deforested area)	215	69%	149	48.8
Forest Degradation				
Forest degradation emission - Biomass	3,928	54%	2,130	207.9
Peat Decomposition Emission (in forest degraded area)	508	0%	-	16.2
AGB+DOM fire emission (in forest degraded area)	5	54%	3	41.4
Enhancement of Forest Carbon Stock			-	
Enhance of forest carbon stock (EFCS) - Biomass	1,786	53%	939	-358.2
Peat Decomposition Emission (in EFCS area)	528	54%	287	41.8
Total and Average	106,646	51%	59,098	

A total of annual activity data of REDD+ in West Kalimantan is 106.6 thousand hectares. With the average of effectiveness of 51% of the project activities to reduce emissions, the expected reduced activity data is 59 thousand hectares. The largest contribution are REDD+ activities related to reducing deforestation with total impacted activity data of 55.7 thousand hectares (mostly from biomass loss, i.e. 36.7 thousand hectares). The effectiveness factors range from 0% to 69%. Emissions from peat decomposition in forest degradation areas are not impacted by the intervention, due to the unavailability of primary peat swamp forests in the area. Component 2 has the lower average effectiveness in reducing the emissions, due to the nature of the measures. Component 2 focuses on improved and climate resilient agriculture. On the other hand, Component 1 and Component 3 have higher effectiveness rates to reduce emissions. Most direct mitigation activities are in Component 3, while the activities in Component 1 are mostly related to the enabling conditions at province level.

Methods for estimating GHG ER impacts

To estimate the impact of the project, several factors are included in the calculation, including the types of intervention project, potential implementation areas related to REDD+ activities, as well as emission baseline and the historical activity data (see Figure A22-1).

Figure 1: Flow chart of method on estimating GHG impact



The total expected emission reduction (TER) was the sum of all expected emission reduction of i REDD+ subactivity. The expected emission reduction of i REDD+ subactivity (ER_i) was generated through the multiplication of the expected activity data of i REDD+ subactivity (eAD_i) in hectares, and the associated implied emission factors (iEF_i) in tCO_2e/ha (see equation below).

$$TER = \sum ER_i$$

$$ER_i = eAD_i \times iEF_i$$

The expected activity data of i REDD+ sub-activity (eAD_i) is the activity data (such as, the size of deforestation) that are expected to be reduced due to the implementation of the project activities. The eAD_i was calculated using below equation, where AD_i is the activity data of i REDD+ subactivities (see Table A22-8) and EFF is effectiveness factor, that represents the effectiveness of the project activities to reduce the annual activity data.

$$eAD_i = AD_i \times EFF$$

$$EFF = ACF \times PIA_i$$

The EFF is calculated using the above equation. The EFF considers two factors, including:

- Types of project activity, such as enabling conditions or direct mitigation actions. The type of project defines the activity contributing factor (ACF). The factors used for the calculation are 3.5% for enabling conditions and for direct mitigation actions depend on the scale of the intervention areas.
- The scope of implementing areas, which defines the proportion of implementing areas (PIA_i) to province level's implementing areas (Table A22-7) for example, the selection of priority districts as the scope of project implementation will have higher PIA than the scope of village level (Table A22-8).

Table 6: REDD+ subactivities and the associated implementing areas

No	REDD+ Sub Activities	Implementing areas of sub-activities
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1	Deforestation Emission - Biomass	Total Forest
2	Peat Decomposition Emission (in deforested area)	Forested areas in peatland
3	Peat fire emission	Forested areas in peatland
4	AGB+DOM fire emission (in deforested area)	Total Forest
5	Mangrove soil emissions (in deforested area)	Total mangrove
6	Forest degradation emission - Biomass	Total primary forest
7	Peat Decomposition Emission (in forest degraded area)	primary forest in peatland
8	AGB+DOM fire emission (in forest degraded area)	Total primary forest
9	Enhance of forest carbon stock (EFCS) - Biomass	Non forested areas
10	Peat Decomposition Emission (in EFCS area)	Non-forested areas in peatland

The Implied emission factors were derived from the total emission or removal from each REDD+ activity divided by total AD of each REDD+ subactivity (Table A22-9). The total emissions and removals for each activity were derived from the FRL analysis. The AD for each REDD+ activity was generated from the spatial data analysis of the historical data (source: 2nd FRL of West Kalimantan).

Identifying Intervention Areas based on Selected Priority Districts and Villages

The potential impacted REDD+ areas was derived from the proportion of intervention areas (PIA) (forested areas in mineral soil, peat swamp forest, mangrove forests, and non forested areas that potentially replanted or reforested) at project scope to total province REDD+ intervention areas (Table A22-7). The proportions are generated from Table A22-8.

Table 7: The total implementing areas based on each project intervention level (source: forest and land cover map 2020)

Project intervention scope	Total Forest	Forested areas in peatland	Non-forested areas in peatland	Total mangrove	Total primary forest	Primary forest in peatland	Non forested areas	Total Area of Intervention
Province	5,521,895	771,598	776,717	116,396	2,208,933		918,133	6,440,028
Priority Districts	4,512,952	604,181	583,118	91,598	1,899,830	-	709,262	5,222,214
FMUs at priority districts	3,136,201	411,988	130,273	79,583	1,027,014	-	304,548	3,440,750
Private sectors in priority districts	1,418,920	221,129	96,078	29,255	173,889	-	190,014	1,608,933
CA in priority districts	934,909	11,333	7,763	-	856,506	-	9,539	944,448
Priority Villages	3,841,634	425,884	184,670	74,449	1,884,027	-	404,714	846,556
FMUs in priority villages	2,728,758	338,461	88,983	68,747	1,014,269	-	176,986	4,018,620
APL in priority villages	340,538	66,253	84,889	5,439	1,175	-	918,133	2,837,761
Social Forestry in priority villages	227,937	37,851	12,956	35,121	23,137	-	709,262	392,377
CA in priority villages	909,020	7,301	1,428	-	854,449	-	304,548	246,592

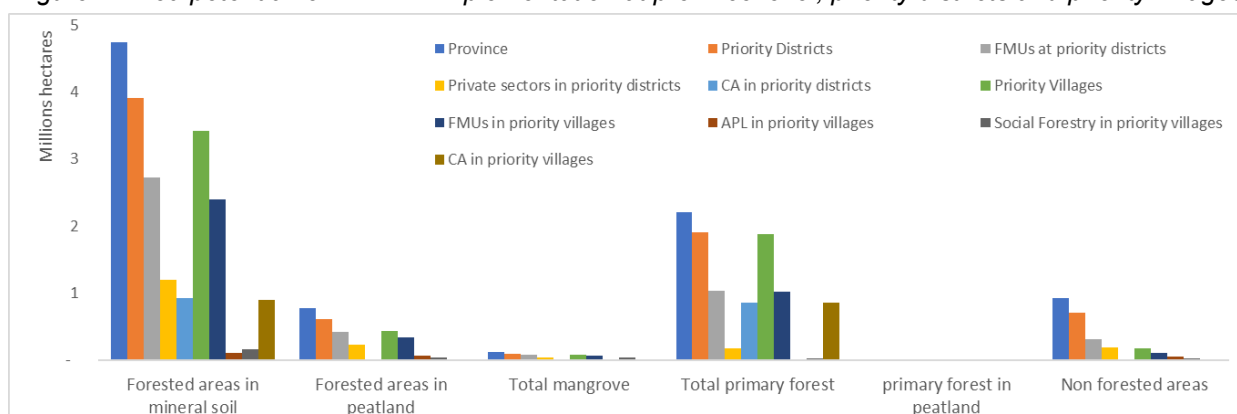
Table 8: Proportion of implementing areas (PIA) of each intervention level to province level's implementing areas

Project intervention level	Total Forest	Forested areas in peatland	Non-forested areas in peatland	Total mangrove	Total primary forest	Primary forest in peatland	Non forested areas
Province	100%	100%	100%	100%	100%		100%
Priority Districts	82%	78%	75%	79%	86%		77%
FMUs at priority districts	57%	53%	17%	68%	46%		33%
Private sectors in priority districts	26%	29%	12%	25%	8%		21%
Conservation areas in priority districts	17%	1%	1%	0%	39%		0%
Priority Villages	70%	55%	24%	64%	85%		19%
FMUs in priority villages	49%	44%	11%	59%	46%		12%
Other land use in priority villages	6%	9%	11%	5%	0%		6%
Social Forestry in priority villages	4%	5%	2%	30%	1%		2%
Conservation areas in priority villages	16%	1%	0%	0%	39%		1%

The REDD+ Task Force selected five priority districts for the implementation of the GCF project in West Kalimantan, including Kapuas Hulu, Ketapang, Kubu Raya, Sanggau and Sintang Districts. The priority districts covers 82% of total province's forests. The forest management units and the forest concessions within the priority districts, covers 57% and 26% of province's forests, respectively. These data were used as the potential implementing areas of the GCF project related to the priority districts, FMUs and private sector. For the project related to policy development at province level, we assume that will have impact at all districts, including the non-priority districts.

In addition, for the field implementation, the REDD Taskforce further selected 200 priority villages within the priority districts to be engaged with project intervention. The selection of priority villages are based on the largest distribution of forested areas, given the significant source of province's emissions . Selected villages are distributed within the priority districts, including 77 villages in Kapuas Hulu, 19 villages in Ketapang, 15 villages in Kubu Raya, 21 villages in Sanggau and 68 villages in Sintang. The selection results have been consulted with the representatives of the priority districts. Based on the village selection, we further identified the potential REDD+ intervention areas within the village selection.

Figure 2: Area potential for REDD+ implementation at province level, priority districts and priority villages



The intervention areas are also defined by the type of REDD+ activities that each project potentially addressed (Figure A22-2). For example, if a project is designed to address deforestation, then the intervention areas will include all forest-related areas. Or when a project is designed to rehabilitate degraded areas, then the intervention areas will include only the non forested areas that are potentially reforested (i.e. barelands, grasslands and shrublands). If the project being more specific on the location, for example reducing deforestation at FMUs of the priority districts, then only forested areas in the selected FMU are included in.

Project (sub-) activity	Project Category	Expected Activity Impact*
Activity 1.1.1	Adaptation	0.0%
All enabling activities	Enabling conditions	3.5%
Sub-activity 1.2.1.2	Direct mitigation1	20.4%
Sub-activity 2.1.2.1	Direct mitigation2	3.7%
Sub-activity 3.1.1.4	Direct mitigation3	12.5%
Sub-activity 3.2.1.1	Direct mitigation4	43.9%
Sub-activity 3.2.1.4	Direct mitigation5	1.4%

* For detail calculation on the expected impact on direct mitigation activities, please refer to the calculation worksheet.

Each project activity was categorized into enabling conditions and mitigation actions to define the potential impact to emission reduction, i.e. 3.5 % for enabling conditions and 1.4% to 43.9% for mitigation actions. For example, if the project related to the policy shaping, capacity development or other interventions that are not directly related to emission reduction, then it is categorized as enabling conditions, multiplied with potential impact of each project activity to reduce emission.

Calculation of the Implied Emission Factors

The implied emission factors was derived from the estimated emission baseline divided by the activity data of each REDD+ activity (Table A22-9). The baseline was derived from the analysis using the national 2nd FRL method (see below section). The activity data used for the baseline estimates was generated from the national forest monitoring system. The same activity data was used to generated the implied emission factors.

Table 9: The emission baseline, annual activity data and the implied emission factor for each REDD+ subactivity

Activity	Baseline (tCO ₂ e)	AD (ha/year)	Implied EFs
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			(tCO ₂ e /ha/y)
Deforestation			
Deforestation Emission - Biomass	24,733,966	66,475	372.1
Peat Decomposition Emission (in deforested area)	959,658	25,443	37.7
Peat fire emission (in deforested area)	3,694,418	7,258	509.0
AGB+DOM fire emission (in deforested area)	25,164	500	50.3
Mangrove soil emissions (in deforested area)	10,492	215	48.8
Forest Degradation			
Forest degradation emission - Biomass	816,600	3,928	207.9
Peat Decomposition Emission (in forest degraded area)	8,234	508	16.2
AGB+DOM fire emission (in forest degraded area)	207	5	41.4
Enhancement of Forest Carbon Stock			
Enhance of forest carbon stock (EFCS) - Biomass	639,758	1,786	358.2
Peat Decomposition Emission (in EFCS area)	22,070	528	41.8
Total emission deforestation, forest degradation and EFCS	30,910,567	106,646	168

Methods for GHG Emission Baseline Estimation

Baseline of GHG emissions and removals was generated based on the method used for developing the national 2nd FRL (MoEF, 2022)³, which is an updated version of the 1st FREL (MoEF, 2016)⁴. Comparison of method between the 1st FREL and the 2nd FRL can be seen in Table A22-6. The method cover several REDD+ activities, including reduction emissions from deforestation and forest degradation, as well as enhancement of forest carbon stocks. The reference period for baseline development was from 2006 – 2020 and applicable for the next 10 years.

The carbon pools of aboveground biomass and belowground biomass are included in the calculation of emissions and removals from deforestation, forest degradation and enhancement of forest carbon stock. Soil organic carbon are included in the calculation for peat decomposition,

³ MoEF, 2022. National Forest Reference Level for Deforestation, Forest Degradation and Enhancement of Forest Carbon Stocks. In the Context of Decision 1/CP.16 para 70 UNFCCC (Encourages developing country Parties to contribute to mitigation actions in the forest sector), Directorate General of Climate Change. The Ministry of Environment and Forestry. Indonesia.

https://redd.unfccc.int/files/modified_2nd_frl_indonesia_20220529_clean.pdf

⁴ MoEF, 2016, National Forest Reference Emission Level for Deforestation and Forest Degradation: In the Context of Decision 1/CP.16 para 70 UNFCCC (Encourages developing country Parties to contribute to mitigation actions in the forest sector), Directorate General of Climate Change. The Ministry of Environment and Forestry. Indonesia.

https://redd.unfccc.int/files/frel_submission_by_indonesia_final.pdf

peat fires and mangrove conversion. Dead organic matter is included in the calculation of biomass burning. Gases included in the calculation are CO₂, CH₄ and N₂O.

Table 10: Comparison of method between the 1st FREL and the 2nd FRL

Component	1 st FREL	2 nd FRL
Activity	<ul style="list-style-type: none"> Reducing deforestation Reducing forest degradation Peat decomposition 	<ul style="list-style-type: none"> Reducing deforestation Reducing forest degradation Enhancement of forest carbon stocks Peat fires Peat decomposition Biomass burning
Carbon pool	<ul style="list-style-type: none"> AGB and BGB, SOC of peatland 	<ul style="list-style-type: none"> AGB, BGB, DOM, SOC (peatland and mangrove)
Gases	<ul style="list-style-type: none"> CO₂ 	<ul style="list-style-type: none"> CO₂, CH₄, N₂O
Baseline	<ul style="list-style-type: none"> Historical average Legacy emissions from peat decomposition 	Historical average
Reference period	1990/1996 – 2011/2012	2006/2009 – 2019/2020
Activity data	<ul style="list-style-type: none"> Forest and land cover maps from 2 point of time (beginning and end of reference period) Peatland map 2019 	<ul style="list-style-type: none"> Forest and land cover maps from 2 point of time (beginning and end of reference period) Peatland map 2019 Annual burned areas
Emission factor	<ul style="list-style-type: none"> AGB Forest carbon stocks : Tier 2 stratified into region/island BGB : Root shoot ratio Peat decomposition : Tier 1 	<ul style="list-style-type: none"> AGB Forest carbon stocks : Tier 2 stratified into region/island AGB Non-forest carbon stock: Tier 2 for national level BGB : Root shoot ratio DOM : Tier 2 Peat decomposition : Tier 2 Peat fires: Tier 2 and Tier 1 Mangrove soil: Tier 1
Baseline (tCO ₂ e)	5003.0 – 577.4 Million tCO ₂ e	192.9 Million tCO ₂ e

Emission Factors

For developing the baseline of West Kalimantan, we use the same datasets used in the 2nd FREL (see Table A22-11 to Table A22-15), compiled at national level which mostly considered as Tier 2 (MoEF, 2022). The aboveground biomass data of forest classes were estimated from the national forest inventory (NFI) data, which were collected from the plots distributed throughout Indonesia. The aboveground biomass of non-forest classes were compiled from various studies in Indonesia. Belowground biomass and dead organic matters were estimated using ratios to aboveground biomass which were derived from studies in Indonesia (Krisnawati, et al, 2014). Some Tier 1 data were also used to fill the gaps of unavailable data, in particular for the emission factors related to soil emissions due to mangrove conversion.

Table 11: Aboveground and belowground biomass values used for emission calculation from land cover changes.

Land Cover	AGB (t d.m. /ha)*		BGB (t d.m. /ha)		Source
	Mean	SE	Mean	SE	
Primary dryland forest	325.90	10.05	94.51	2.89	Table 6. Modified_2nd FRL Indonesia
Secondary dryland forest	222.91	4.48	64.64	1.32	Table 6. Modified_2nd FRL Indonesia
Primary mangrove forest	247.98	14.39	77.12	4.43	Table 6. Modified_2nd FRL Indonesia
Primary swamp forest	285.09	24.16	62.72	7.10	Table 6. Modified_2nd FRL Indonesia
Secondary mangrove forest	155.74	19.21	17.91	2.32	Table 6. Modified_2nd FRL Indonesia
Secondary swamp forest	215.71	7.38	47.46	1.83	Table 6. Modified_2nd FRL Indonesia
Plantation forest	161.23	16.00	52.40	5.20	Table 7. Modified_2nd FRL Indonesia
Dry shrub	128.49	15.36	30.32	3.63	Table 7. Modified_2nd FRL Indonesia
Estate crop	102.35	14.67	33.26	4.77	Table 7. Modified_2nd FRL Indonesia
Settlement	4.61	2.48	1.34	0.72	Table 7. Modified_2nd FRL Indonesia
Bare ground	5.11	2.89	1.21	0.68	Table 7. Modified_2nd FRL Indonesia
Savanna and grasses	8.64	4.13	2.04	0.98	Table 7. Modified_2nd FRL Indonesia
Open water	-	-	-	-	Table 7. Modified_2nd FRL Indonesia
Wet shrub	41.15	8.44	9.71	1.99	Table 7. Modified_2nd FRL Indonesia
Pure dry agriculture	29.95	16.38	5.99	3.28	Table 7. Modified_2nd FRL Indonesia
Mixed dry agriculture	137.52	4.89	27.50	0.98	Table 7. Modified_2nd FRL Indonesia
Paddy field	21.27	8.26	5.02	1.95	Table 7. Modified_2nd FRL Indonesia
Fish pond/aquaculture	-	-	-	-	Table 7. Modified_2nd FRL Indonesia

Land Cover	AGB (t d.m. /ha)*		BGB (t d.m. /ha)		Source
	Mean	SE	Mean	SE	
Port and harbor	-	-	-	-	Table 7. Modified_2nd FRL Indonesia
Transmigration areas	29.95	16.38	5.99	3.28	Table 7. Modified_2nd FRL Indonesia
Mining areas	-	-	-	-	Table 7. Modified_2nd FRL Indonesia
Open swamp	-	-	-	-	Table 7. Modified_2nd FRL Indonesia

Table 12: Emission factors of peat decomposition

Land Cover	EF for Peat Decomposition (tCO ₂ ha ⁻¹ yr ⁻¹)		
	Mean	SE	Source
Primary dryland forest	-	-	Table 10. Modified_2nd FRL Indonesia
Secondary dryland forest	32.42	3.71	Table 10. Modified_2nd FRL Indonesia
Primary mangrove forest	-	-	Table 10. Modified_2nd FRL Indonesia
Primary swamp forest	-	-	Table 10. Modified_2nd FRL Indonesia
Secondary mangrove forest	32.42	3.71	Table 10. Modified_2nd FRL Indonesia
Secondary swamp forest	32.42	3.71	Table 10. Modified_2nd FRL Indonesia
Plantation forest	72.95	10.28	Table 10. Modified_2nd FRL Indonesia
Dry shrub	45.04	8.45	Table 10. Modified_2nd FRL Indonesia
Estate crop	36.63	4.44	Table 10. Modified_2nd FRL Indonesia
Settlement	45.04	8.45	Table 10. Modified_2nd FRL Indonesia
Bare ground	63.79	3.30	Table 10. Modified_2nd FRL Indonesia
Savanna and grasses	45.04	8.45	Table 10. Modified_2nd FRL Indonesia
Open water	-	-	Table 10. Modified_2nd FRL Indonesia
Wet shrub	45.04	8.45	Table 10. Modified_2nd FRL Indonesia
Pure dry agriculture	45.42	8.58	Table 10. Modified_2nd FRL Indonesia
Mixed dry agriculture	54.66	8.73	Table 10. Modified_2nd FRL Indonesia
Paddy field	33.71	10.82	Table 10. Modified_2nd FRL Indonesia
Fish pond/aquaculture	-	-	Table 10. Modified_2nd FRL Indonesia

Land Cover	EF for Peat Decomposition (tCO ₂ ha ⁻¹ yr ⁻¹)		
	Mean	SE	Source
Port and harbor	-	-	Table 10. Modified_2nd FRL Indonesia
Transmigration areas	54.66	8.73	Table 10. Modified_2nd FRL Indonesia
Mining areas	63.79	3.30	Table 10. Modified_2nd FRL Indonesia
Open swamp	-	-	Table 10. Modified_2nd FRL Indonesia

Table 13: Emission factors for estimating peat fire emissions

Land Cover	CO ₂ emission (t CO ₂ e/ha)		CH ₄ emission (t CO ₂ e/ha)		Source
	Mean	SE	Mean	SE	
Primary dryland forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Secondary dryland forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Primary mangrove forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Primary swamp forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Secondary mangrove forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Secondary swamp forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Plantation forest	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Dry shrub	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Estate crop	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Settlement	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Bare ground	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Savanna and grasses	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Open water	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Wet shrub	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Pure dry agriculture	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Mixed dry agriculture	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Paddy field	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Fish pond/aquaculture	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Port and harbor	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia

Transmigration areas	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Mining areas	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia
Open swamp	460.03	91.23	48.99	11.77	Table 8. Modified_2nd FRL Indonesia

Table 14: Fuel mass values for estimating emissions from biomass burning

Land Cover	AGB+DoM (CH ₄) (t CO ₂ e/ha)		AGB+DoM (N ₂ O) (t CO ₂ e/ha)		Source
	Mean	SE	Mean	SE	
Primary dryland forest	31.22	9.23	13.55	0.90	Table 9. Modified_2nd FRL Indonesia
Secondary dryland forest	37.23	11.00	16.16	1.00	Table 9. Modified_2nd FRL Indonesia
Primary mangrove forest	22.14	6.68	9.61	1.33	Table 9. Modified_2nd FRL Indonesia
Primary swamp forest	26.37	7.88	11.45	1.35	Table 9. Modified_2nd FRL Indonesia
Secondary mangrove forest	17.92	5.71	7.78	1.53	Table 9. Modified_2nd FRL Indonesia
Secondary swamp forest	34.68	10.27	15.06	1.23	Table 9. Modified_2nd FRL Indonesia

Table 15: Emission factors for estimating emissions from mangrove soil conversion

Land Cover	Mangrove Soil ((tCO ₂ e/ha)		
	Mean	SE	Source
Plantation forest	28.97	5.75	Table 11. Modified_2nd FRL Indonesia
Estate crop	28.97	5.75	Table 11. Modified_2nd FRL Indonesia
Pure dry agriculture	28.97	5.75	Table 11. Modified_2nd FRL Indonesia
Mixed dry agriculture	28.97	5.75	Table 11. Modified_2nd FRL Indonesia
Paddy field	28.97	5.75	Table 11. Modified_2nd FRL Indonesia
Fish pond/aquaculture	90.06	22.82	Table 11. Modified_2nd FRL Indonesia

Activity Data

The activity data used were the same dataset and method used in the 2nd FRL. We used the forest and land cover mapping, the map products generated from the national forest monitoring system (NFMS). Similarly with the burned area maps, we used the burned area maps generated by the MoEF. The peatland distribution map generated by the Ministry of Agriculture was used for this analysis. The reference period used for this analysis is similar to the period in the 2nd FRL, i.e., 2006 – 2020. For this analysis, all maps were cropped using the boundary of West Kalimantan Province. REDD+ activity data for deforestation, forest degradation and forest gain

were then generated using the cropped database. In addition, activity data for peat fires, peat decomposition, mangrove conversion that were overlapped with those REDD+ activities were also generated (see the 2nd FRL document of West Kalimantan).