Using land use & land cover datasets to assess variability in estimates of land use change and associated GHG emissions in selected regions of Indonesia

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Collaboration between:

agrimetrics
UNIVERSITY OF LEICESTER
Unilever

agrimetrics | We work with Innovate UK

Introduction

Background

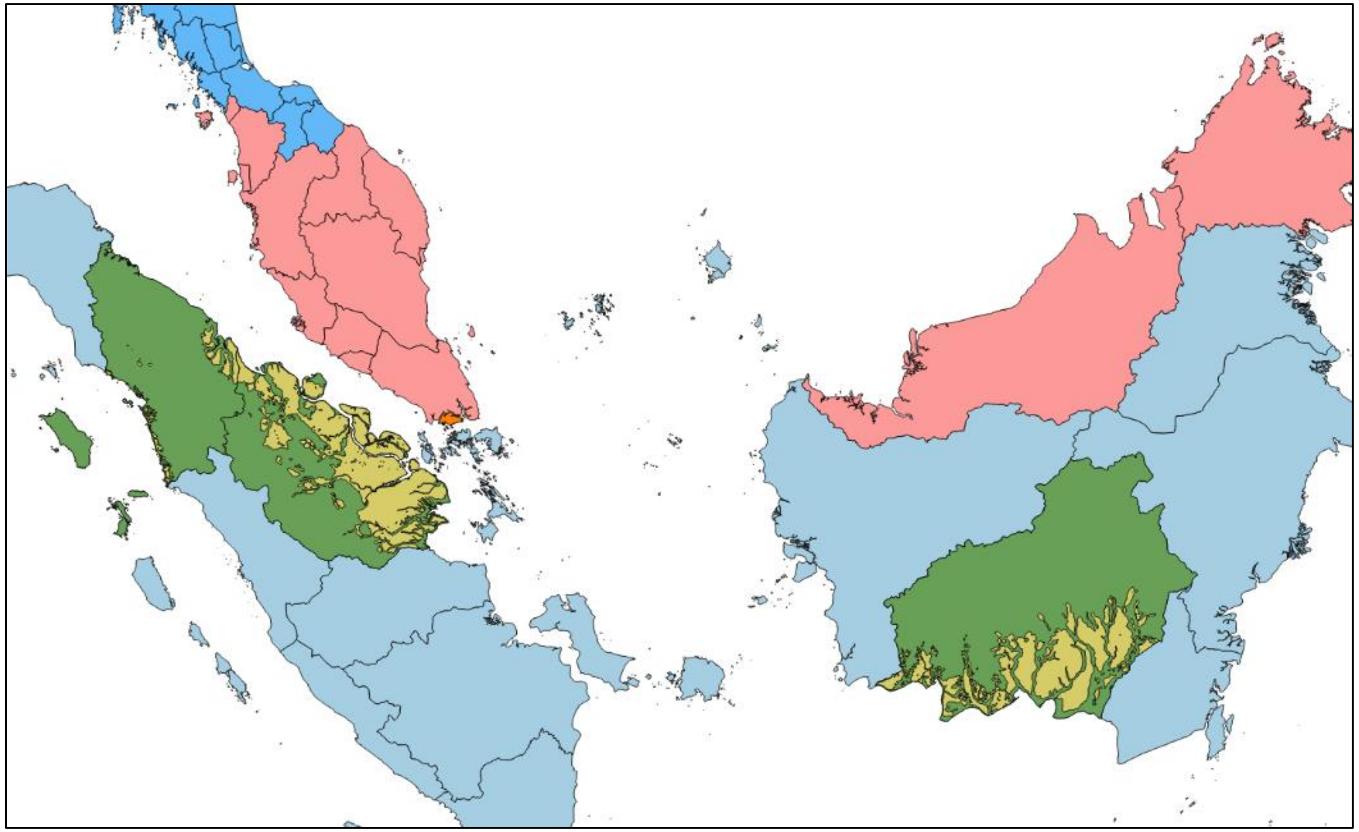
- Main goal is to assess variability of Greenhouse Gas (GHG) emissions estimates from several existing Land Use/Land Cover (LULC) data sets
- Special attention given to GHG emissions from peat soils.
- This could help monitor emissions related to Palm Oil (PO) industry, which is responsible for large-scale LULC change and related GHG emissions in main producing countries, Malaysia and Indonesia.

Palm Oil plantation

Introduction
Study areas

- Three Indonesian provinces:
  - North Sumatra (Sumatera Utara)
  - Riau
  - Central Kalimantan (Kalimantan Tengah)
- All study areas contain peat soils
- PO industry well developed in all study areas

Study area	Total area (ha)	Peat soil area (ha)	Peat soil of total (%)
North Sumatra	7,241,177	348,020	4.81
Riau	9,117,318	4,058,456	44.51
Central Kalimantan	15,344,440	3,004,890	19.58



Location of study areas in Indonesia

Data

LULC Datasets

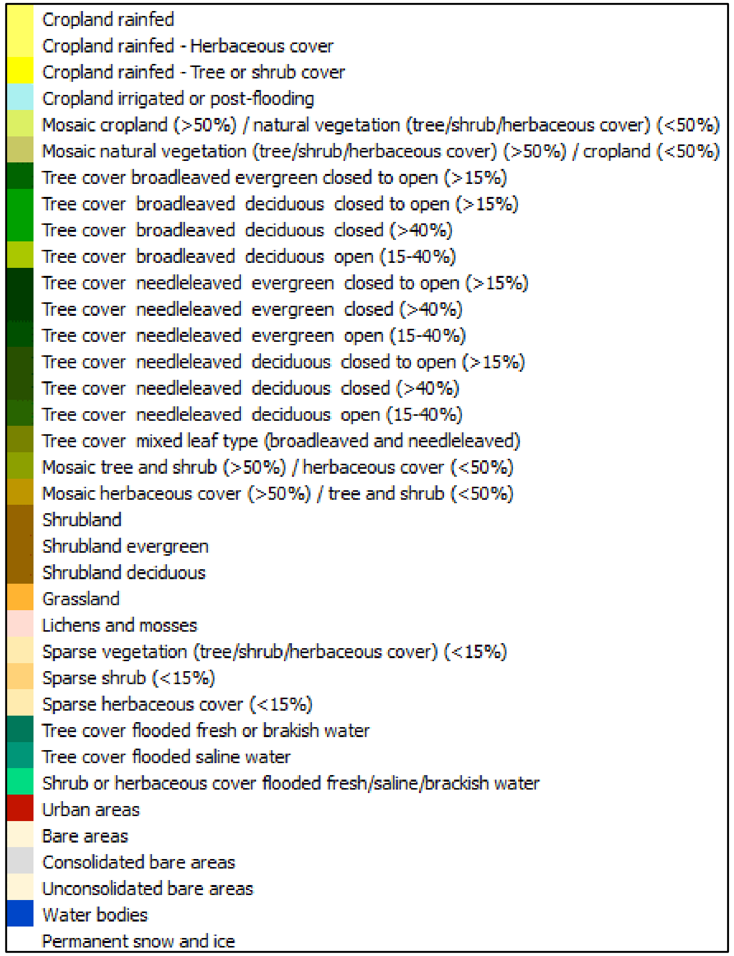
Data source	Data type	Spatial resolution (m)	Geographic cover	Updates	URL data archive
ESA CCI Land Cover (CCI)	LULC	300 x 300 (MERIS)	Global	Yearly between 1992-2015	http://maps.elie.ucl.ac.be/CCI/viewer/
Centre for Remote Imaging, Sensing and Processing (CRISP)	LULC	250 x 250 (MODIS)	Southeast Asia	2000, 2010, 2015*	https://ormt-crisp.nus.edu.sg/ormt/Home/Disclaimer
Indonesia Ministry of Forestry (MoF)	LULC	100 x 100 (Landsat)	Indonesia	1990, 1996, 2000, 2003, 2006, 2009, 2011, 2012, 2013, 2015	http://www.greenpeace.org/seasia/id/Global/seasia/Indonesia/Code/Forest-Map/en/index.html
Global Forest Watch (GFW)	Forest cover change	30 x 30 (Landsat)	Global	Yearly between 2000-2016	http://data.globalforestwatch.org/

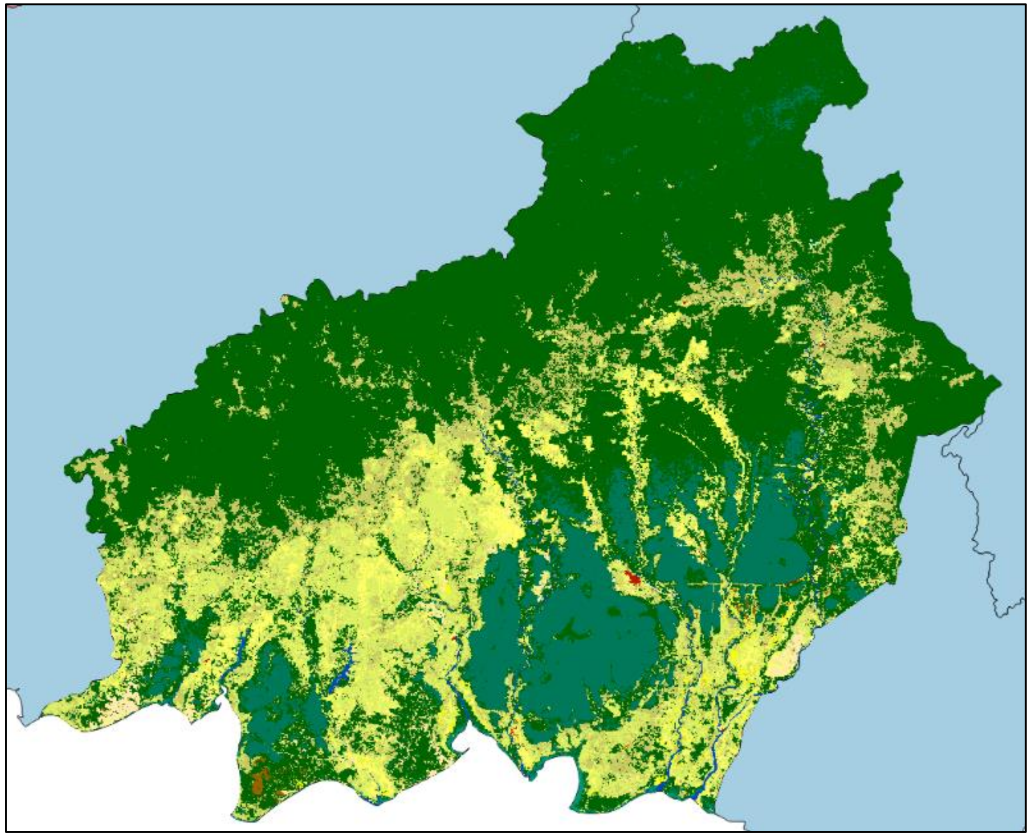
Data

LULC Datasets

<u>CCI LULC data</u>

- Developed by ESA CCI Land Cover initiative as a global data set
- <u>Global (vague) LULC class descriptions, no specific plantation class</u>
- Well documented methodology
- Initially based on MERIS (300x300m) data
- After recent re-processing, data now available with yearly updates between 1992 and 2015.





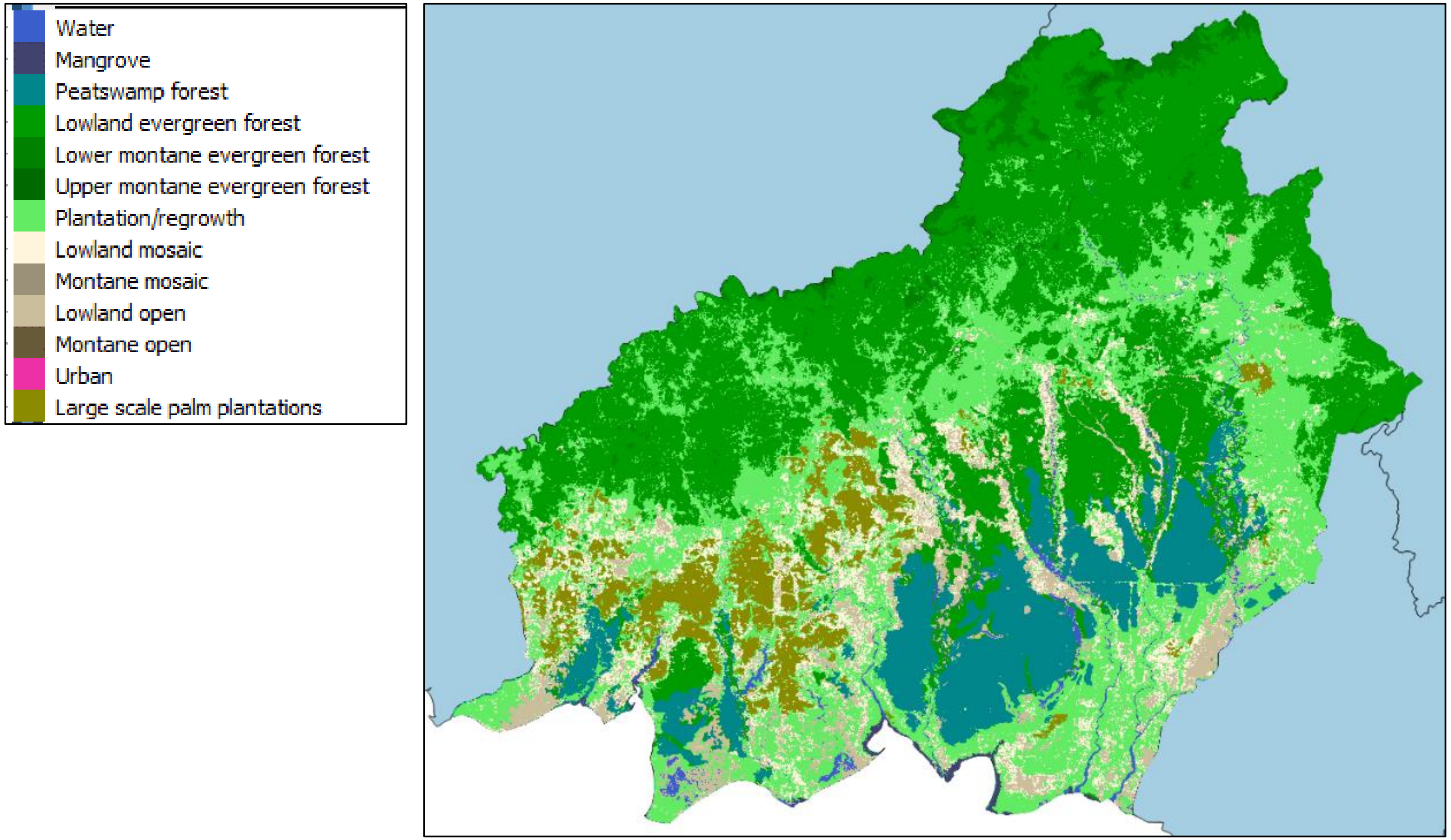
LULC map Central Kalimantan from CCI, 2015

Data

LULC Datasets

<u>CRISP LULC data</u>

- Developed by Centre for Remote Imaging, Sensing and Processing in Singapore as LULC data set covering Southeast Asia
- Specific LULC classes for plantations
- Well documented methodology
- Based on interpretation of MODIS (250x250m) imagery
- Updates in 2000, 2010 & 2015. <u>2015 data based on different methodology, therefore not comparable to 2000 & 2010 data</u>



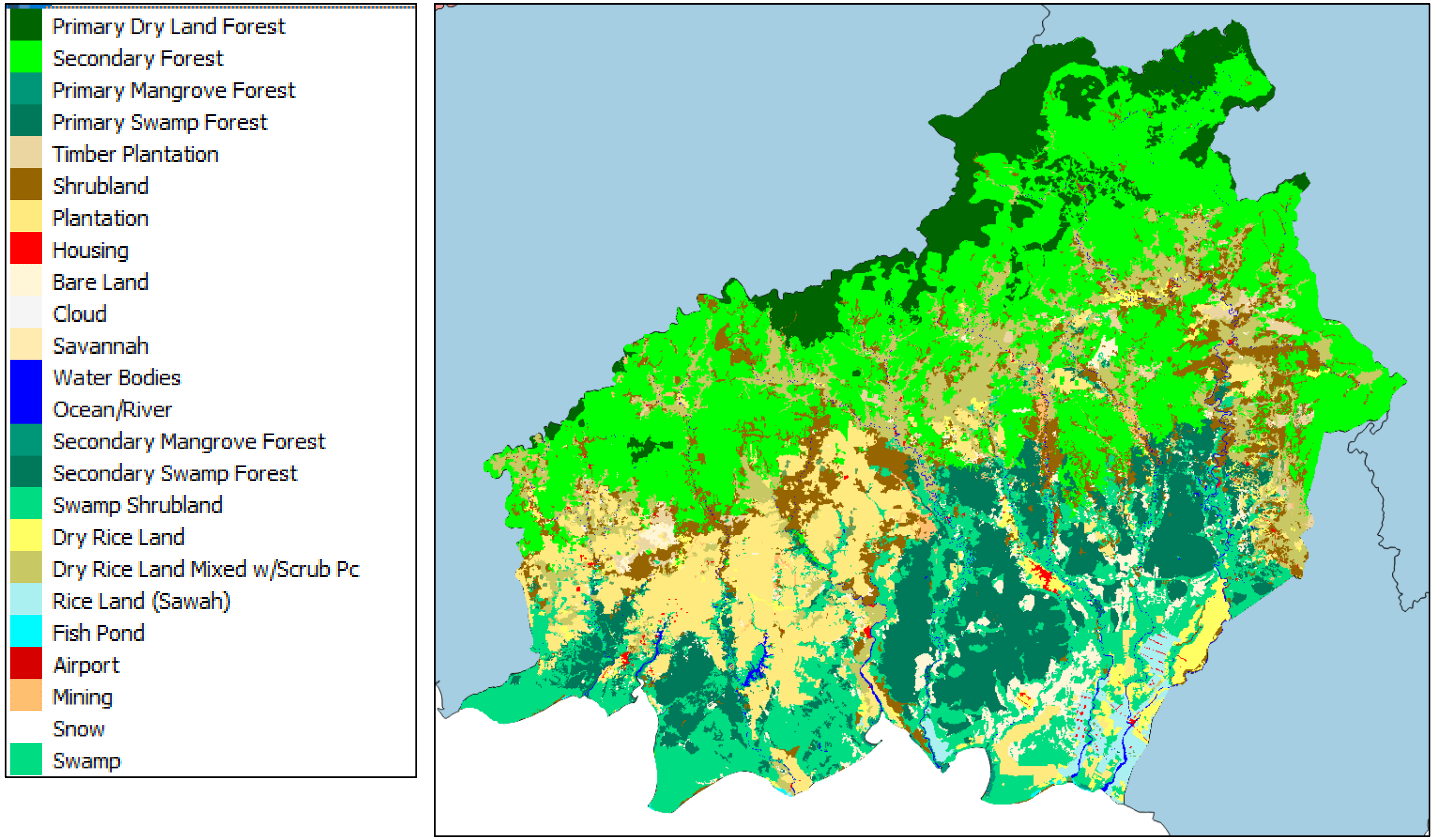
LULC map Central Kalimantan from CRISP, 2015

Data

LULC Datasets

<u>MoF LULC data</u>

- Developed by Ministry of Forestry of Indonesia
- Specific LULC classes for plantations
- <u>Exact methodology unclear, primarily based on visual interpretation and manual mapping</u>
- Based on Landsat (30x30m) imagery. For this study resampled to 100x100m
- Irregular updates between 1990 and 2015, in recent years almost yearly.



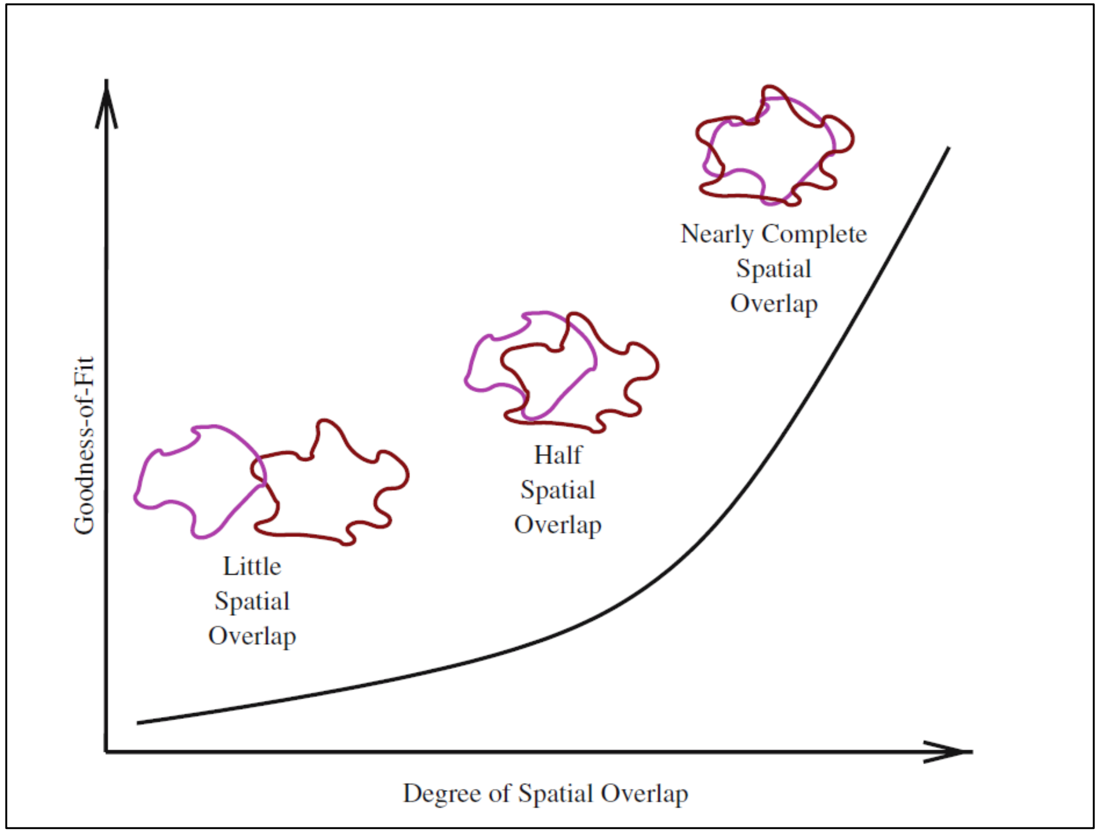
LULC map Central Kalimantan from MoF, 2015

Data

Cross-comparison LULC data sets

Mapcurves analysis to compare LULC data sets

- Shows similarity between categorical maps (like LULC maps) by using one map as original and one as reference and calculating overlap of each LULC class of original with LULC class of reference
- Indication of consistency in spatial overlap between LULC classes of two maps
- It does not give information about relative quality of maps



Principle of Mapcurves analysis

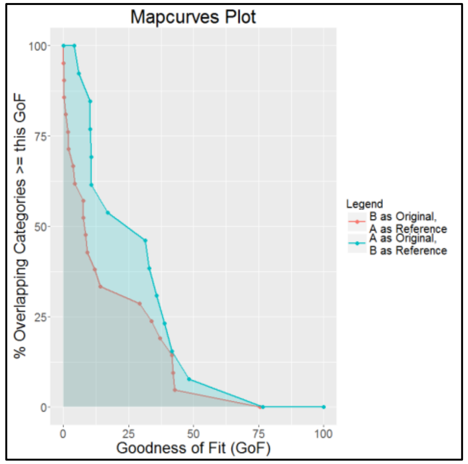
Hargrove, W.W., Hoffman, F.M., Hessburg, P.F., 2006. Mapcurves: A quantitative method for comparing categorical maps. J. Geogr. Syst. 8, 187–208. doi:10.1007/s10109-006-0025-x

Data

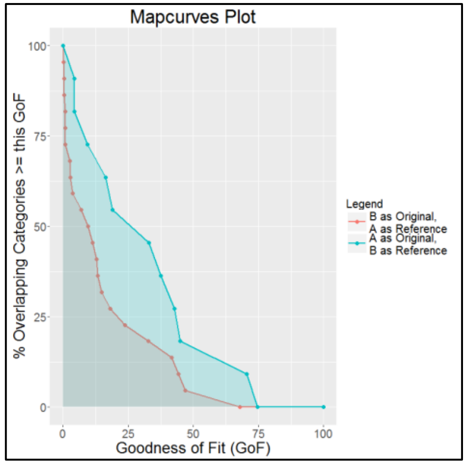
Cross-comparison LULC data sets

Results Mapcurve analysis

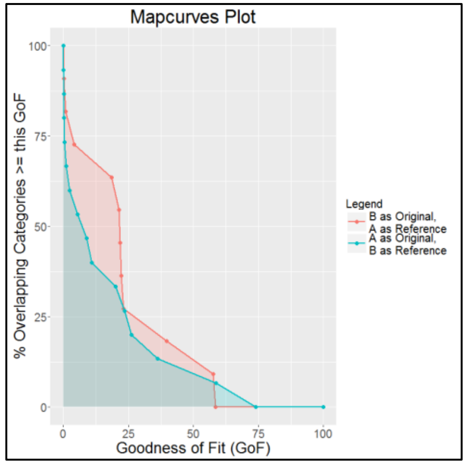
- Highest consistencies are:
  - North Sumatra: 25.7%
  - Riau: 29.1%
  - Central Kalimantan: 21.8%
- MoF data is best original map for North Sumatra & Riau, CCI for Central Kalimantan
- CRISP best reference map in all three regions



Best GoF curve North Sumatra



Best GoF curve Riau



Best GoF curve Central Kalimantan

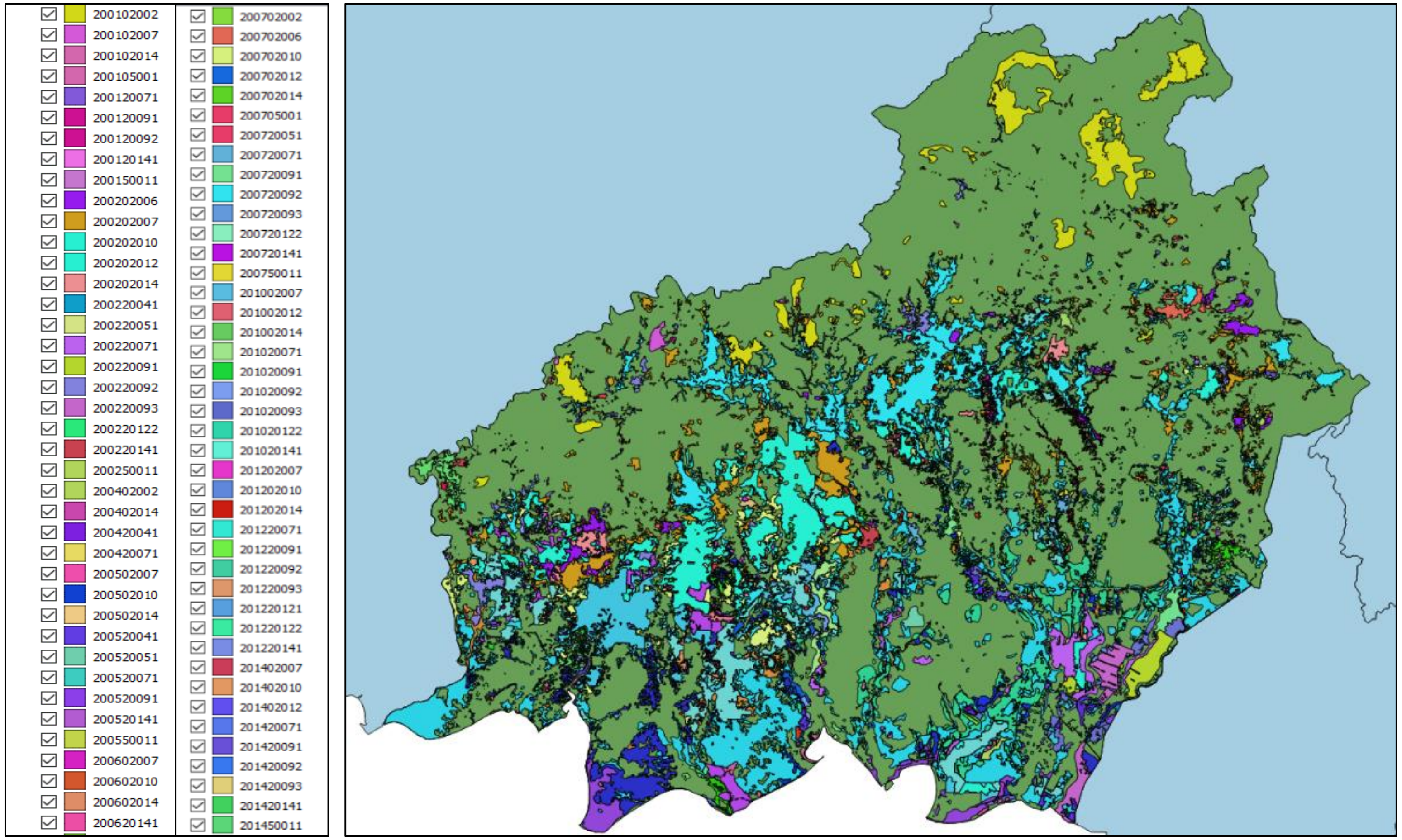
	CRISP <-> CCI		MoF <-> CCI		MoF <-> CRISP	
	CRISP -> CCI	CRISP <- CCI	MoF -> CCI	MoF <- CCI	MoF -> CRISP	MoF <- CRISP
North Sumatra	0.2281	0.2107	0.2069	0.1185	**0.2571**	0.1603
Riau	0.2019	0.2646	0.1764	0.1072	**0.2906**	0.1468
Central Kalimantan	0.1543	**0.2175**	0.1573	0.1117	0.2038	0.1137

Analysis

LULC change maps

Indication of LULC changes between map updates

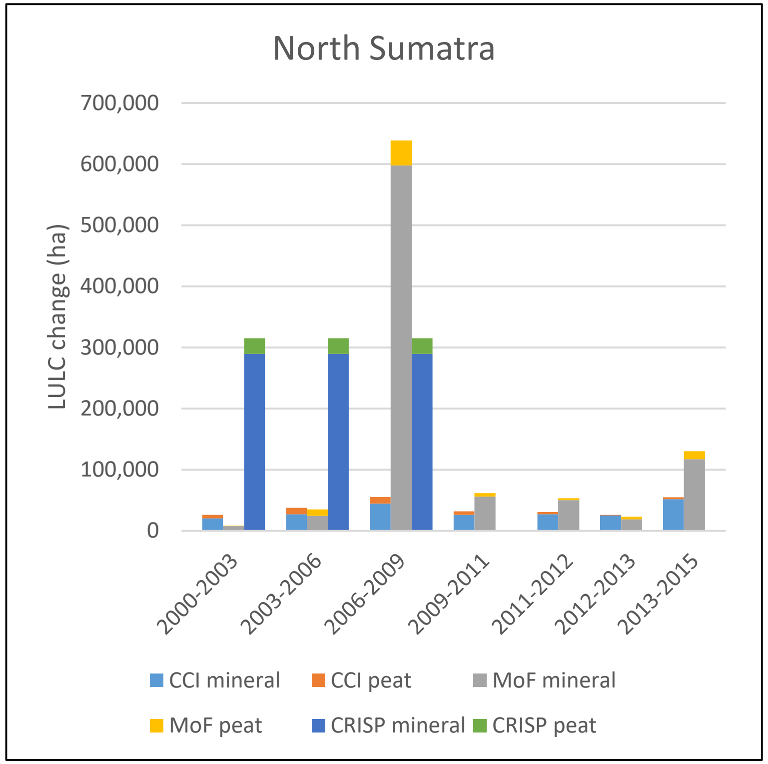
- For example: for MoF data for Central Kalimantan between 1990 and 2015 283 different types of change observed from one LULC class to another
- From this information historic GHG emissions estimates calculated

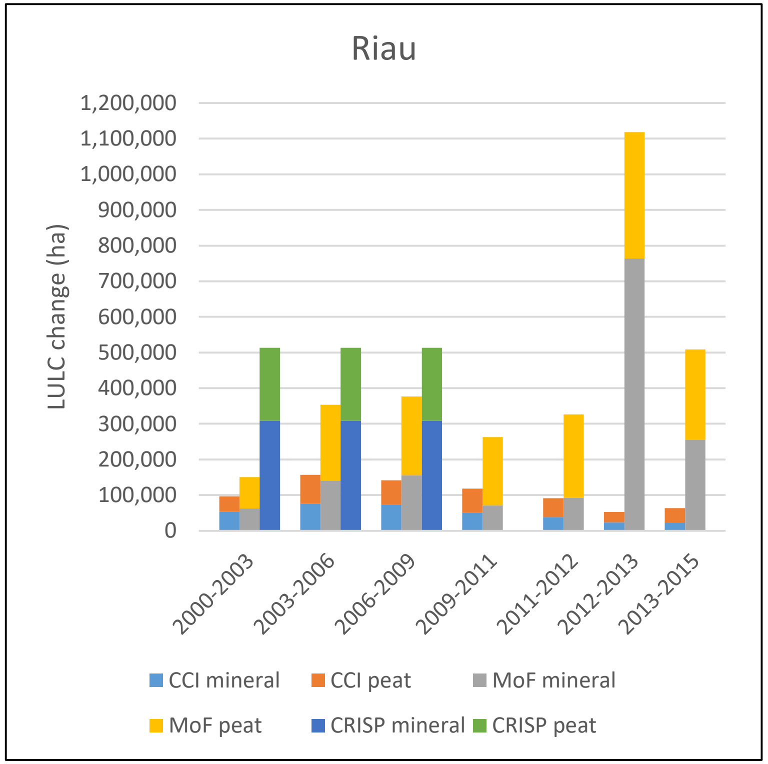


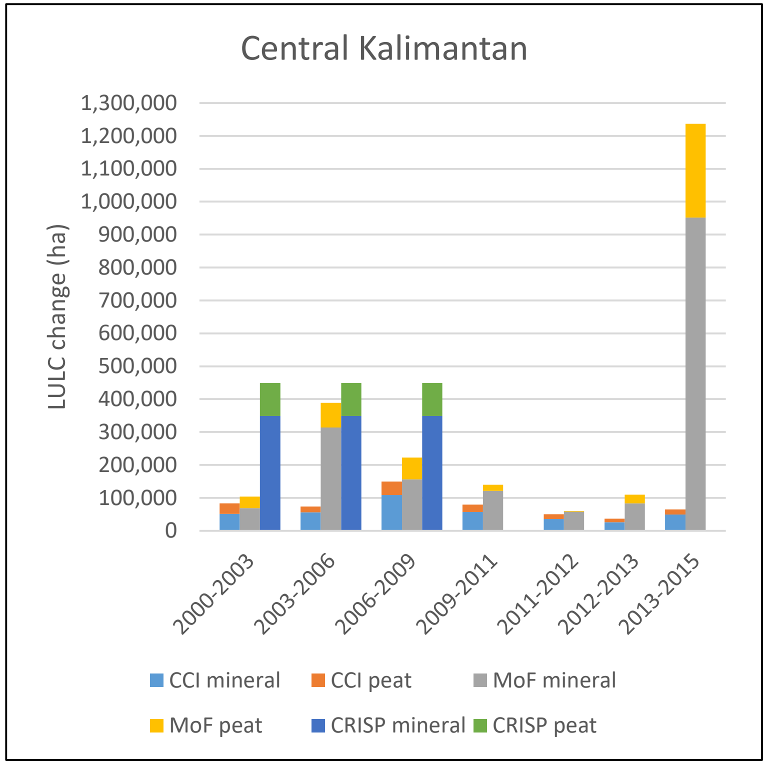
MoF-based map of LULC changes in Central Kalimantan between 1990-2015

Analysis

Cross-comparison LULC change between LULC data sets







- Some extreme LULC changes observed, likely to be related to new mapping methodology
- No clear correlation between data sets

Analysis

GHG emission factors

- Compiled by professor Susan Page, University of Leicester
- Literature study of
  - Aboveground Biomass (AGB) stock values for LULC classes, expressed in Mg C/ha
  - Carbon emission values from organic soil degradation, expressed in Mg C/ha/yr

Agus, F., Henson, I., Sahardjo, B.H., Harris, N., van Noordwijk, M., Killeen, T., 2013. Review of emission factors for assessment of CO2 emission from land use change to oil palm in Southeast Asia 7–28.

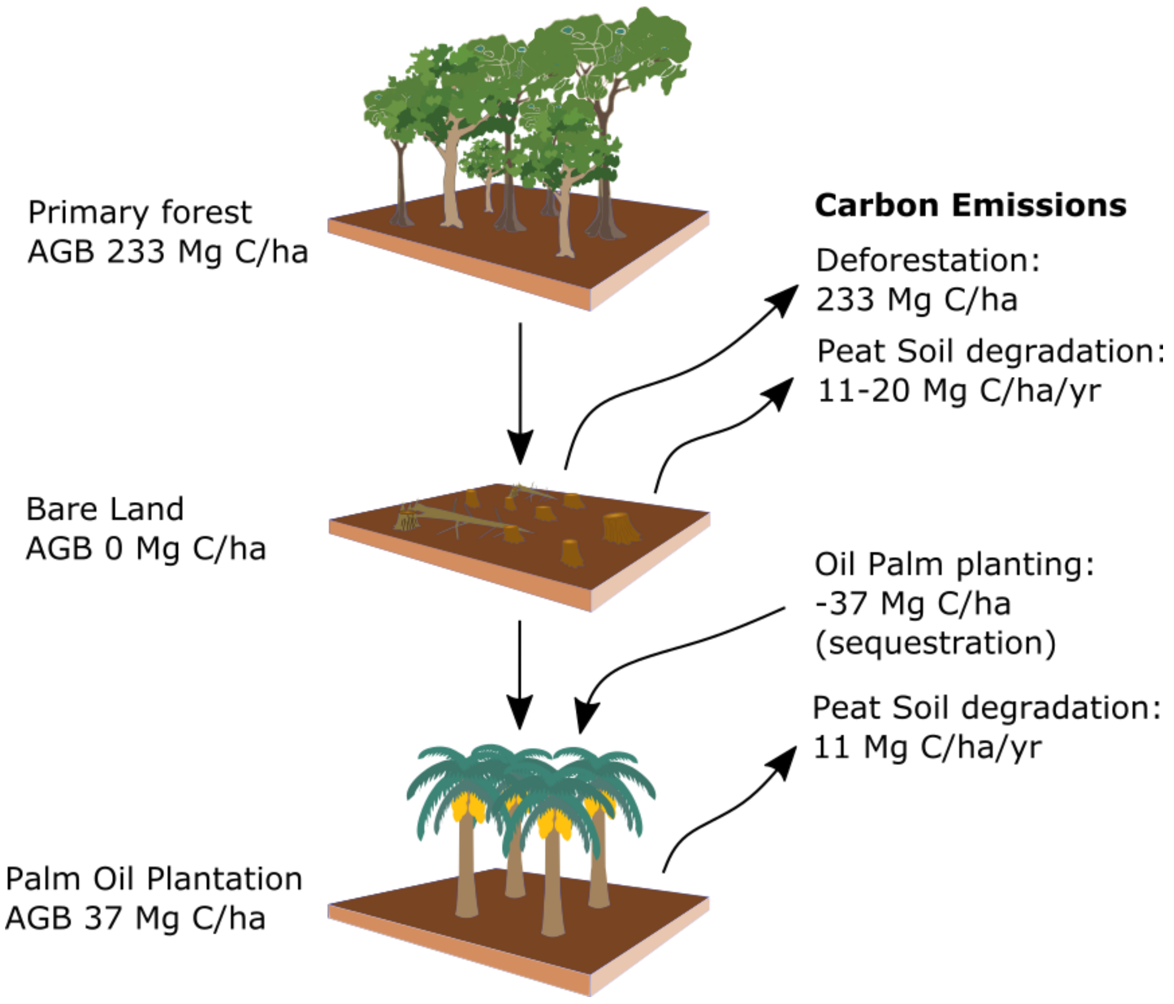
Agus, F., Gunarso, P., Sahardjo, B.H., Harris, N., Noordwijk, M. Van, Killeen, T.J., 2010. Historical Co 2 Emissions From Land Use and Land Use Change From the Oil Palm Industry in Indonesia , Malaysia and Papua New Guinea 65–88.

Collective LC class	CCI class	CRISP class	MoF class	C stock value (Mg C/ha)
Primary forest – intact, natural forest with dense canopy	Tree cover, broadleaved, evergreen, closed to open (>15%)	Lowland evergreen forest	Primary dry land forest	233±72
Secondary forest – disturbed forest with evidence of logging			Secondary dry land forest	128±53
Peatswamp Forest	Tree cover, flooded, fresh or brackish water	Peatswamp forest	Primary swamp forest	157±68
Secondary Peatswamp Forest			Secondary swamp forest	102±37
Mangrove Forest	Tree cover, flooded, saline water	Mangrove	Primary mangrove forest	116±56
Secondary Mangrove Forest			Secondary mangrove forest	101±15
Scrub – small trees and woody shrubs, early stage forest regrowth	Shrubland evergreen; sparse vegetation (tree, shrub, herbaceous cover)	Lowland open	Scrubland (on mineral soils)	31±6
Swamp Scrubland			Swamp scrubland (on peat soils)	25±9
Grassland – dry soils			Savannah	3±1
Plantations	Cropland, irrigated or post-flooding	Large scale oil palm plantations	Plantations	37±10
Timber Plantations			HTI (hutan temanan industri)	41±17
Rice Land			Rice land	4±2
Agroforestry (mixed tree crops)	Mosaic cropland	Lowland mosaic		65±18
Settlements	Urban areas	Urban	Housing	7±3
Bare land			Bare land	0
Water bodies	Water bodies	Water	Bodies of water, fish pond	0

Analysis

GHG emission estimation model

- Initial calculation of LULC change between updates, which class changed into another class
- Then calculation of carbon emissions/sequestration related to AGB loss/gain
- If change occurred on organic soils, then yearly emissions from soil degradation added



Sketch of GHG estimation model

agrimetrics

Analysis

GHG emission tables

Tables showing GHG emissions calculated from LULC data between two updates, using carbon conversion factors

- GHG emissions split between AGB and soil emissions

LULC class at t0	LULC class at t1	Hectare change	AGB emission factor (Mg C/ha)	AGB emissions (Mg C)	Soil emission factor (Mg C/ha/yr)	Soil emissions (Mg C)	Total emssions (Mg C)
Tree cover, broadleaved, evergreen, closed to open (>15%)	Cropland, rainfed	930	222	206460	14	130200	336660
Tree cover, broadleaved, evergreen, closed to open (>15%)	Cropland, irrigated or post-flooding	9	196	1764	11	990	2754
Tree cover, broadleaved, evergreen, closed to open (>15%)	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	53047	168	8911896	14	7426580	1633847 6
Tree cover, broadleaved, evergreen, closed to open (>15%)	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	13793	168	2317224	14	1931020	4248244
Tree cover, broadleaved, evergreen, closed to open (>15%)	Shrubland	228	202	46056	5	11400	57456
Tree cover, broadleaved, evergreen, closed to open (>15%)	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	161	230	37030	0	0	37030

Total emissions: 21020620 Mg C in 10 years.

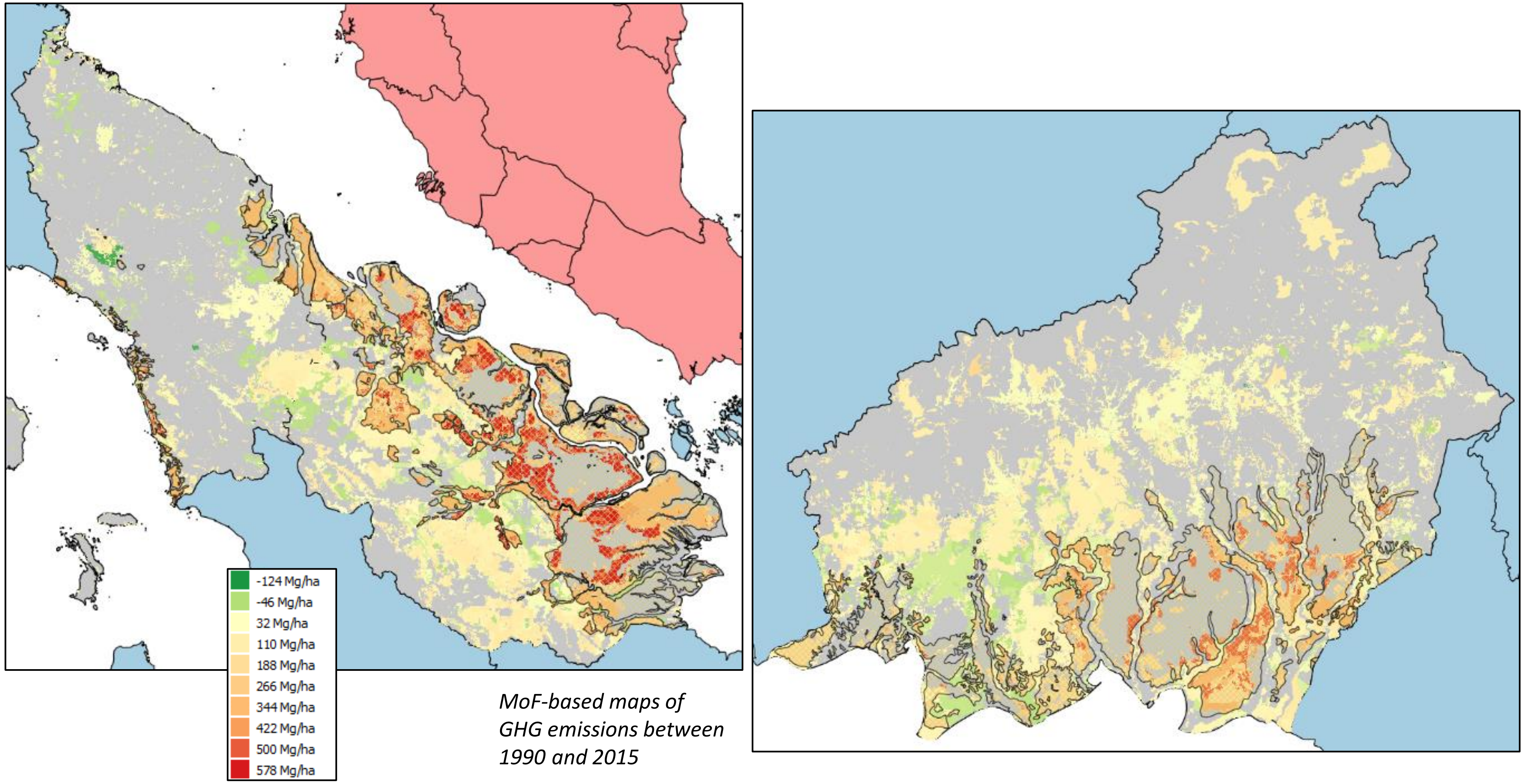
Yearly emissions: 2102062 Mg C per year.

Analysis

GHG emission maps

Maps showing GHG emissions between two map updates

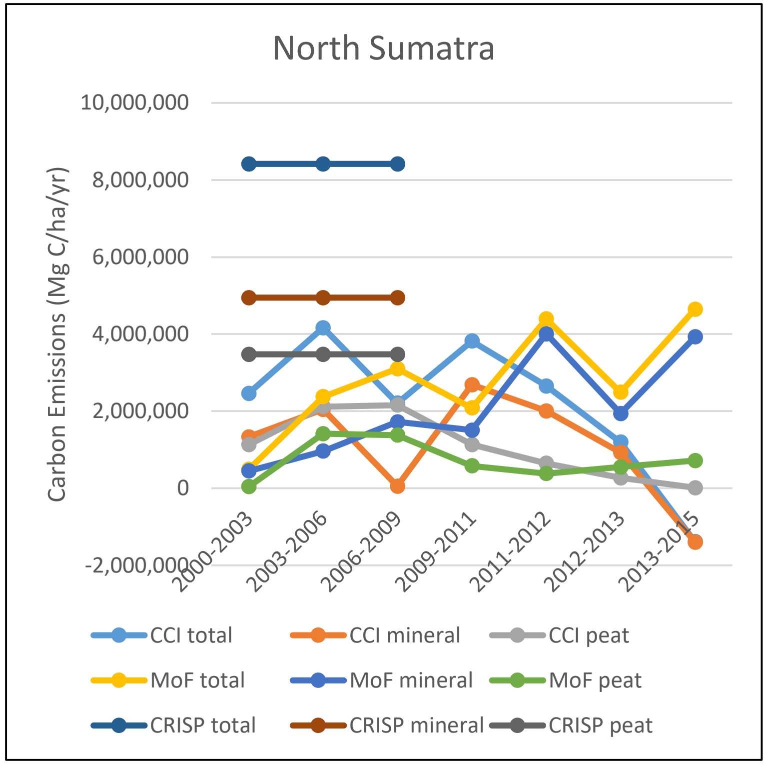
- Carbon emissions and sequestration mapped
- High carbon emissions observed in peat soil areas

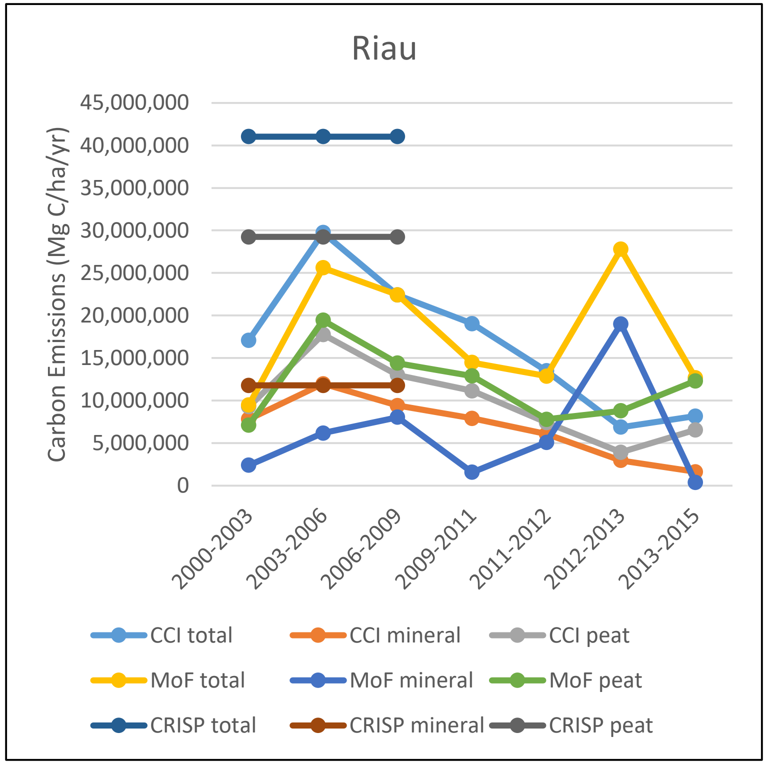


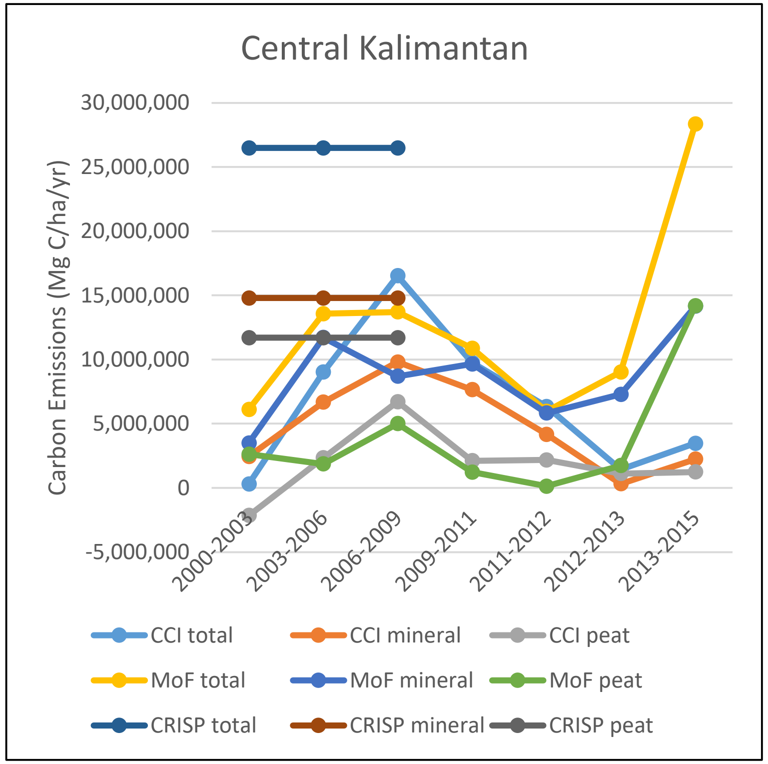
MoF-based maps of GHG emissions between 1990 and 2015

Analysis

Cross-comparison GHG emissions different LULC data sets







- In general large variability observed, CRISP emissions higher than from CCI and MoF data
- Extreme GHG emissions for MoF 2015 in Central Kalimantan, likely to be related to new mapping methodology
- Some consistency between peat soil emissions for MoF and CCI in all areas

Analysis

Cross-comparison GHG emissions different LULC data sets

- Tables comparing estimates of GHG emissions from different LULC data sets

2000-2010/2011						
Emissions per year (Mg C yr^{-1})						
North Sumatra						
	CCI (2000-2010)		CRISP (2000-2010)		MoF (2000-2011)	
Mineral	1,332,551	34.5	3,473,117	58.7	871,984	34.6
Peat	2,526,168	65.5	4,943,071	41.3	1,651,461	65.4
Total	*3,858,718*		*8,416,188*		*2,523,446*	
Riau						
Mineral	9,533,148	33.2	29,246,758	28.7	4,676,420	17.0
Peat	19,174,905	66.8	11,784,303	71.3	22,905,655	83.1
Total	*28,708,052*		*41,031,060*		*27,582,075*	
Central Kalimantan						
Mineral	6,698,051	62.3	11,693,997	55.9	7,229,204	59.1
Peat	4,055,255	37.7	14,791,021	44.1	4,997,529	40.9
Total	*10,753,306*		*26,485,018*		*12,226,733*	

2010/2011-2015				
Emissions per year (Mg C yr^{-1})				
North Sumatra				
	CCI (2010-2015)		MoF (2011-2015)	
Mineral	491,073	47.8	4,036,280	82.5
Peat	536,465	52.2	857,838	17.5
Total	*1,027,538*		*4,894,117*	
Riau				
Mineral	4,054,158	32.12	4,671,123	23.2
Peat	8,571,318	67.88	15,443,351	76.8
Total	*12,625,476*		*20,114,473*	
Central Kalimantan				
Mineral	2,811,681	58.5	8,277,973	44.2
Peat	1,994,455	41.5	10,472,336	55.9
Total	*4,806,135*		*18,750,309*	

Discussion

Methodology

- This study not intended to get realistic carbon emission estimates.
- Simplistic model, not taking into account:
  - Emissions from other GHG gases (N_20, CH_4)
  - Emissions related to fires
  - Continued degradation of peat soils after analysis period

Fires in Central Kalimantan

Discussion

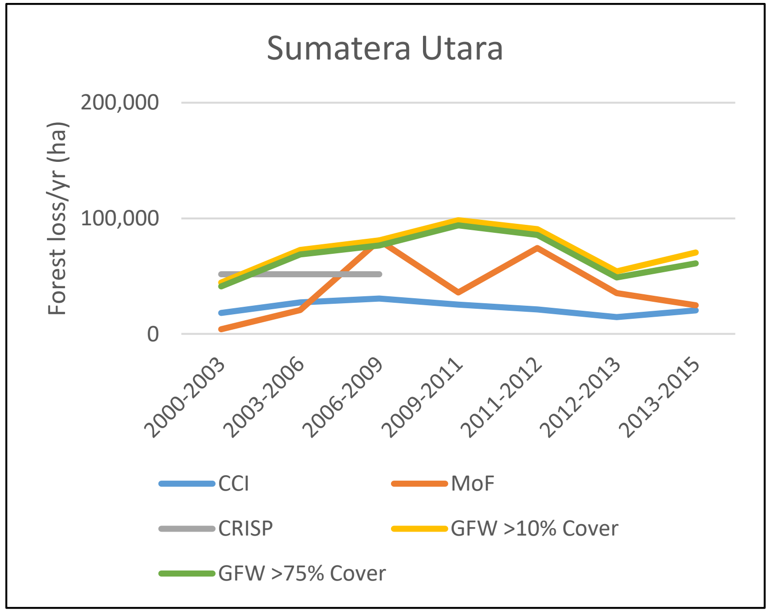
Results

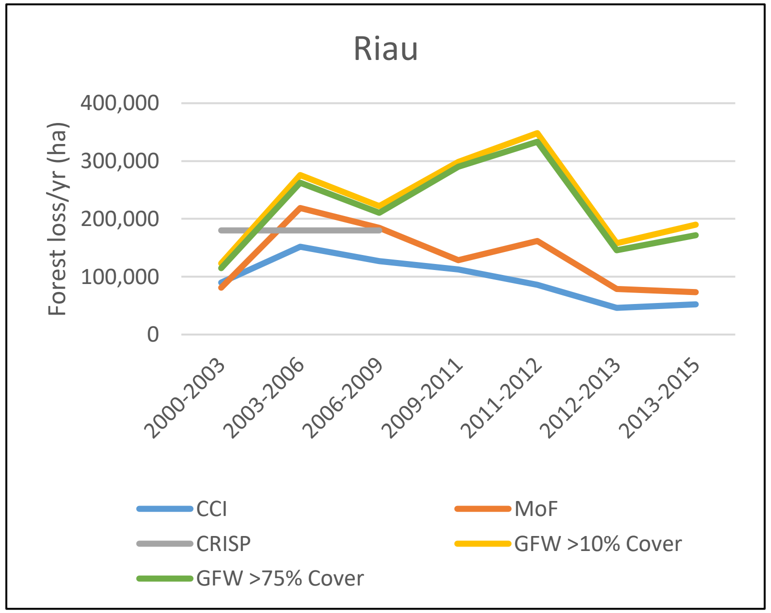
- GHG results highly variable
  - Obvious changes in mapping methodology
  - Difficulties to assign AGB values to vague class descriptions
  - Historic satellite data sources highly variable
    - Spatial resolution
    - Temporal resolution & completeness data archive
    - Quality of data (clouds, sun angles)
- Recommended LULC data set for GHG estimations
  - MoF for Indonesia
  - CRISP for rest of SE Asia, if updates are methodological consistent

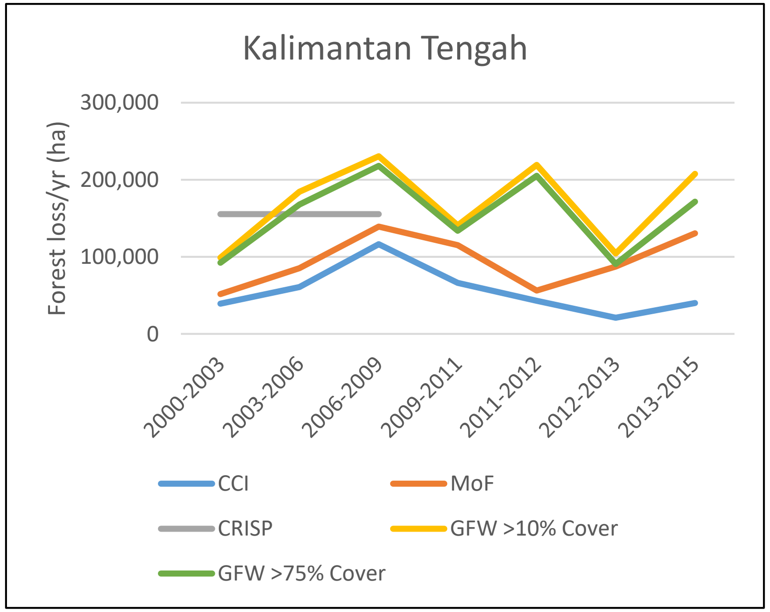
Criteria	CCI	CRISP	MoF
Scientific soundness	+	+	-/+
Geographical coverage	+	+	-/+
Spatial resolution	-	-/+	+
Temporal resolution	+	-	+
LULC class definition	-	+	+
Total	*+1*	*+2*	*+3*

Recommendations

- What would be needed for improvement
  - Consistency in class definitions and methodology for LULC mapping
  - Class definition focused on PO industry
  - Combination and referencing with other data (forest loss from GFW, fire data, ground truth)
  - Use of new-generation data sources (Landsat 8, Sentinel-1 radar, Sentinel-2, Planet, LiDAR)







Questions?