Carbon Footprint of Indonesian Palm Oil Production: a Pilot Study*

Background

In the last five years Indonesian palm oil production grew by 13.41% per year, with growth in export at 16.24% per year and slow growth in domestic consumption. Oil palm production in Indonesia and Malaysia is now in the focus of the debates on Biofuel and Carbondioxide (CO_2) and other greenhouse gas (GHG) emissions, through its association in the public debate with deforestation and (over)use of peatland. The potential use of palm oil as biodiesel to reduce dependency on, and emissions from, the use of fossil fuel has focused debate on the emissions caused by the conversion of land to oil palm and subsequent steps in the production.

Carbondioxide (CO_2) and other greenhouse gas emissions due to the production of palm oil can be attributed to three phases of the production process:

a. the initial conversion of preceding vegetation into a palm oil plantation, usually based on 'land clearing', leading to a 'C debt'

b. the balance of emission and absorption during the growth cycle of the oil palms, depending on growth rate, green manure and organic waste management and fertilizer practices, leading to a time-averaged C-stock that influences 'C debt' and repay time,

c. transport to the refinery followed by CPO and kernel production, transesterification into biofuel and further transport to the end users.

A comprehensive accounting system on carbon and other GHG emissions of biofuel production of oil palm has to include the whole life cycle assessment (LCA) through a life cycle inventory (LCI) (ISO, 1997).

Objectives

The overall objectives of this study are:
1. To estimate carbon emission from land conversion to oilpalm plantation,
2. To estimate carbon emission from oilpalm plantation establishment and management,
3. To enhance in-house capacity of oil palm community in conducting such study

Research Site

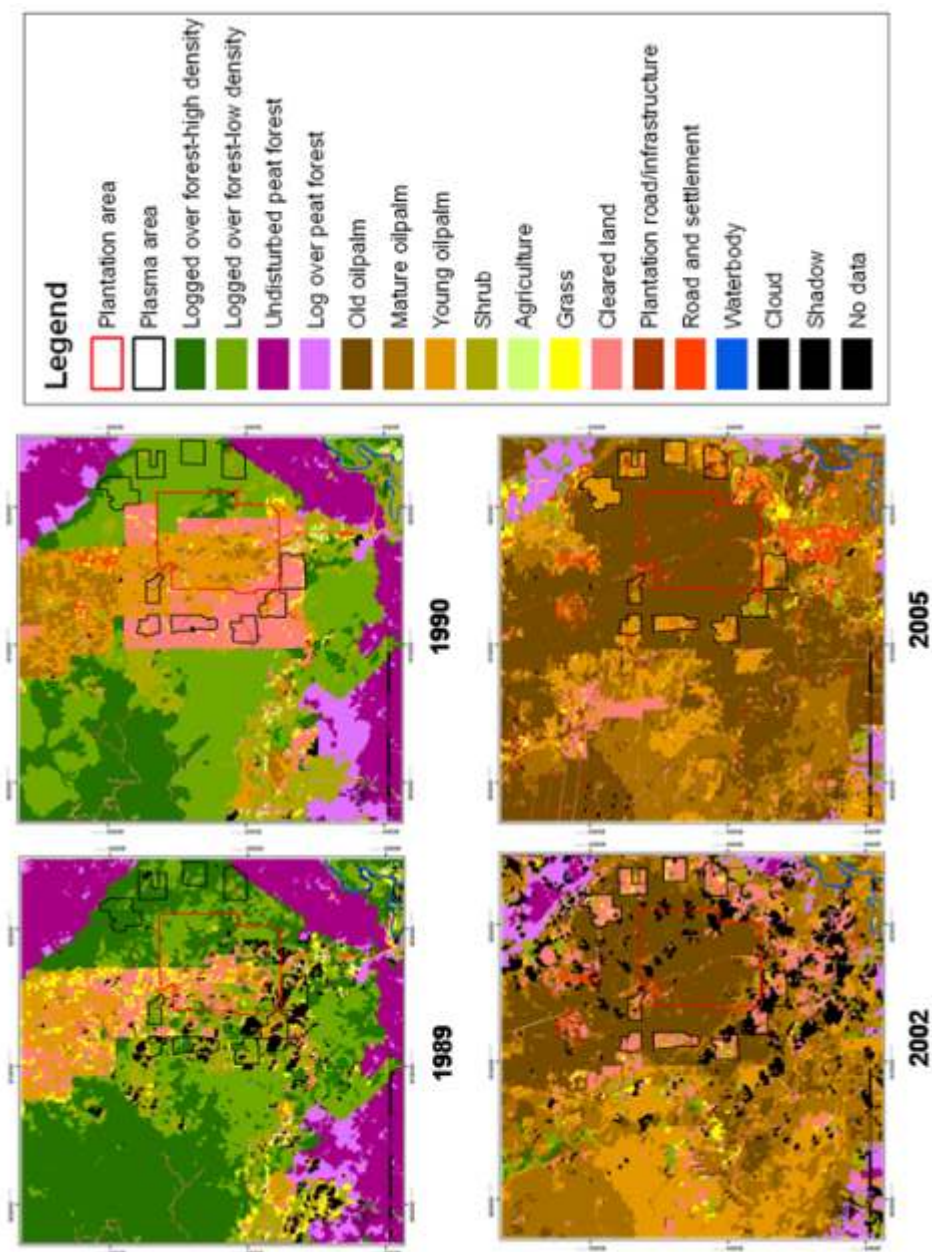The two pilot areas are located in Sumatra (Site 1 estate) and Kalimantan (Site 2 estate).
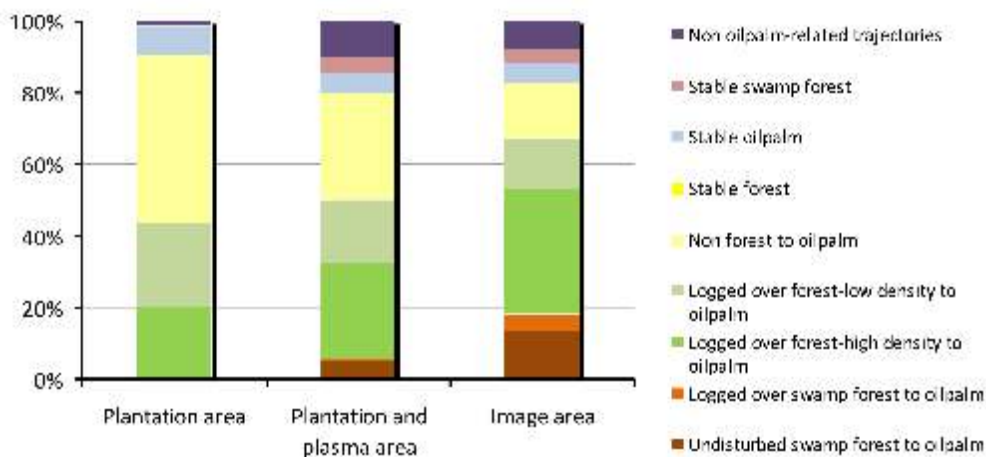

Map of Location

Result

Land cover trajectories

Land cover trajectories analysis of Site 1 (established in the early 1990's) estate clearly showed that more than 40% of conversions within the plantation area were from logged-over forest. Nearly half of it was high-density logged-over forest area. In plantation-plasma area, almost 50% of oil palm was converted from forest, with 27% of it was from high-density logged-over forest and 5% from undisturbed swamp forest. In the surrounding area, 67% of oil palm was converted from forest. From that amount, 12% was undisturbed swamp forest and 34% was high density logged-over forest.
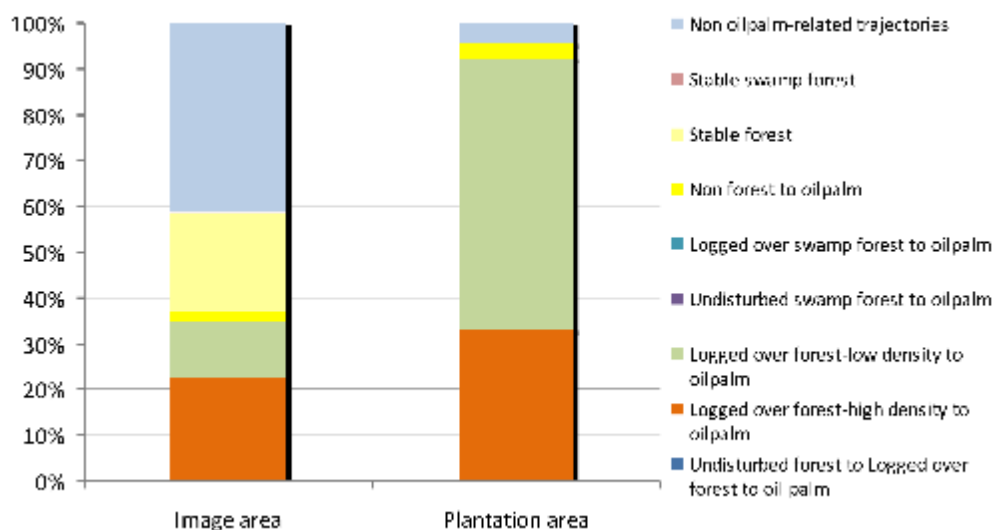
Legend

- Plantation area
- Plasma area
- Logged over forest-high density
- Logged over forest-low density
- Undisturbed peat forest
- Log over peat forest
- Old oilpalm
- Mature oilpalm
- Young oilpalm
- Shrub
- Agriculture
- Grass
- Cleared land
- Plantation road/infrastructure
- Road and settlement
- Waterbody
- Cloud
- Shadow
- No data

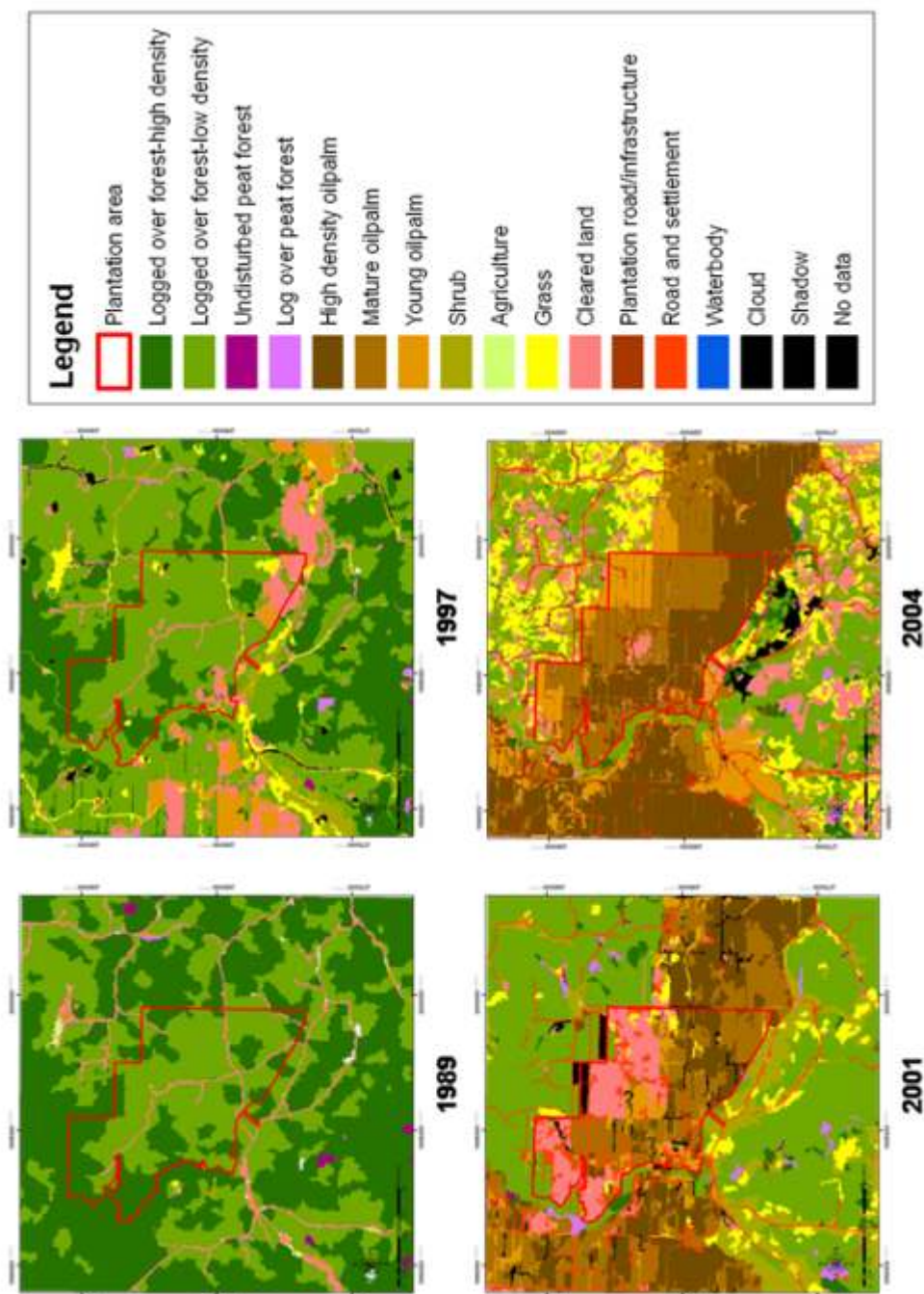*Time series land cover map of site 1 estate*

Summary of land cover trajectories in Site 1 estate and surrounding

In Site 2 (established in the early 2000's), the surrounding area was still undergoing some logging activity. Conversions from undisturbed forest to logged-over forest is a strong indication of this on going process. Conversion to oil palm was only located in less than 35% of the observed area. Inside plantation area, more than 90% of oil palm area were converted from forest, 30% of it was high density logged-over forest.


Summary of land cover trajectories in Site 2 estate and surrounding area

Legend

- Plantation area
- Logged over forest-high density
- Logged over forest-low density
- Undisturbed peat forest
- Log over peat forest
- High density oilpalm
- Mature oilpalm
- Young oilpalm
- Shrub
- Agriculture
- Grass
- Cleared land
- Plantation road/infrastructure
- Road and settlement
- Waterbody
- Cloud
- Shadow
- No data

1997

2004

1989

2001

Time series land cover map of site 2 estate

C-stock estimation in land covered by vegetation other than oil palm at plot level

Above ground C-stock in logged-over forests in Site 1 and Site 2 are markedly different. Logged-over forests in Site 1 contain much higher number of large trees which leads to much higher C-stock than those in Site 2, due to harvesting. It is interesting to note here that whilst the total aboveground C-stock in logged-over forest in Site 1 nucleus plantation is almost double than those in Site 2, those from living biomass is comparable.
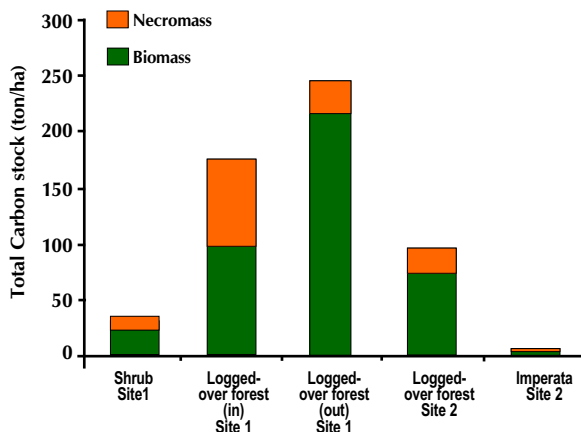
C-stock from necromass and standing biomass in non-oil palm landcover within nucleus and plasma oilpalm plantation in Site 1 dan within nucleus plantation in Site 2

Time-averaged C-stock of oil palm at plot level

Time-averaged C-stock of oil palm plantation estimation was conducted comprehensively, taking into account all components of total biomass of oil palm, soil organic matter, preceding necromass, current necromass, root, understorey, recycling and other additional organic inputs. Therefore, sampling for measurement was designed to cover variation in factors that determine each of the components. Four zones are distinguished within the palm system, and used for a stratified random sampling (two samples per strata per tree).
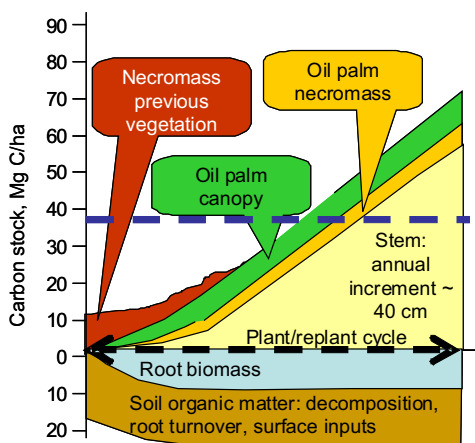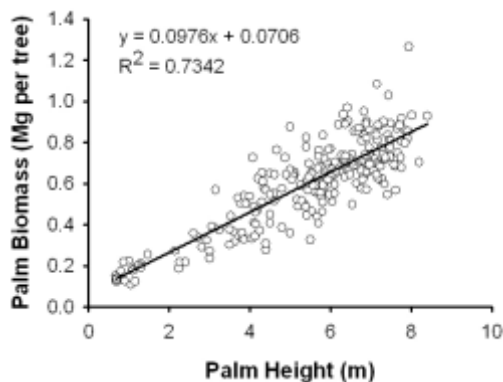

Time-averaged C-stock in oil palm plantation from each component

Frond stack

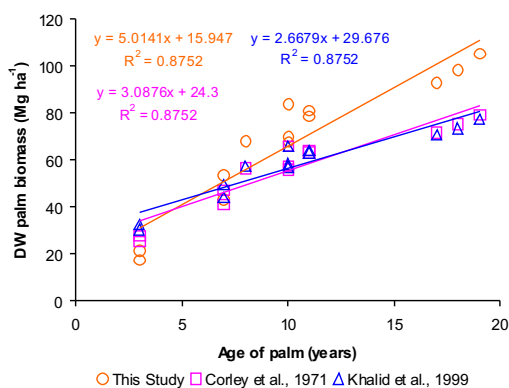Green (or EFB) zone

Weeded circle

Palm

Path

Sampling stratification of above and belowground of C-stock

Total biomass of palm was partitioned into three components: trunk biomass, rachis biomass (including petiole) and frond bases biomass. The total palm biomass was estimated through allometric equation. The allometric equation was developed by measuring, palm height, palm diameter, total number of leaf, frond base biomass and frond biomass.

$y = 0.0976x + 0.0706$
$R^2 = 0.7342$

Allometric equation as a function of palm height

$y = 5.0141x + 15.947$
$R^2 = 0.8752$

$y = 2.6679x + 29.676$
$R^2 = 0.8752$

$y = 3.0876x + 24.3$
$R^2 = 0.8752$

○ This Study □ Corley et al., 1971 △ Khalid et al., 1999

Correlation between age of palm and palm biomass (Mg ha^{-1})

Based on stem diameter, stem height and frond canopy biomass, aboveground C accumulation in oil palm biomass was estimated of about 5 t C ha^{-1} per year. The aboveground time-averaged C-stock of oil palm plantation is similar between the two estates i.e., 38.8 ton ha^{-1} and 39.2 ton ha^{-1} respectively for Site 1 and Site 2, with 25 years planting cycle. This calculation takes into account tree biomass and empty fruit bunches that are returned from the mills to the plantation.

Up-scaling and carbon debt from land use conversion

In general Site 1 estate's emissions and sequestration per unit area are higher than those in Site 2 in each of the region under study. The sequestration per unit area in Site 2 within the estate area is lower than that of Site 1 because of the differences in percentage of total areas which were planted by the end of this study period (91% in Site 1 estate and 84% in Site 2 estate). Emissions from plasma areas in Site 1 are 35 % lower than that of the estate due to more conversions from land cover of higher C-stock initially.

Annual emissions and sequestration per unit area

Site (area*)	Total area (ha)	Annual sequestration	Annual emission	Net annual emission	Total annual sequestration	Total annual emission	Total annual net emission
		(ton ha^{-1} per year)			(ton per year)		
Site 1 (estate)	5,746.32	1.64	25.31	23.67	9,414.19	145,425.47	136,011.29
Site 1 (plasma)	19,364.22	2.54	18.81	16.27	49,134.87	364,251.67	315,116.80
Site 1 (image)	52,144.56	0.48	25.83	25.35	25,113.89	1,346,733.82	1,321,619.94
Site 2 (estate)	3,650.86	0.10	12.41	12.39	378.83	45,296.98	45,241.92
Site 2 (image)	16,898.71	3.28	20.36	17.08	55,449.27	344,086.40	288,637.13

* Estate: considers only the nucleus estate area
 Plasma: considers plasma area
 Image: considers the large surrounding areas of estate and plasma

Conclusion and Recommendation

In order to address carbon debt, threes level of engagement from plantation companies could be taken, while international rules are still under discussion:

- To avoid carbon debt, conversion should be conducted only from shrub and grassland with an aboveground C stock of less than 40 ton C ha^{-1}.
- To reduce/minimize carbon debt, companies should set aside conservation areas which are hot spots of C-stock, to allow natural succession to happen and therefore to achieve co-benefit of biodiversity conservation as well as reducing C-stock emission.
- To neutralize, rehabilitate larger areas in different places to achieve comparable sequestration, buy CER's.

The next phase of our study will try to capturing generalities and specificities in Indonesia, reducing uncertainty of estimation in plot and estate level and being more comprehensive in including all components, especially in within plantation management through some modeling.