SECTION 10: SOIL PROPERTIES AND CARBON STOCKS

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10.1. Introduction:

The integrated biodiversity survey compared a range of land-use practices in the Bungo-Tebo district in the lowland peneplain of Jambi. The landscape consists of an undulating plain, formed as marine sediment in the tertiary period (Van Noordwijk *et al.*, 1995, 1997b). Most of the land in the interfluves is covered by highly leached oxisols/ultisols, with more recent sediment and generally higher fertility near the rivers where inceptisols and entisols dominate. The survey was intended to highlight the effects of land use on biodiversity, so variation in soil types would be minimized in the selection of sample points. As older human settlements, and hence an important land use type in the form of extensive rubber agroforest, are usually found close to the streams and rivers, not all sampling points could be located in the oxisol/ultisol complex.

Data on conservative soil properties such as texture, pH and exchangeable cations were collected to check the extent to which all variation in biodiversity can be attributed to land use and management, rather than to *a priori* differences in soil and vegetation. Soil organic matter content and bulk density are likely to be influenced by land use, and may themselves become factors influencing development of vegetation and ecosystem function. The above-ground biodiversity sampling protocol (Gillison *et al*., this volume) includes an estimate of woody plant basal area. For the full characterization of terrestrial carbon stocks the ASB project has developed a protocol quantifying biomass in trees, understorey vegetation, surface litter and dead wood, and soil carbon in the top 30 cm of the profile. Data were collected with this protocol to help calibrate the simpler assessment of woody plant basal area.

Decline of soil organic carbon content of (former) forest soils after forest conversion is a major concern, both for the on-site fertility of such soils and for estimating the impacts of land-use change on the global C balance in the context of climate change. Effects of land-use change on soil organic carbon (C_{org}), may be difficult to quantify from limited datasets, as generally no historical data are available of C_{org} before forest conversion, and one normally has to rely on 'paired' datasets of sites still under forest and those now under other land uses. Even moderate differences in soil texture and/or pH, however, can lead to changes in C_{org} of similar magnitude as those of the land use change. Van Noordwijk *et al.* (1999) proposed to use a ratio of the measured C_{org} and a reference C_{org} value for forest (top) soils of the same texture and pH as a 'sustainability indicator'. A substantial dataset of soils on Sumatra (Indonesia) was used to derive a pedotransfer function for such a reference value (Van Noordwijk *et al.*, 1997a).

10.2. Methods:

Methods for quantifying carbon stocks were used as specified in the ASB protocol (Palm *et al.*, 1994). For the vegetation and soil macrofauna, the sampling area was based on the 40 x 5 m^2 transect, as before. All tree diameters above 5 cm in the forest plots were measured by the BIOTROP team and data were converted into aboveground biomass with an allometric equation modified from Brown (1997) on the basis of additional data collected in the Jambi area (Ketterings et al., *in prep.*):

$$Y\ (kg\ tree^{-1}) = 0.092\ Diam^{2.60}$$

where tree diameter (Diam) is measured in cm.
Understorey and herbaceous layer vegetation was measured in eight 0.25 m^2 quadrat samples (or four 1-m^2 samples for non-forest plots); total fresh weight was measured, and subsamples were collected for determining dry matter content. Diameter and length of dead wood (> 5 cm diameter) were measured within the 40 x 5 m^2 transect and converted to volume on the basis of a cylindrical form; three apparent density classes were used and ring samples were taken to assess the dry weight bulk density (g cm^{-3}) of the partly decayed wood . Surface litter (including wood < 5 cm diameter) was collected down to the surface of the mineral soil in eight 0.25 m^2 samples. To remove mineral soil particles, the litter samples were washed and sundried; subsamples were taken for dry matter content.

Soil bulk density was measured for the 0-5 cm top soil layer (8 replicates per sampling point) by carefully inserting a 165 cm^3 ring from the mineral soil surface, just below the litter layer.

Soil samples were collected (composited from 8 sample points per 200 m^2 sampling area) for the 0-5, 5-10, 10-20, 20-30 cm depth zone below the litter layer, passed through a 2 mm sieve and air-dried for analysis of texture (sand, silt, clay), pH (1N KCl), pH(H2O), P $Bray_{II}$, C_{org} (Walkey and Black), N_{tot} (Kjeldahl), exchangeable K, Ca, Mg, Na, Al and H, and effective cation exchange capacity (ECEC) by summation. All these routine soil measurements were done on air-dried, sieved soil in the soils laboratory of Brawijaya University (Malang, Indonesia) with methods consistent with those described in Anderson and Ingram (1993). In addition, a size-density fractionation of macro-organic matter based on Ludox solutions of various densities was used, as described by Hairiah *et al.* (1995, 1996a) and Meijboom *et al.* (1995), for the 0-5 and 5-10 cm depth zone. The reference value for C_{org} ('Cref') was calculated on the basis of soil texture on the basis of a large data set of Sumatran soils (Van Noordwijk *et al.* 1997a, 1998, 1999).

10.3. Field notes on sampling points:

Primary forest (BS 1,2) - two samples behind the permanent forest plots of BIOTROP but in the 25 ha reserve; the plots are on two sides of a small stream.

Logged-over forest (BS 3,4,5) - three samples: no. 3 close to the second primary forest plot, on a ridge with logging track overgrown by ferns, secondary forest regrowth and patches of undisturbed forest; no. 4 and 5 in the logged-over forest (1983) where BIOTROP has permanent plots; no. 4 includes a recent tree fall, no. 5 appears to be little affected by the logging. ***Industrial timber plantation (HTI) (BS 6,7)*** - 5-year old *Paraserianthes falcataria* plantation; no. 6 close to the road and forest edge, no. 7 in the centre of the HTI area; (the *Paraserianthes* still seemed to be affected by a moth). ***Rubber plantation (BS 8,9)*** - 8-year old intensively managed rubber established by slash-and-burn from logged-over forest, along the main logging road in Pasir Mayang; both plots are part of a 18 ha farm established by a former employee of PT IFA, and currently partly operated by share-tappers; the plantation was established from seedlings obtained from the plantation project across the river (GT1 ?) and was managed in plantation-style (but without legume cover crops). ***Jungle rubber (BS 10,11)*** - a 45 (?) year old rubber agroforest in Dusun Tuo (across the Batang Hari river from Pasir Mayang), in a landscape with a lot of newly planted rubber (mostly seedlings). ***Imperata grassland (BS 12,13)*** - in Kuamang Kuning, close to the *Imperata* plots sampled in 1996. ***Cassava (BS 14,15)*** - in Kuamang Kuning, close to *Imperata* plots; part of the fields was opened by tractor, apparently for planting oil palm. ***Chromolaena fallow (BS 16)*** - in Dusun Tuo, close to the jungle rubber (10 and 11); a 3 (?) year old fallow, about to be re-opened for planting rice.

10.4. Results and Discussion:

Soil characteristics are summarized in Table 10.1. Soil texture data show that the sampling points belong to essentially three groups:

- soils with less than 20% clay in the top 5 cm (sampling points BS 1, 2 ,4, 5 and 6),
- soils with 20-40% clay in the top 5 cm (BS 3, 7, 10, 11, 12, 13, 14, 15 & 16),
- soils with more than 40% clay in the top 5 cm (sampling points BS 8 and 9).

These differences are probably *a priori* and not caused by current land use. The location of the rubber plantation (8&9) on a soil of higher clay content is probably typical for the position of rubber in the landscape. Comparisons between sites in different classes have to take these soil differences into account.

All sites were acid, with the highest pH (H_2O) values found in the *Imperata* and Cassava sites around the transmigration village, possibly indicative of past lime applications (note that pH(KCl) values show less variation) and the *Chromolaena* fallow plot.

Soil organic carbon (C_{org}) and total N (N_{tot}) showed a strong decrease with depth, justifying the separation of the 0-5 and 5-10 cm depth layer. Available soil phosphorus levels were very low in sample 8, and relatively high in 10 and 11. The effective cation exchange capacity was low (< 12 $cmol_e\ kg^{-1}$) in all soils. Al saturation was high in all soils, but lowest in sites 12 and 13. Overall, a weak buyt statistically significant relationship was found between Al-saturation and $pH(H_20)$:

Al-sat = 104.0 – 12.5 * $pH(H_2O)$ [$n = 63$, $r^2 = 0.23$, $P < 0.001$]

Al-sat = 99.2 – 14.8 * pH(KCl [$n = 63$, $r^2 = 0.05$, $P = 0.045$]

Bulk density measurements (Table 10.2) showed substantial differences between the plots; tracks in the logged over forest, the young industrial timber plantation and the Cassava and *Imperata* plots had a bulk density substantially higher than that of natural forest; the logged over forests outside the skidding track had a high coefficient of variation in bulk density, indicating patch-wise soil compaction

The differences between C_{org} of the topsoil between the sampling points probably reflect differences in soil texture as well as land use. When the C_{org}/C_{ref} ratio is compared, the data appear to reflect land use effects more clearly (compare Figure 10.1A and 10.1C). The size/density fractionation data (Figure 10.1C) failed to differentiate clearly between the land uses.

Table 10.1. Measured soil parameters

No.	LUT	Depth	Texture			pH_	pH_	C_org	N_tot	C/N	P_bray_{II}	Exchangeable cations						ECEC	Al_sat
			Sand	Silt	Clay	H_2O	KCl			ratio		K	Na	Ca	Mg	Al	H		
		cm	%					%	%		mg kg^{-1}	$cmol_e\ kg^{-1}$							%
1	NF	0_5	62	24	14	4.0	3.5	4.01	0.28	14.3	10.2	0.16	0.34	1.65	0.41	4.19	1.16	7.91	53.0
1	NF	5_10	62	20	18	4.7	3.8	1.86	0.14	13.3	4.19	0.09	0.24	1.54	0.51	4.19	0.85	7.42	56.5
1	NF	10_20	62	20	18	4.9	3.9	1.20	0.09	13.3	2.09	0.08	0.22	1.54	0.10	3.59	0.89	6.42	55.9
1	NF	20_30	64	18	18	4.9	4.0	0.80	0.06	13.3	1.69	0.06	0.22	1.03	0.07	3.53	0.83	5.74	61.5
2	NF	0_5	67	22	11	4.2	3.5	3.21	0.19	16.9	9.19	0.19	0.31	1.54	0.62	3.71	1.27	7.64	48.6
2	NF	5_10	69	19	12	4.7	3.8	2.01	0.13	15.5	6.69	0.11	0.24	1.54	0.10	3.53	0.83	6.35	55.6
2	NF	10_20	66	17	17	4.8	3.7	1.61	0.12	13.4	2.69	0.11	0.23	3.61	1.03	3.17	0.93	9.08	34.9
2	NF	20_30	67	17	16	4.8	4.0	0.96	0.07	13.7	1.69	0.09	0.20	1.54	0.1	2.99	1.06	5.98	50.0
3	LOF	0_5	54	8	38	4.5	3.7	1.85	0.13	14.2	2.69	0.12	0.25	1.55	0.51	2.93	0.8	6.16	47.6
3	LOF	5_10	81	10	9	5.2	3.8	1.53	0.12	12.8	5.19	0.10	0.29	2.06	0.21	2.69	0.24	5.59	48.1
3	LOF	10_20	67	13	20	5.0	4.0	1.36	0.11	12.4	4.69	0.08	0.20	1.03	0.51	2.69	0.74	5.25	51.2
3	LOF	20_30	65	13	22	4.8	4.0	1.20	0.08	15.0	3.16	0.06	0.18	1.02	0.51	3.02	0.99	5.78	52.2
4	LOF	0_5	81	11	8	4.5	3.6	4.66	0.28	16.6	18.0	0.15	0.25	1.12	1.02	4.15	1.09	7.78	53.3
4	LOF	5_10	79	10	11	4.0	3.5	3.13	0.18	17.4	5.19	0.11	0.25	1.55	1.34	3.29	1.38	7.92	41.5
4	LOF	10_20	77	10	13	4.6	3.7	2.09	0.12	17.4	3.69	0.09	0.25	2.57	0.41	3.29	1.38	7.99	41.2
4	LOF	20_30	74	10	16	4.7	3.7	1.85	0.12	15.4	2.69	0.08	0.28	2.37	0.21	3.41	0.95	7.30	46.7
5	LOF	0_5	79	13	8	4.2	3.3	4.41	0.28	15.8	6.19	0.20	0.39	2.06	0.31	2.69	1.65	7.30	36.8
5	LOF	5_10	79	13	8	4.5	3.8	1.91	0.12	15.9	6.13	0.10	0.28	1.12	1.22	2.97	0.97	6.66	44.6
5	LOF	10_20	76	11	13	4.8	3.9	1.61	0.10	16.1	4.65	0.07	0.22	1.33	0.41	2.97	0.73	5.73	51.8
5	LOF	20_30	75	15	10	4.8	4.0	1.27	0.10	12.7	4.15	0.07	0.16	1.22	0.61	2.67	0.66	5.39	49.5
6	HTI	0_5	84	8	8	4.4	3.9	2.78	0.17	16.4	18.5	0.18	0.38	2.04	0.61	2.61	0.47	6.29	41.5
6	HTI	5_10	82	10	8	4.3	3.9	2.15	0.13	16.5	9.10	0.06	0.19	1.33	1.22	2.67	0.72	6.19	43.1
6	HTI	10_20	79	8	13	4.8	4.0	1.67	0.10	16.7	5.64	0.06	0.14	1.54	1.02	2.31	0.77	5.84	39.6
6	HTI	20_30	74	10	16	4.8	4.1	0.50	0.05	10.0	2.66	0.04	0.13	1.22	0.31	2.55	0.60	4.85	52.6

Table 10.1. Measured soil parameters

No.	LUT	Depth	Texture			pH_ H_2O	pH_ KCl	C_org	N_tot	C/N ratio	P_bray$_{II}$	Exchangeable cations							Al sat
			Sand	Silt	Clay							K	Na	Ca	Mg	Al	H	ECEC	
		cm	%					%	%		mg kg^{-1}	cmol$_e$ kg^{-1}							%
7	HTI	0_5	46	28	26	5.2	3.8	4.21	0.28	15.0	8.78	0.41	0.62	4.68	1.56	1.33	0.87	9.47	14.0
7	HTI	5_10	45	19	36	5.2	3.9	2.11	0.16	13.2	1.20	0.21	0.45	4.16	1.14	1.89	0.21	8.06	23.4
7	HTI	10_20	43	22	35	4.8	3.6	1.78	0.14	12.7	0.69	0.19	0.43	3.12	1.04	4.23	0.80	9.81	43.1
7	HTI	20_30	43	22	35	4.8	3.6	1.62	0.11	14.7	0.19	0.12	0.38	1.87	1.25	5.14	0.90	9.66	53.2
8	RUB_P	0_5	14	27	59	4.6	3.5	5.97	0.38	15.7	1.20	0.19	0.36	2.41	0.95	3.96	2.07	9.94	39.8
8	RUB_P	5_10	14	11	75	4.5	3.7	2.95	0.18	16.4	0.19	0.12	0.29	2.10	0.31	2.81	1.25	6.88	40.8
8	RUB_P	10_20	12	16	72	4.9	3.7	1.96	0.13	15.1	0.19	0.12	0.33	1.68	0.41	2.81	0.86	6.21	45.2
8	RUB_P	20_30	11	13	76	4.9	3.8	1.86	0.12	15.5	0.19	0.1	0.32	1.52	0.94	1.63	0.71	5.22	31.2
9	RUB_P	0_5	15	41	44	4.4	3.6	3.27	0.53	6.2	10.0	0.27	0.38	1.78	0.59	5.67	1.89	9.40	60.3
9	RUB_P	5_10	13	15	72	4.8	3.7	2.41	0.31	7.8	7.50	0.13	0.36	1.62	0.42	3.23	1.21	7.65	42.2
9	RUB_P	10_20	13	18	69	4.7	3.9	2.19	0.16	13.7	1.25	0.09	0.18	1.80	1.08	3.14	1.04	7.50	41.9
9	RUB_P	20_30	12	23	65	4.5	3.9	2.13	0.14	15.2	0.18	0.05	0.17	1.57	0.63	3.36	1.08	6.82	49.3
10	J_RUB	0_5	6	70	24	5.2	3.8	6.23	0.46	13.5	41.5	0.51	0.69	2.37	0.76	5.31	2.63	10.7	49.5
10	J_RUB	5_10	7	58	35	5.1	3.8	3.97	0.28	14.2	17.2	0.23	0.63	2.12	0.42	5.05	1.49	11.1	45.6
10	J_RUB	10_20	5	54	41	5.1	3.8	2.81	0.22	12.8	10.5	0.22	0.37	1.59	0.21	4.93	1.48	8.81	56.0
10	J_RUB	20_30	5	46	49	5.1	3.8	2.13	0.19	11.2	4.78	0.13	0.31	1.26	0.31	4.88	1.15	8.37	58.3
11	J_RUB	0_5	9	52	39	5.4	3.9	5.76	0.37	15.6	32.8	0.46	0.68	2.46	0.33	3.39	1.76	8.47	40.0
11	J_RUB	5_10	9	50	41	5.3	3.9	3.20	0.27	11.9	10.2	0.25	0.45	1.71	0.23	3.98	1.53	8.38	47.5
11	J_RUB	10_20	9	42	49	5.2	3.8	2.44	0.23	10.6	5.44	0.25	0.42	1.84	0.32	3.77	1.26	8.13	46.4
11	J_RUB	20_30	7	33	60	5.1	3.8	2.11	0.20	10.6	1.30	0.27	0.52	1.72	0.34	3.10	1.02	7.21	43.0
12	IMP	0_5	66	14	20	5.8	4.1	2.19	0.13	16.8	8.27	0.20	0.36	1.56	1.04	1.21	0.05	5.39	22.4
12	IMP	5_10	67	11	22	5.5	4.2	2.03	0.12	16.9	6.25	0.12	0.37	1.35	0.41	1.03	0.61	3.33	30.9
12	IMP	10_20	69	9	22	5.3	3.8	1.78	0.10	17.8	1.20	0.11	0.31	1.35	0.73	1.51	0.31	4.62	32.7
12	IMP	20_30	61	13	26	5.2	3.9	1.22	0.09	13.6	1.20	0.05	0.22	1.56	0.52	2.00	0.39	4.66	42.9
13	IMP	0_5	66	13	21	5.7	4.0	2.23	0.13	17.2	4.15	0.09	0.42	1.12	0.51	1.18	0.67	3.71	31.8
13	IMP	5_10	67	5	28	5.6	4.0	2.10	0.12	17.5	3.16	0.20	0.45	1.12	0.71	1.48	0.68	4.63	32.0

Table 10.1. Measured soil parameters

No.	LUT	Depth	Texture			pH_ H_2O	pH_ KCl	C_org	N_tot	C/N ratio	P_bray$_{II}$	Exchangeable cations							Al sat
			Sand	Silt	Clay							K	Na	Ca	Mg	Al	H	ECEC	
		cm	%					%	%		mg kg^{-1}	cmol$_e$ kg^{-1}							%
13	IMP	10_20	65	8	27	5.4	4.0	2.07	0.12	17.3	2.66	0.18	0.44	1.72	0.41	1.78	0.19	5.21	34.2
13	IMP	20_30	65	8	27	5.4	4.0	1.51	0.09	16.8	1.67	0.14	0.41	1.34	1.02	1.78	0.38	4.88	36.5
14	CAS	0_5	61	16	23	5.0	3.8	1.51	0.11	13.7	18.0	0.11	0.25	1.02	0.81	2.19	0.09	4.76	46.0
14	CAS	5_10	57	16	27	5.0	3.8	1.27	0.10	12.7	6.13	0.10	0.24	1.63	0.94	2.07	0.82	5.07	40.8
14	CAS	10_20	54	19	27	5.0	3.8	0.97	0.09	10.8	2.21	0.06	0.23	2.29	0.63	2.12	0.71	6.15	34.5
14	CAS	20_30	51	16	33	4.8	3.8	0.49	0.05	9.8	0.19	0.05	0.22	1.56	1.04	2.48	0.41	6.06	40.9
15	CAS	0_5	68	13	19	5.1	3.9	1.78	0.12	14.8	17.4	0.11	0.36	2.08	0.45	1.51	0.50	4.92	30.7
15	CAS	5_10	61	18	21	5.1	3.8	1.70	0.11	15.5	7.77	0.11	0.34	1.56	0.52	1.51	0.69	4.54	33.3
15	CAS	10_20	60	16	24	5.2	3.9	1.62	0.10	16.2	6.76	0.11	0.31	1.56	1.04	1.81	0.70	5.52	32.8
15	CAS	20_30	60	16	24	5.2	3.9	1.38	0.10	13.8	4.23	0.08	0.29	1.56	0.41	1.81	0.70	4.85	37.3
16	CHRO	0_5	9	66	25	5.7	4.2	4.66	0.32	14.6	35.1	0.48	0.88	2.64	2.41	1.20	0.88	8.31	14.4
16	CHRO	5_10	9	59	32	5.3	3.9	3.64	0.28	13.0	17.9	0.28	0.71	2.28	0.57	2.65	1.49	7.37	36.0
16	CHRO	10_20	6	57	37	4.9	3.8	2.72	0.20	13.6	6.49	0.27	0.61	2.96	0.22	2.85	1.43	8.40	33.9
16	CHRO	20_30	10	52	38	4.8	3.7	2.27	0.16	14.2	3.37	0.12	0.54	1.62	0.54	3.45	1.12	7.70	44.8

Table 10.2.
Bulk density (g cm^{-3}) of the top 5 cm based on 8 replicates per sampling point

Number	Code	Mean	Standard deviation	Coefficient of variation	Standard error of mean
BS01	NF	0.67	0.164	0.245	0.06
BS02	NF	0.69	0.141	0.203	0.05
BS03	LOF	0.87	0.377	**0.434**	0.13
BS04	LOF	0.75	0.155	**0.206**	0.05
BS05	L0F	0.69	0.268	**0.386**	0.09
BS05	TRACK	**1.20**	0.218	0.181	0.08
BS06	HTI	**1.01**	0.155	0.154	0.05
BS07	HTI	**1.00**	0.108	0.107	0.04
BS08	RUB_P	0.79	0.069	0.088	0.02
BS09	RUB_P	0.66	0.138	0.208	0.05
BS10	J_RUB	0.65	0.063	0.097	0.02
BS11	J_RUB	0.73	0.103	0.141	0.04
BS12	IMP	**1.12**	0.076	0.068	0.03
BS13	IMP	**1.26**	0.089	0.071	0.03
BS14	CAS	**1.31**	0.142	0.108	0.05
BS15	CAS	**1.16**	0.146	0.126	0.05
BS16	CHROM	0.77	0.079	0.103	0.03

Table 10.3.
Soil organic matter data compared to the reference value C_{ref}
(based on regression of C_{org} on soil texture fore a large data set of Sumatran soils)
and results of the size/ density fractionation of soil with Ludox

Depth LUT	C_{org} %	C_{ref} %	C_{org}/C_{ref}	Light g kg^{-1}	Intermediate g kg^{-1}	Heavy g kg^{-1}
0-5 cm						
Nat.Forest	3.88	2.84	1.37	6.68	8.11	1.81
Logged F.	3.26	2.91	1.20	2.06	5.64	1.73
R.Agroforest	6.00	4.36	1.38	1.87	3.31	0.90
Rub.plant.	4.62	4.62	0.99	3.25	5.90	8.59
Timb.plant.	3.50	2.83	1.23	5.94	7.15	1.63
Cassava	1.65	2.84	0.58	1.22	1.41	2.13
Imperata	2.21	2.72	0.81	0.72	1.35	2.11
Chromolaena	4.66	4.01	1.16	1.08	5.53	0.92
5-10 cm						
Nat.Forest	1.93	2.69	0.72	0.96	1.21	0.52
Logged F.	2.33	2.54	0.91	1.23	3.17	1.24
R.Agroforest	3.59	4.43	0.81	0.59	0.44	0.63
Rub.plant.	2.68	4.84	0.55	0.43	0.60	0.28
Timb.plant.	2.13	2.88	0.76	1.31	4.50	1.58
Cassava	1.49	3.00	0.50	0.68	1.37	1.86
Imperata	2.07	2.71	0.76	0.29	2.28	1.41
Chromolaena	3.64	4.28	0.85	0.48	0.87	2.15

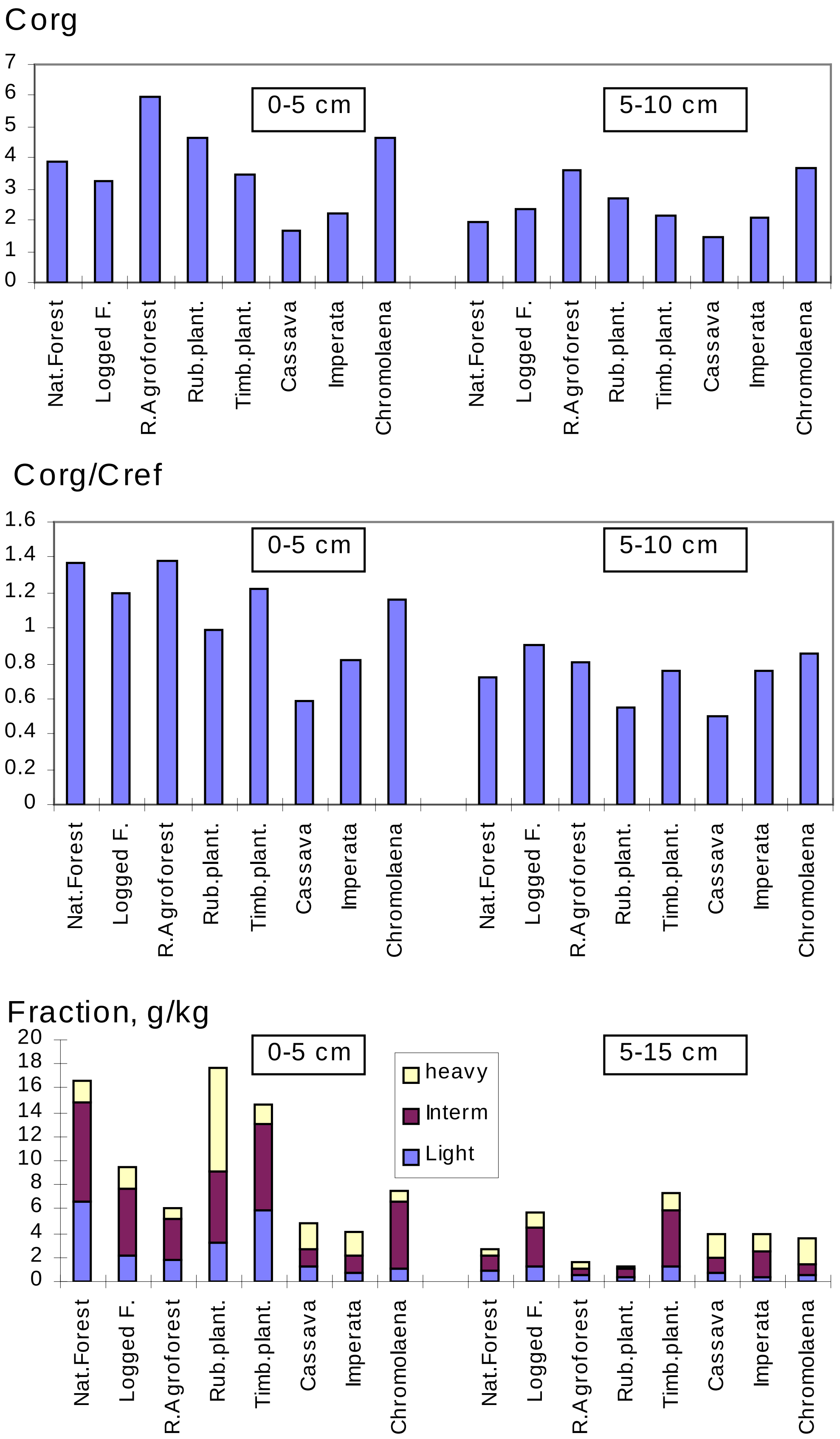

Figure 10.1. Indicators of soil organic matter saturation: A.l; C_{org}, B. C_{org}/C_{ref}, C. Size-density fractions (LUDOX method), grouped by land use.

Table 10.4
Dry weights and C stocks for the 16 sampling points

BS No.	Code	SystAge, year	Dry weight kg m^{-2} Dead wood	Litter	Green biomass	Trees	C-stock kg m^{-2} Necromass	Biomass	Soil 0-20 cm	Total
1	NF	100.0	21.31	1.37	0.13	93.60	10.21	42.18	3.33	55.72
2	NF	100.0	4.16	1.28	0.00	88.50	2.45	39.83	3.58	45.85
3	LOF	15.0	16.76	1.50	0.00	11.30	8.21	5.09	3.13	16.43
4	LOF	15.0	22.19	0.91	0.05	25.80	10.40	11.63	5.46	27.49
5	LOF	100.0	1.26	1.11	0.01	86.20	1.07	38.79	3.95	43.81
6	HTI	5.0	14.94	1.78	0.25	8.00	7.53	3.71	4.53	15.77
7	HTI	5.0	0.56	1.03	0.09	9.45	0.71	4.29	5.18	10.18
8	RUB_P	10.0	7.67	0.77	0.11	13.70	3.80	6.21	5.83	15.84
9	RUB_P	10.0	12.30	0.68	0.08	17.80	5.84	8.05	4.30	18.19
10	J_RUB	35.0	13.50	0.62	0.03	21.60	6.35	9.73	6.51	22.60
11	J_RUB	35.0	2.02	0.91	0.02	28.70	1.32	12.92	6.23	20.48
12	Imp	1.0	0.00	0.11	0.23	0.00	0.05	0.10	4.53	4.68
13	Imp	1.0	0.00	0.09	0.18	0.00	0.04	0.08	5.46	5.58
14	Cas	0.5	0.00	0.06	0.21	0.00	0.03	0.09	3.16	3.28
15	Cas	0.5	0.00	0.04	0.29	0.00	0.02	0.13	4.08	4.22
16	Chrom	3.0	0.00	0.56	0.34	0.00	0.25	0.15	6.42	6.82

Table 10.4 summarizes data on the above and belowground carbon stocks for all sampling points. The total values for the forest plots (around 50 kg m^{-2}, corresponding to 500 Mg ha^{-1}) are consistent with other data for lowland forests sampled in the ASB project (Woomer *et al*., 1998?). The logged over forests had substantially lower biomass AC stocks, but partly made up fror the difference by high dead wood (necromass) stocks.

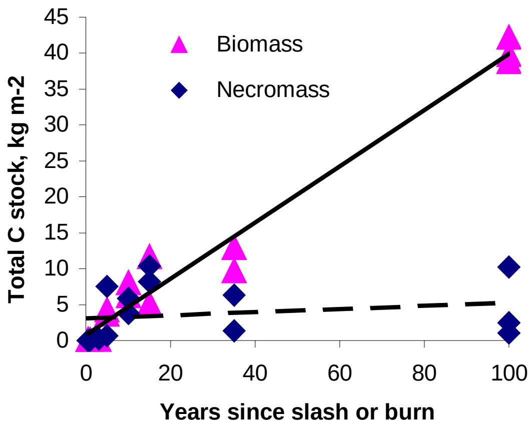

Figure 10.2. Relation between total aboveground C stock (biomass and necromass) and time since last slash, burn or cultivation event; the slope indicates an average annual C stock increment of 2.5 Mg C ha^{-1} year^{-1}

10.5. References

Anderson J.M. and J.S.I. Ingram (eds.) (###) *Tropical Soil Biology and Fertility, a Handbook of Methods*. CAB International, Wallingford (UK)

Brown, S., (1997). Estimating Biomass Change of Tropical Forest. FAO, Forestry Paper. FAO.USA.

Hairiah, K., Cadisch, G. van Noordwijk, M., Latief, A.R.,Mahabharata and Syekhfani, (1995). Size-density and isotopic fractionation of soil organic matter after forest conversion. *In:* A. Schulte and D. Ruhiyat eds. *Proc. Balikpapan Conf. on Forest Soils* Vol. 2: 70-87. Mulawarman University Press, Samarinda, Indonesia

Hairiah, K., Van Noordwijk, M. and Latief, A.R., (1996a). Soil organic matter fractionation under different land use types in N. Lampung. *AGRIVITA* 19: 146-149.

Hairiah, K., Kasniari, D.N., Van Noordwijk, M. and de Foresta, H. and Syekhfani M.S., (1996b). Soil properties, litterfall, above-and belowground biomass during a *Chromolaena odorata* fallow. *AGRIVITA* 19: 184-192.

Meijboom F.W., Hassink J. and Van Noordwijk, M., 1995 Density fractionation of soil macroorganic matter using silica suspensions. *Soil Biology and Biochemistry* **27**: 1109-1111.

Palm, C, Hairiah, K. and Van Noordwijk, M., (1994). Methods for sampling above and belowground organic pools for ASB sites. *in:* D.M. Murdiyarso, K. Hairiah and M. Van Noordwijk (Eds.) *Modelling and Measuring Soil Organic Matter Dynamics and Greenhouse Gas Emissions after Forest Conversion*. Proceedings of Workshop/ Training Course 8-15 August 1994, Bogor/Muara Tebo. ASB-Indonesia publication No. 1. pp 57-71

Van Noordwijk, M., Tomich, T.P., Winahyu, R., Murdiyarso, D., Partoharjono, S. and Fagi, A.M. (Eds.) (1995). *Alternatives to Slash-and-Burn in Indonesia, Summary Report of Phase 1*. ASB-Indonesia Report Number 4, Bogor, Indonesia

Van Noordwijk, M., Woomer P., Cerri C., Bernoux, M. and Nugroho, K., (1997a). Soil carbon in the humid tropical forest zone. *Geoderma 79*: 187-225

Van Noordwijk, M, T.P. Tomich, D.P. Garrity and A.M. Fagi (Eds.), (1997b). Alternatives to Slash-and-Burn Research in Indonesia. *ASB-Indonesia Report Number 6.* Agency for Agricultural Research and Development, Bogor, Indonesia (ISBN 979-8161-59-9)

Van Noordwijk, M., D. Murdiyarso, K. Hairiah, U.R. Wasrin, A. Rachman and T.P. Tomich, (1998). Forest soils under alternatives to slash-and-burn agriculture in Sumatra, Indonesia. In: A. Schulte and D. Ruhiyat (eds.) *Soils of Tropical Forest Ecosystems: Characteristics, Ecology and management*. pp. 175-185. Springer-Verlag, Berlin.

Van Noordwijk, M., Hairiah, K., Woomer, P.L. and Murdiyarso, D. (1999) Criteria and indicators of forest soils used for slash-and-burn agriculture and alternative land uses in Indonesia. *in:* E. Davidson (Ed.) ASA publication *in press*

Woomer, P.L., Palm, C.A., Alegre, J., Castilla, C., Cordeiro, D.G., Hairiah, K., Kotto-Same, J., Moukam, A., Ricse, A., Rodriguez, V. and Van Noordwijk, M., 1998?. Carbon dynamics in slash-and-burn systems and land use alternatives. *In:* .(Eds.) .... *in press*