Hardware requirements and installation

The PC version of CENTURY is written in Fortran and requires an IBM PC or compatible with at least 512K RAM. While CENTURY can run on older processors such as an 80086, the simulations are quite time consuming. It is recommended that users run CENTURY on either a 80286 or 80386. For high resolution screen output, a VGA monitor is recommended although VIEW is supported by CGA and EGA monitors as well.

Together CENTURY and VIEW occupy 614K of hard disk drive. VIEW must be loaded as a sub-directory of the directory where CENTURY model files are stored. CENTURY site files (.DAT) may be stored directly in the main CENTURY directory, furthermore, site files cannot be read from an external drive.

Running century

A session with the CENTURY model is always initiated by entering either INITPAR, if the users intent is to create a new site.DAT file or CENTURY site.DAT if the user plans to run a simulation with existent site files. INITPAR is a user friendly routine whereby site files are constructed or modified. To enter INITPAR, the user must always refer to an already existent site.DAT file, modifying this file until representative of a new environment or land use. INITPAR is separated into minimum and complete initialising variables. After entering new variables through initpar, the user must save the file under a new name as CENTURY does not overwrite existing files. Selected initialising variables and user options required for the application of the CENTURY model to shifting cultivation systems are presented in Table 3.1.

General information on ecological attributes is contained within the site.FIX files. For example, this file sets limits on the relationship between precipitation and plant productivity or on the rates of plant nutrient complexation with soil minerals. A HUMID.FIX file has been developed at TSBF headquarters that can be universally used for sites of the lowland humid tropics with predominantly oxide soil mineralogies. These site.FIX files are more difficult to create than site.DAT files, requiring the use of a line editor. A standard S&B.FIX file applicable to humid tropical conditions will be developed at TSBF Headquarters for use by all cooperators.

A site data file must always accompany the CENTURY com- mand (e.g. CENTURY SITE.DAT). Users are than asked to select a land use, pattern of events, a site.FIX file and management inputs. Several options of climate inputs are available, although the climate records contained within the site.DAT files are the most conveniently used. A CENTURY simulation is then generated for those conditions and the results of that simulation are automatically accessed through VIEW.

Principal model routines

CENTURY simulates the carbon, nitrogen, phosphorus and sulphur dynamics for grasslands, forests and cropping systems. These different plant production systems are linked to a common organic matter sub-model that consists of 3 functional pools based on the residence time of organic materials in soils. The plant nutrient subroutines (N, P and S) are incorporated into plant productivity and organic matter dynamics through user defined C:nutrient ratios that float within

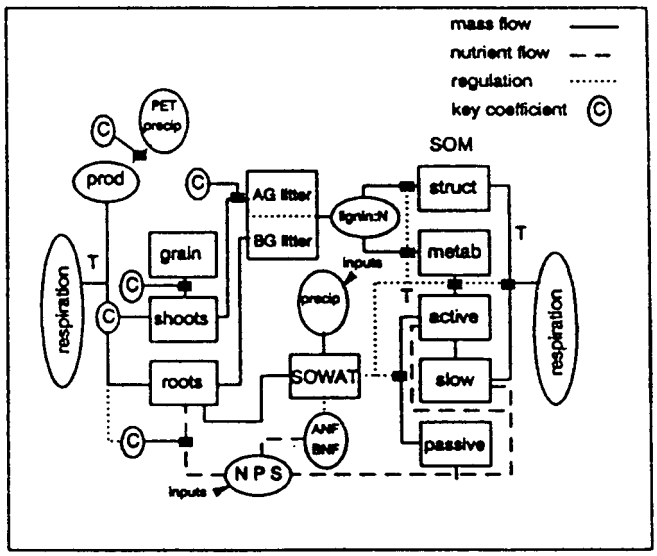

Figure 3.2 Principal routines of the CENTURY model include soil organic matter, plant and litter dynamics.certain limits. The dynamics of these plant nutrients is centred about a labile form that is available to plant uptake, subject to complexation with soil minerals or loss from leaching or erosion.

An example of the overall organic matter C and N dynamics for a crop-soil system is presented in Figure 3.2. Plant productivity is controlled by moisture availability, temperature and the maximum and minimum C:nutrient ratios of new plant growth. User defined partitioning coefficients determine the relative proportions of grain, shoots and roots. Upon senescence, plant materials enter the litter pools that are divided between easily metabolised and more recalcitrant materials. These litter forms enter into the different soil organic matter fractions at rates determined by their chemical compositions, soil textures and soil microclimate. System losses primarily occur as respiration of CO_2, and the nutrients associated with the respired C are assumed to become mineralised and enter their respective labile pools.

Applying CENTURY to shifting cultivation systems

In version 3.0, the Century model is applied to shifting cultivation systems through use of the EXTEND feature in the VIEW Module. This requires that a site data file (SITE.DAT) be developed in INITPAR that is able to simulate both forest and crop productivity. Then the forest sub-model is run for the entire interval of the shifting cultivation simulation (TEND in INITPAR) and then the cropping/fallow intervals are inserted in subsequent model runs as follows:

1. Initialise CENTURY as a forest system with a FOREST REMOVAL EVENT (clearing/burning) coinciding with the beginning of the cropping phase and reflective of the decrease in forest biomass compartments and the FOREST RETURN EVENT indicative of the changes in C:nutrient ratios observed as a result of burning. This typically involves increases in C:N and C:S ratios and decreases in C:P ratio.
2. Run the forest simulation. CENTURY will automatically enter VIEW.

3. Select all model outputs (including crop parameters) by entering PLOT and PRINT routines. Once the simulation is extended the model is unable to recover values from previous model runs that are not selected at this time.
4. In VIEW, select VIEW/CHANGE/EXTEND. The user will be asked when the extended simulation is to begin. Enter a year in agreement with the FOREST REMOVAL EVENT previously entered. CENTURY initialisation will resume automatically.
5. Initialise CENTURY in the CROP sub-model. Run simulation and enter VIEW/ CHANGE/EXTEND. Enter year that the cropping phase ends (fallow begins). Again, CENTURY initialisation resumes.
6. Repeat step 1 being careful to select forest removal and return events that correspond to the beginning of the next cropping phase (end of fallow). Repeat step 5 to simulate the cropping phase.
7. Recover model outputs by entering either PLOT or PRINT options. Data files of model outputs may be saved by selecting PRINT/DEVICE/FILE and imported into many commercially available spreadsheet programmes.
8. During the process of simulating a shifting cultivation system, users may alter file parameter values immediately before extending the simulation by selecting VIEW/CHANGE/CHANGE, entering the revised parameter value adjacent to the fortran code for that variable and the selecting EXTEND.

An example of a CENTURY model simulation of the carbon dynamics of a miombo woodland, shifting cultivation and permanent, commercial maize cultivation at Marondera, Zimbabwe was given by Woomer (1993b). Figure 3.3 gives results of a trial run on the *Jambi* data file created during the workshop. It shows a sequence of forest growth, slash-and-burn, upland rice, fallow growth, permanent rice cultivation and the introduction of manure applications.

An important difference between CENTURY version 3.0 and its update, 4.0 is the inclusion of an events scheduler which will automatically allow the model to change from one production sub-routine (e.g. forest to cropland to pasture to forest). Other atvantages of using the update include greater flexibility in scheduling burning events, the ability to simulate several crops a year and the inclusion of agroforestry routines which allow for crops and trees to grow simultaneously. TSBF staff are currently familiarising themselves with CENTURY 4.0 and it is intended that files developed by TSBF that facilitate the model's application to S&B systems will accompany the release when the model is distributes to cooperators at the benchmark sites. Examples of these files are include the initialisation of forest clearing and burning, hand tillage and growth and allocation coefficients for selected tropical crops and trees.

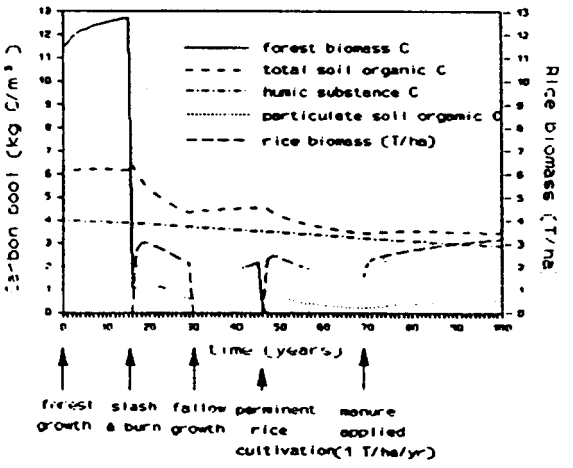

Figure 3.3 CENTURY 3 model output for the *Jambi* file developed during the workshop

Century outputs

The results of CENTURY simulation may be output as either line graphs or tables. CENTURY line graphs may contain up to six variables on the y axis. Users may select from a number of line styles and colours, and can create titles and legends within view, then output these directly to a printer or capture the image using an external grab feature. Graphs may also be stored as files within VIEW. Tables are created using the PRINT routines. The column headings may berenamed (e.g. different from their respective FORTRAN codes) or be products of combined output variables. These tables may be either printed or saved as data files importable into a number of commercially available spreadsheet and graphics programmes. The complete results of a simulation may also be stored within CENTURY for future use but these files occupy nearly as much disk space as the total programme. An example of a simulation in which land use begins as a Zimbabwean miombo woodland on which first shifting cultivation and then permanent maize cultivation is practised is presented in Figure 3.3 (Woomer, 1993b). In this example the carbon dynamics of soil and vegetation are presented separately, and summed to indicate changes in total system carbon as a function of land management practises. Similar simulations will be generated and compared for S&B collaborative sites during the first year of the Consortium's activities.

4. Greenhouse gas emissions

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4.1. Backgrounds

The atmospheric concentrations of the major long-lived greenhouse gases (CO_2, CH_4, CFCs, and N_2O) continue to increase because of human activities. However, the rate of increase of some of the greenhouse gases like CH_4 has been shown to decline. Uncertainties still remain concerning the rates of emission. Their influence to the radiative budget termed as radiative forcing is diagrammatically shown in Figure 4.1.1.

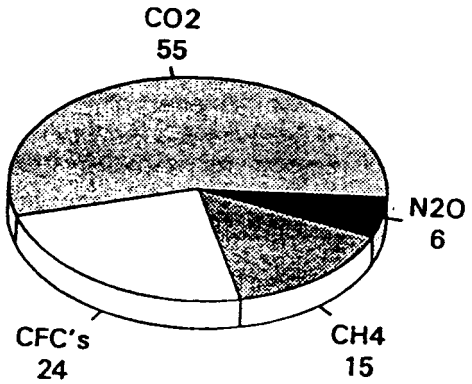

Figure 4.1.1 Influence of various greenhouse gases on total radiative forcing.

As background to 'alternatives to slash and burn' project, the distribution, trends, sources, and sinks of the major greenhouse gases will be briefly discussed here. As far as forest conversion is concerned, only CO_2, CH_4, and N_2O are involved. Their annual emission and contribution to the global greenhouse effect is summarized in Table 4.1.1.

Land use change is one of the important causes of global change, by changes in land cover affecting the absorption and reflection of radiation and the capability of the terrestrial ecosystems in fixing atmospheric carbon and (temporarily) accumulating it in aboveground biomass, litter and or soil. Global change in its turn has direct effects on terrestrial ecosystems. Changes in temperature and water availability, increased carbon accumulation caused by elevated CO_2 concentrations, or net release of soil carbon or respiration due to increased temperature may be considered in this respect.

Land use change through forest conversion has been recorded to have both local and global effects. One of the major concerns of the global effects of deforestation is the emission of radiatively active trace gases such as CO_2, CH_4 and N_2O to the atmosphere.

Table 4.1.1 Global annual emissions of greenhouse gases in the 1980's

	Annual emission (Tg)	Contribution to greenhouse effect, (%)
CO_2 Total		50
Industrial	5600 (C)	
Biotic	2000-2800 (C)	
Tropical deforestation	2000-2800 (C)	13-16
CH_4 Total		20
Industrial	50-100 (C)	
Biotic	320-785 (C)	
Tropical deforestation	155-340 (C)	8
N_2O Total		5
Industrial	1 (N)	
Biotic	3-9 (N)	
Tropical deforestation	1-3 (N)	1-2

Source: Houghton (1990).

4.1.1. Carbon dioxide

Current atmospheric CO_2 concentration is 353 ppmv. It has been increased by 1.8 ppmv/yr (5%) since the pre-industrial period when it was only 280 ppmv. The main sources of CO_2 in the atmosphere are fossil fuel burning and deforestation + other land use changes. During 1850 to 1986 the total emissions were 195 $\pm$ 20 Gt C and 117 $\pm$ 35 Gt C respectively, adding up to a cumulative of 312 $\pm$ 40 Gt C (1 Gt (giga ton) = 1 billion (10^9) metric ton). Estimate during the last decade (1980-1989) indicated that the annual release of carbon from those sources were 5.4 ($\pm$0.5) Gt from fossil fuel burning and 1.6 ($\pm$1.0) Gt from deforestation. The amount of carbon accumulated in the atmosphere and taken up by the ocean were 3.3 ($\pm$0.2) and 2.0 ($\pm$ 0.8) Gt, respectively, resulting in a net imbalance of 1.6 ($\pm$1.0) Gt (IPCC, 1990). Different explanations have been given for this 'missing carbon', but the issue has not been fully resolved as yet. A more recent estiimate (IPCC, 1992) indicated that carbon release from land use change was higher (1.1 - 3.6 Gt C), and yet, it has to be reconciled with the known rate of carbon uptake in terrestrial ecosystems such as reforestation, including plantation of tree crops in both monoculture and agroforestry systems. Another term of the balance that is open for debate is uptake by oceanic ecosystems, which appears to depend on the degree of turbulence in the upper oceanic layers.

World's deforestation during 1850-1985 has contributed about 117 Gt C to the atmosphere. Temperate zone deforestation has contributed some 0.5 Gt C/yr during this period (Houghton and Skole, 1990). It is only in the last 40 years that CO_2 emissions from tropical deforestation exceed the rate of emissions from temperate zone deforestation. The rate of carbon release associated with deforestation is considered as biotic release of CO_2 (Woodwell *et al.*, 1983). The net carbon release is usually calculated by considering the amount of biomass harvested, emissions of carbon released from soil, and carbon sequestration when reforestation is taking

place. It is estimated that forest and their soils hold 20 to 100 times more carbon per unit area than agricultural lands (Houghton, 1990). In the tropics larger portion is held in the biomass than in the soil, except for swamp forest on peat soils. The inverse condition occurs in the temperate/boreal regions, with generally higher soil organic matter stocks due to slower decomposition at lower temperature. Another reason is that tropical forest may contain a larger C stock in it's above-ground biomass than mono-layer, mono-specific temperate forests.

The amount of carbon presently stored in forests is equivalent to the atmospheric pool, namely 700 Gt C. Houghton *et al.*, (1987) estimated that in 1980 carbon emission from tropical deforestation ranged from 0.6 to 2.6 Gt C. If this figure was taken as annual carbon release from tropical deforestation (1.6 ± 1.0 Gt C/yr), it was equal to the last decade's anthropogenic carbon imbalance. This calculation takes the emissions from fossil fuel burning (5.4 Gt C/yr) into account as well as the atmospheric and oceanic sinks of 3.4 and 2.0 Gt C/yr, respectively. This does not mean that tropical deforestation should be completely stopped in order to balance the sinks and sources budgets. Bearing those emission rates in mind one has to find the alternatives of reducing the sources (including fossil fuel use) and at the same time increasing the sinks for carbon. Atmospheric CO_2 has a relatively long half-life time of 50 - 200 years. An immediate reduction of anthropogenic carbon emission of 60-80 percent is necessary (IPCC, 1990) in order to stabilize the atmospheric concentration and bring release in balance with the CO_2 sequestration rates of the oceans.

Current global estimates of carbon flux from land use changes vary between 0.6 and 2.5 Gt for 1980, and between 1.1 and 3.6 Gt C for 1990 (Houghton *et al.*, 1987 and Houghton, 1991). Those figures were almost entirely from the tropics after taking accumulation of carbon in forests regrowing and abandonment of agriculture into account. Such large uncertainties were caused by uncertainties in estimating deforestation. It is expected that the uncertainties may be reconciled by the use of satellite data. None of the studies to date has made more than minimal

Table 4.1.2. Estimated net release of carbon from tropical deforestation in 1980

Country	CO_2 release (Gt C)
Brazil	0.336
Indonesia	0.192
Colombia	0.123
Ivory Coast	0.101
Thailand	0.096
Laos	0.085
Nigeria	0.060
Philippines	0.057
Myanmar	0.051
Peru	0.045
Others	0.516

Source : IPCC (1990)

use of data from satellite, although such data offer the most effective and objective means for measuring worldwide change in the area of forests (Houghton, 1990). Country by country estimate of carbon release from deforestation are shown in Table 4.1.2.

The famous data of the atmospheric CO_2 concentrations measured at Mauna Loa and South Pale since 1958 and summarized by C.D. Keeling's indicate spectacular annual oscillation of CO_2 concentration. These oscillations suggest the potential and importance of evergreen foliage in the tropics to balance the seasonal CO_2 release in the temperate zone of the northern hemisphere. The warming of the earth involves both negative and positive feedbacks (Woodwell, 1992). Elevated CO_2 concentration possibly enhances CO_2 fixation, in the absence of limiting factors in nutrient and water supply, although plants with a C_3 or C_4 pathway in photosynthesis differ in their response. Photosynthetic rates of C_3 species, including most trees, are expected to rise moderately with CO_2 when N and P are not limiting (Acock and Allen, 1985). Increased CO_2 concentration causes stomatal conductance to decrease and as a consequence water use efficiency increases, enhancing the capacity of plants to grow in water-limited environments (Morison and Gifford, 1984).

Globally, there is a dramatic increase of tropical tree plantation establishment since 1940's, resulting in an area of 11 Mha in 1980 with more than 60 percent planted during late 1970's (Brown *et al.*, 1985). Although this tropical plantations provide a small sink of up to 0.11 Gt C/yr, it may be sufficient to balance the source of carbon from harvesting forest and other land use change in the temperate zone. The estimates, however, did not take tree or estate crops into account which in the case of Jambi province and the neighboring provinces practiced by both smallholders (rubber forest) and large estates (oil palm).

As far as Jambi Province is concerned the uptake of CO_2 may not globally be significant. There are possible CO_2 sinks which are manageable as well as having economic value, namely plantation forests and development of estate crops. The World Bank (FAO/GOI, 1990) estimates indicate that in Indonesia there would be a new plantation of about 20 Mha in 2030 if the rate of reforestation was 100,000 ha/yr and tree crops development was 160,000 ha/yr. That is not taking rubber jungle planted traditionally by local peoples into account. With a pessimistic NPP of 6 ton/ha/yr (most of tropical equatorial forest type have NPPs well above 10 ton/ha/yr), such plantation would sequester carbon about 0.21 Gt C/yr (Murdiyarso, 1993).

4.1.2. Methane

Although CH_4 has a lower current concentration of 1.7 ppmv with an annual increase of less than 0.02 ppm, and shorter half life time in the atmosphere of 8 - 10 years, it has 25 times as much heat-trapping capacity as CO_2 per molecule of gas. Global methane (CH_4) concentrations have almost doubled in the last 100-200 years (Rasmussen and Khalil, 1984). Ice core measurements showed that the concentration of CH_4 from interglacial period until 200 years ago (pre-industrial period) was between 650 and 750 ppbv. The present globally averaged concentration is about 1770 ppbv (Steel *et al.*, 1987; Khalil 1992), with an annual rate of increase of about 0.7 % or 12 $\pm$ 1 ppbv/year. This increase is due to an imbalance between sources and sinks, amounting to about 36 $\pm$ 9 Tg/year. Crutzen (1991) estimated that the total source of annual atmospheric CH_4 was 505 $\pm$ 105 Tg, while the annual sink was only 460 $\pm$

100 Tg. Almost 70 % of the total emission of CH_4 comes from anthropogenic sources mainly from anaerobic decomposition of organic matter in rice agriculture and enteric fermentation in ruminants. Other sources of anthropogenic CH_4 emission are land fills, coal mining, coal burning, biomass burning and natural gas industries. The remaining 30 % is from natural sources, mainly wetlands. The current estimated sources and sinks of methane (IPCC, 1992) are shown in Table 4.1.3.

Table 4.1.3 Estimated sources and sinks of methane (Tg CH_4 per year)

	Mean	Range
Sources		
Natural		
Wetlands	115	100-200
Termites	20	10- 50
Oceans	10	5- 20
Fresh water	5	1- 25
CH_4 hydrate	5	0- 5
Man-made (anthropogenic)		
Coal mining, natural gas and petroleum industries	100	70-120
Rice paddies	60	20-150
Enteric fermentation	80	65-100
Domestic animal wastes	25	20- 30
Domestic sewage treatments	25	?
Landfills	30	20- 70
Biomass burning	40	20- 80
Sinks		
Atmospheric removal	470	420-520
Removal by soils	30	15- 45
Atmospheric increase	32	28- 37

Source: IPCC (1992)

The anthropogenic sources of methane may also be grouped into agricultural group (livestock management, rice cultivation, biomass burning and land clearing), energy and industry group (coal mining, natural gas mining, fossil fuel combustion), and urban group (landfill and waste water treatment). This grouping is necessary in order to relate with national sectoral policies in agricultural production, energy consumption, and urban planning. Since mitigation measures also require the availability and applicability of the technologies the grouping will ease in identifying such technologies, their costs or capital needs and the benefit to be gained by applying them. It is still uncertain to which extent the decrease in net emission rates is caused by a decrease of the source and/or an increase of sinks (Prinn *et al.*, 1992).

4.1.3. Nitrous oxide

The global nitrous oxide (N_2O) source has increased by about 50 % since pre-industrial period; out of the total source of 27 Tg/year, only 1.9 Tg/year was from anthropogenic sources (Prinn *et al*, 1990). The major pre-industrial contributor may have been oceanic sources. A large shift of sources has been observed by Bouwman (1992) who stated that the global emission from non-cultivated lands was 5.8 Tg/year. Fertilizer-induced emission from agricultural soil was globally estimated as much as 3.3 Tg/year (FAO, 1990), close to IPCC (1990) estimate of 2.3 Tg/year. The industry/energy group which consists of fossil fuel combustion, nitric acid production and adipic acid (nylon) production have contributed 1.1 Tg/year. The other minor contributors are biomass burning and land clearing which emit 0.6 and 0.8 Tg/year, respectively (Hao *et al*, 1990; Crutzen and Andrea, 1990). Animal excreta is the most difficult element to estimate since methods in raising animals vary from country to country. Wild animals are of minor importance at the global scale (Lerner *et al*, 1988). Tentative estimates by Eichner (1990) on the N_2O release due to mineral fertilizer amounted to 0.3 Tg/year.

The estimates of sources and sinks of N_2O is shown in Table 4.1.4. These figures are revised from IPCC (1990) mainly involving new information from soil fluxes and tropical ecosystems, especially with cultivated soils. It is also suggested in the IPCC report (1992) that the contribution of stationary combustion sources is very low. Considerable uncertainties exist as to the contribution of biomass burning.

Table 4.1.4 Estimated sources and sinks of nitrous oxide (Tg N per year)

Sources	
Natural	
Oceans	1.4 - 2.6
Wet forest	2.2 - 3.7
Dry savanna's	0.5 - 2.0
Forests	0.05- 2.0
Grasslands	?
Antropogenic	
Cultivated soils	0.03- 3.0
Biomass burning	0.2 - 1.0
Stationary combustion	0.1 - 0.3
Mobile sources	0.2 - 0.6
Adipic acid production	0.4 - 0.6
Nitric acid production	0.1 - 0.3
Sinks	
Removal by soils	?
Photolysis in the stratosphere	7 - 13
Atmospheric increase	3 - 4.5

Source: IPCC (1992)

4.2. Methods for methane research at IPB's Experimental Site, Darmaga

During the workshop, a visit was paid to one of Bogor Agricultural University's (IPB) experimental fields. The object was a research activity funded by the Ministry of Education and Culture and in collaboration with Oregon Graduate Institute of Science and Technology. The purpose of the visit was to observe the sampling technique of methane emissions from rice fields using a closed-chamber method. It was also demonstrated how the samples were analyzed in the laboratory using gas chromatography.

Field measurements were meant to collect samples of ambient or background concentration and flux rate from a set of consecutive measurements in a closed chamber. In order to get the diurnal fluctuation of methane emission, measurements were carried out four times per day, at dawn, morning, mid-day, and evening. The experiment includes a number of treatments as regards organic matter amendment, irrigation technique and rice variety. At any sampling time, samples were taken four times at 3, 6, 9, and 12 minutes after installation of the chamber to get the flux rate, as shown in Figure 4.1.2.

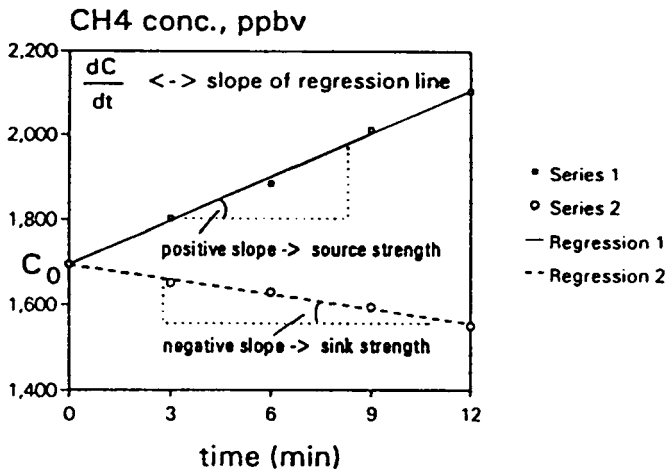

Fig. 4.1.2 Calculating the methane source or sink strength from a time series of concentration measurements in a sampling chamber

Data of the ambient concentration are used as a zero point for the time series, but they are also analyzed separately in relation to atmospheric conditions and time of day. Similar techniques will be applied for measuring greenhouse gas emissions in the ASB Project. However, they need modification concerning the size of samples, sampling methods and devices, bearing in mind that N_2O is a very unstable gas, which requires extra care.

4.3. Initial methane measurements in Jambi

During the field work the techniques in sampling greenhouse gases (GHG), for both ambient concentration and flux rate, was demonstrated. The sampling was also meant to test the effectivity of using low-cost syringes followed by transportation both by air and overland before the samples were analyzed. In doing so the samples were sub sampled in the consecutive days.

Ambient concentration of methane was sampled by means of canisters followed by sub sampling using syringes. Measurements were carried out in various land use types such as logged-over forest, crop land, abandoned land, and during burning events. The flux of methane was measured using a closed-chamber method. Preliminary results obtained during the field work are shown in Table 4.1.5 for ambient concentration of methane in various land use type, and Table 4.1.6 for methane flux from forest floor.

Table 4.1.5. Measurement of ambient CH_4 concentration

Type of land use	Methane concentration (ppbv)		
	canister	syringe-1	syringe-2
Smoldering fire, newly burnt shrubs	25,769	18,754	13,519
Newly burnt forest	1,739	1,983	1,760
Heavily logged-over forest	1,450	1,690	1,594
Logged-over forest	1,604	1,788	1,681
Mixed upland crop	1,722	1,731	-
Pond, rice field	1,879	1,956	-
Basecamp (7 am)	2,131	1,930	1,561
Basecamp (12.45 pm)	1,630	1,762	-

Note : Syringe-1 transported by air (analyzed 3 days after sampling)
Syringe-2 transported by land (analyzed 10 days after sampling)

Table 4.1.5 compares three methods of sample storage during transport to the lab. The canister samples are considered to be the best sampling device. Samples analyzed from the sub-samples in the syringes seem to suffer from diffusion or leakage: high CH_4 concentrations, above the "standard" ambient concentration of 1700 ppbv, are reduced and low CH_4 values, less than 1700 ppbv increased. The leakage may be caused by changes in pressure or untight seals. It is also obvious that in general the samples which were transported by land, although they took longer time to reach the lab suffered less from leakage than those transported by air.

Sampling by syringes may be permitted if the time between sampling and analysis of the samples is not too long, say maximum 3-4 days, and samples are not exposed to changes in air pressure (that means transported by land, not by airplane). Another solution to overcome leakage may be the use of vacutainers, bottles with a rubber stopper used for taking blood samples and other medical applications. Further checks on these methods are needed; the canisters give a reliable point of reference, but are too expensive to be used in large numbers for a replicated sampling scheme

Although the data for the various systems were not replicated and can only serve as a first indication, some interesting trends appear to emerge. The current ambient methane concentration is close to 1700 ppbv. It is shown that the ambient methane concentration during a burning event (smoldering fire) was enormous. Meanwhile, the forest environment shows a low ambient concentration of methane, which indicates that no net emission is occurring and/or that dry forest soil acts as a sink for methane. In agricultural lands methane concentration is slightly higher, especially close to a rice field. It is interesting to compare morning and daytime methane concentration at the same site (basecamp): morning concentration appeared to be higher than around noon. This might be associated with atmospheric conditions when nightly inversion probably still persists in the morning.

Table 4.1.6. Measurements of net methane flux; a negative flux indicates that the soil under the sampling chamber acted as a sink for CH_4

Type of land use	Flux rate (mg m^{-2} hr^{-1})
Logged-over forest	-0.05
Newly burnt forest	-0.01

The flux measurements in Table 4.1.6 indicate that in the dry season, logged-over forest soil acts as a sink for methane. A much lower sink strength was shown for a recently burnt forest soil, which might be caused by less active methanothrope bacteria due to higher soil temperature or as a direct effect of the burning.

No analysis of N_2O concentrations could be made as yet, since IPB's gas chromatograph is under service. However, there is a possibility to do it at IPB in the future when a new Gas Sampling Valve has been acquired. Another urgent supporting material is N_2O standard gas samples for calibrating the equipment.

5. Methods for sampling above and belowground organic pools for asb sites

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The decline in soil fertility within a few years of forest clearing and burning is often related to the depletion of nutrient-rich soil organic matter pools. Understanding the dynamics of the various pools of organic matter is very important. The objectives of this study are:
(a) Measure changes in C and nutrient stocks (above and belowground) with changes in land-use,
(b) Determine SOM pools and OM inputs to the soil,
(c) Test (and possibly modify) the CENTURY simulation model for C dynamics.
To ensure that C pool data collection is standardized, personnel handling the samples should be trained. Above and below-ground biomass, including standing biomass, litter fall, surface litter and roots were measured in a forest site in Jambi, close to the field campus of Gadjah mada University. Most of the methods to be used have been described in the TSBF handbokk of methods (Anderson and Ingram, 1993). Here we give some furthert detail and some new methods.

5.1 Aboveground vegetation biomass

5.1.1 Introduction

An estimate of the vegetation biomass can provide us with information about the nutrients and carbon stored in the vegetation, the amount of extractable wood available. To measure the biomass of vegetation which includes trees is not easy. It requires considerable labor and it is difficult to obtain an accurate measurement given the variability of tree size distribution. In general there are two methods for estimating biomass, a laborious but more accurate estimate obtained by *destructive sampling* or a quicker but less accurate, non-destructive method using *allometry*. The latter method, however, depends on equations developed from data obtained by destructive sampling.

5.1.2 Biomass estimation by destructive sampling

The area to be sampled depends on the homogeneity of the vegetation types and their spatial distribution, in addition, to the labor and resources available. The area sampled is usually stratified according to the type of vegetation, to get a more accurate estimate. Suggested plot sizes are 1 square meter for herbaceous vegetation, 10-20 square meters for shrubs or saplings to 3 m in height; and 100 square meters for forest tree communities. Plot shape will also depend on the plant community. Circular plots are easiest for low vegetation and square or rectangular plots where trees are present. Rectangular plots may give better estimates than square plots of equal area.

The larger the total area sampled the more accurate the estimate. Also, instead of sampling a large, contiguous area it is better to divide the sampling into several, smaller, randomly chosen areas within the field of study.

In destructive sampling, the vegetation in a given area is cut and weighed (fresh weight), subsamples of parts of the vegetation (understorey, trunks, leaves, branches, fruits) are weighed and dried to make dry weight conversions.

The following example illustrates how the biomass of forest fallows of varying ages in the area around Yurimaguas, Peru have been measured. An alternative method would be to sample vegetation at points along transects (see TSBF Handbook for more details).

Four circular plots (6 m radius, 113.1 m^2) are randomly selected within a hectare. Plot location is stratified if there are marked discontinuities in the vegetation. In other words, be sure that the four plots do not all fall in the area with the densest (or least) vegetation. Within **each** plot the vegetation is sampled as follows (Figure 5.1.1).

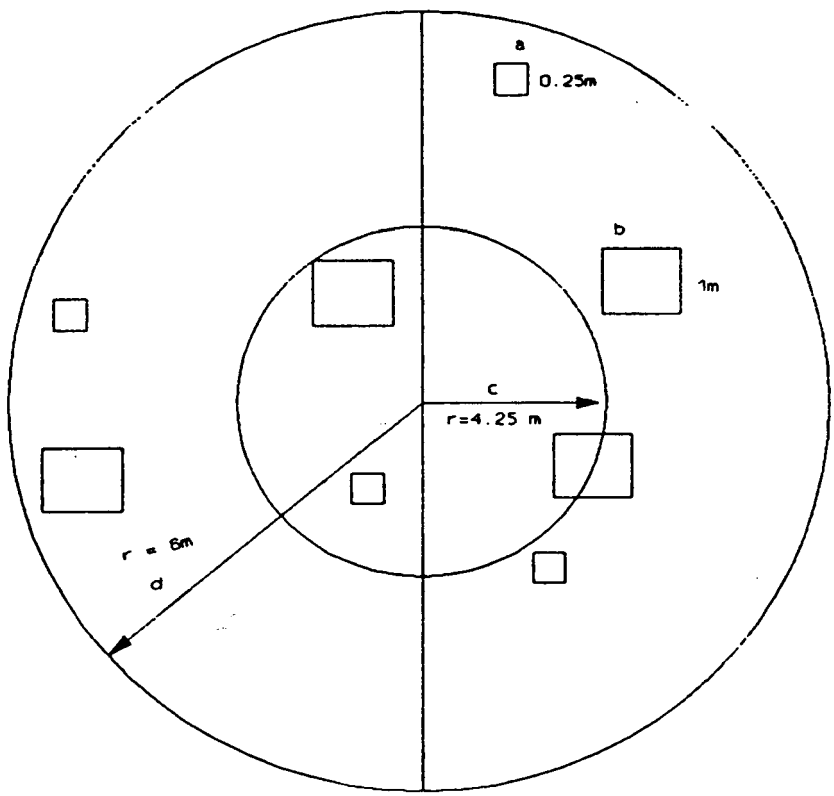

Fig. 5.1.1 Suggested lay out of plots for biomass sampling: a. litter (0.0625 m^2), b. understorey (1 m^2), c. trees < 15 cm dbh (57.64 m^2), d. trees > 15 cm dbh (113.1 m^2).

Litter layer: The litter is collected in four 0.25 m x 0.25 m quadrats (0.0625 m^2), located randomly within each quarter circle. The litter is dried (80°C), cleaned of mineral soil by washing and weighed. Samples are then ground and analyzed for nutrients. The samples can also be ashed to correct for mineral soil contamination.

Understorey: All vegetation less than 2.5 cm dbh is sampled within four 1m x 1m ($1m^2$) quadrats, each located randomly within the circle. The vegetation is dried (80°C), weighed (and analyzed for nutrients).

Small trees: All trees between 2.5 and 15 cm dbh are sampled in a subcircle with radius of 4.25m ($56.74m^2$). Each tree is cut. Height and dbh are recorded (and can be used later for producing site specific allometric equations). The tree is separated into leaves, small branches (less than 2.5 cm diameter), large branches (greater than 2.5 cm diameter), and trunk (which includes the largest branch to 2.5 cm diameter). Each fraction is weighed fresh in the field. Fresh subsamples are taken and weighed, then dried (80°C) to correct for water content. Subsamples can also be used to determine nutrient contents.

Large trees: All trees greater than 15 cm dbh within the circular plots of 6 m ($113.1m^2$) radius and are analyzed in the same manner as the small trees.

The vegetative biomass is then obtained by summing the biomass of the various components, once they have been converted to an equal area basis e.g., per m^2 or per hectare basis.

Table 5.1 Allometric relations for estimating biomass from tree diameter and height (after Brown *et al.*, 1989).

Life zone (Rainfall, mm/yr)	Equation (Y=tree biomass, kg/tree; D=dbh, cm; H=height, m)	R^2
Dry (< 1500 mm)	$Y = 34.4703 - 8.0671 * D + 0.6589 * D^2$	0.67
Moist (1500-4000 mm)	$Y = 38.4908 - 11.7883 * D + 1.1926 * D^2$	0.78
	$Y = \exp\{-3.1141 + 0.9719 \ln (D^2H)\}$	0.97
Wet (>4000mm)	$Y = 13.2579 - 4.8945 * D + 0.06713 * D^2$	0.90
	$Y = \exp\{-3.3012 + 0.9439 \ln (D^2H)\}$	0.90

5.1.3 Biomass estimation by allometry

For this method, data from previous destructive sampling of trees are used to develop best fitting equations relating easy-to-measure parameters, such as tree height or dbh to tree biomass. Once such equations have been obtained, one only needs to measure the parameter necessary to estimate the biomass. This nondestructive method is rapid and a much larger area can be sampled, reducing the sampling error encountered with the destructive method. If possible, the equations used for estimating biomass should be developed for each location, species, or group of species, and for trees of similar sizes and ages. For example, equations derived from destructive sampling of a virgin forest, where many of the trees have dense wood, will not be appropriate for estimating biomass of a young secondary forest where there are many soft-wood trees. For the purposes of the Alternatives to Slash and Burn projects, if equations have not been developed at the sites, the equations of Brown *et al.*, 1989 can be used (Table 5.1). The equations developed by Brown and colleagues are based on diameter (D) at breast height (1.3 m); height of tree (H); and the density of the wood (s). Often only diameter measurements are possible to obtain; however the estimates generally improve with more parameters. Separate equations have been developed for tropical forests in different rainfall regimes : dry < 1500mm rainfall per year; moist 1500-4000mm; and wet > 4000mm.

5.1.4 Vegetation biomass - sampling protocol

Vegetation will be sampled along land-use transects (see SCETSOM details). Each transect should include original forest, if relevant to the site; a recently cleared site; cultivated lands, either crops or pastures; degraded crop/pasture land if applicable; and recovering lands. Within each land-use the tree, understorey, litter, root and soil organic matter pools are measured. There should be three transects at each site, if possible.

This section describes the methods for sampling the aboveground vegetation, litter and surface charcoal.

Tree biomass: For forest and forest fallows where the majority of the trees have a diameter > 5 cm.

Equipment:

1. Wooden sticks of 1.30 m and 1 m in length
2. Measurement tape (tree diameter)
3. Knife
4. Hagameter (to measure tree height - optional)

Set out five 100 m^2 quadrats. Fifty by two meter quadrats are easy to set up and can be used when there are few trees greater than 50 cm dbh. This can be done by running a 50 m tape through the area and then sampling the trees that are within one meter of each side of the tape. If there are many large trees quadrats of 25 m X 4 m or even 10 m x 10 m are more appropriate. Regardless of the dimensions of the quadrat, record the diameter of each tree > 2.5 cm dbh (see report form). Calculate the tree biomass for each tree using the appropriate allometric equation. The equations of Brown *et al.*, 1989, using dbh (D) can be used (see previous section).

Sum the tree biomass for each quadrat, take the mean of the five quadrats and record this as the total tree biomass for each transect (kg/100 m^2). (See data report forms and worksheets).

Understorey or shrub biomass

Destructively harvest the aboveground biomass, including trees < 2.5 cm dbh, in ten 1 m x 1 m quadrats. These square meter quadrats can be placed within the larger 2 m x 50 m quadrats if sampling in a forest or fallow.

Weigh the total fresh sample collected in the field from each 1 m^2 quadrat. Take subsamples (~300 g) to dry at 80°C for conversion to dry weight.

$$\text{Total dry weight} = \frac{\text{Total fresh weight x Subsample dry weight}}{\text{Subsample fresh weight}} \quad (kg/m^2)$$

Take the average of the 10 samples to record the understorey biomass for the transect replicate.

Litter

Herbaceous litter (including grasses and forest ground flora or trees <2.5 cm in diameter) and crop residue sampling in quadrats.

Equipment:

1. Quadrat of 1 x 1 m and 0.5 x 0.5 m
2. Scale
3. Marker pen
4. Paper bag

Collect and separate the fine litter and woody litter, from the soil surface of 0.5 m x 0.5 m quadrats placed in each of the understorey biomass sampling quadrats. Take the fresh weight in the field and subsample for dry weight determination as described for the understorey. Use the mean of the ten 0.5 m x 0.5 m samples for the fine litter, coarse litter, and surface charcoal for the transect replicate. (See data report forms and worksheets in appendix).

Unburned biomass

In the recently cleared and burned areas the remaining living biomass should be measured using the tree and understorey sampling designs.

Burned tree biomass

The remaining charred trees, branches and litter also need to be measured in the newly cleared sites. The biomass of the burned/unburned felled trees (those lying of the ground) is estimated by measuring the length (h) and diameter (D) of the trunks in five 2 m x 50 m plots. Measure only trunks with diameter greater than 10 cm. Calculate the mass (kg/trunk) by the equation $D^2/4*\pi*h*s$ (where s, the specific gravity is estimated as 0.4 g/cm^3). See data report forms.

Burned litter, charcoal and ash
The burned and unburned woody litter (litter worksheets), charcoal, and ash (see worksheets) are collected and separated from ten 0.5 m x 0.5 m quadrats. Total fresh weight and subsampling for dry weight are done as described in understorey sampling.

Litter trap for recording tree litter fall
Litter falls during growing season has to be taken on consideration. Litter traps has to be installed randomly over the site.

Equipment:
1. Wooden box about 1 x 1 x 0.25 m supported of the ground by 4 poles (0.50 m height).
2. Mesh Screen with mesh size around 1 mm or less should be installed attach to 4 sides of box. The traps must allow free drainage of rain water but fine enough to retain fine litter fractions.
3 Traps should be randomly located within moderately homogeneous plots in each sites with different cropping systems.
4. Collect the litter every week, and separate the litter into leaves, twigs (less than 2 cm in diameter) and reproductive structure (flowers and fruits)
5. Determine its dry weight (oven dry at 80 °C). Also determine ash (at 450°C) weight to correct dust contaminations. Results should be expressed in g m^{-2} yr^{-1} or t ha^{-1} yr^{-1}
6. Determine total C, N, P etc.

Note
Trays or pieces of screen on the ground surface should be installed in order to measure litter input from dwarf shrubs, but there are some potential problems e.g. drainage (if trays are used), material blown away by wind or destroyed by animals activity (depending on the edge used).

5.2 Belowground biomas

5.2.1 Introduction
Roots as organic inputs in tropical agriculture have often neglected due to difficulties in measurement. Two techniques for measuring root biomass were demonstrated during the workshop, a semi-quantitative and a quantitative one, based on root mapping and monolith (pinboard) sampling, respectively. These methods are explained here in more detail than in Anderson and Ingram (1993).

5.2.1 Root mapping on profile walls

Equipment:
1. Square (60 x 100 cm) grid (10 x 10 cm) net
2. Knapsack sprayer
3. Soil knife
4. Spade
5. Needle

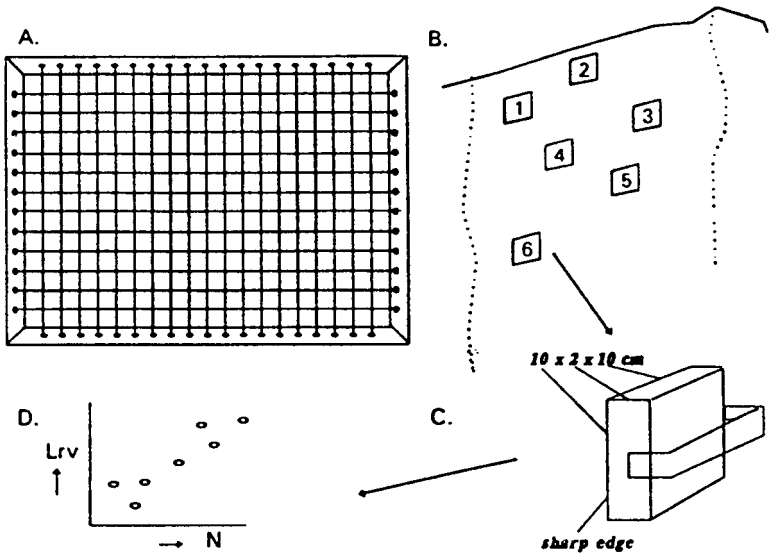

Figure 5.2.1 Root mapping. A. Frame with 10 cx 10 cm grid of strings, B. Possible position of subsamples on the profile wall, C. Metal box for taking subsamples for washing fine roots and measuring their length, D. Calibration line of the number of intersctions per unit area and root length density per unit soil volume for the subsamples.

6. Scissors
7. Transparent Polytene (PVC) sheets
8. Marker pen
9. Filter paper
10. Metal Box (10 x 10 x 2 cm)

Field procedure

1. Dig a soil pit close to the plant (about 10 cm) selected for study.
2. Identify some main roots, and carefully follow their course in the profile (abandon them when they disappear too far beyond the plane of observation) and observe root distribution and rooting depth; then smoothen the profile wall.
3. Cut roots which stick out of profile wall and clean the soil profile with a sharp knife.
4. Spray the profile wall with some water to remove about 2 mm of soil to expose roots. (For clay soil gently brushing the profile wall may help).
5. Place a clear PVC sheet on the profile wall and carefully place the grid wooden frame on it.
6. Mark major features in soil structure (e.g. soil crack, termite holes etc), and also horizon boundaries.
7. Mark all roots with dots on sheet, differently coloured pens can be used for different size classes or plant species. Branch roots outside the observations plane can be neglected. Use the grid to work systematically and pay equal attention to all grids.
8. Calibration Line (optional): Take about 12 small block samples (circa 20 x 10 x 2 cm^3) from various layers (Figure 5.2.1); map the position of each sample on the map

and store the sample in a plastic bag with a label referring to the number of the root map and the sample number.

9. When the map is complete, use the upper right corner to write the date, location, map number and persons mapping the roots. Then take the map off the profile, dry it and store between filter paper (to prevent 'printing' additional roots)

Data analysis

10. Root maps: For analyzing data, cover the map with a 10x10 cm grid and count the number of interceptions per cell. Express results as (N, number of dots cm^{-2}) per soil horizon (or depth interval) and as a function of distance to the plant. More advanced methods of map analysis can quantify spatial correlation of roots and other map features (cracks, termite holes, roots of another species), but these need some form of computer image analysis tools.
11. Calibration line: Wash the sample on a fine sieve (0.3 mm mesh), determine total root length by counting intersections with a grid (Anderson and Ingram, 1993) and calculate root length density, L_v (cm cm^{-3}). Dry the subsample, weigh and express as root weight density D_v (mg cm^{-3}). For each subsample also count the number of intersections (N, cm^{-2}) with the map and make a calibration line of L_v versus N and one for D_v versus N. If roots have no preferential orientation and all roots are mapped correctly, the calibration line should be approximately L_v = 2 N. Total root biomass per unit area can now be calculated from root counts N for the whole map and the calibration line.

Potential problems with this method:

a. Roots of different plants may be hard to distinguish (it helps to trace some of them to the stem base to be sure of their identity)
b. Distinction of live and dead roots is not easy
c. A considerable fraction of fine roots may be overlooked, especially in the topsoil; an 'operator bias' is likely to remain and comparisons of maps made by different persons are less reliable (check with the calibration lines)
d. Difficulties of observing plants roots due to condensation behind the PVC (it helps to build a small shelter and avoid direct sunlight on the profile wall).

5.2.2 Pinboard monolith sampling

Equipment

1. Pinboard ('fakir beds') are made by inserting U-shaped stainless steel pins into a piece of plywood or board with holes every 5 cm (fig. 5.2). These pins can be made from bicycle (in Indonesia: becak) spokes bent into a U-shape, with a 5 cm base and upright length of about 14 cm (if the plywood or board is 2 cm thick, this gives an effective sampling length of 12 cm). The tops of the pins are sharpened, but take care as it becomes a dangerous piece of equipment. After insering the pins, a back cover is screwed on to the board. The size of the pinboard is determined by rooting depth of plants and practical considerations. The pinboard can be stored and transported in pairs, or in a dis-assembled state.

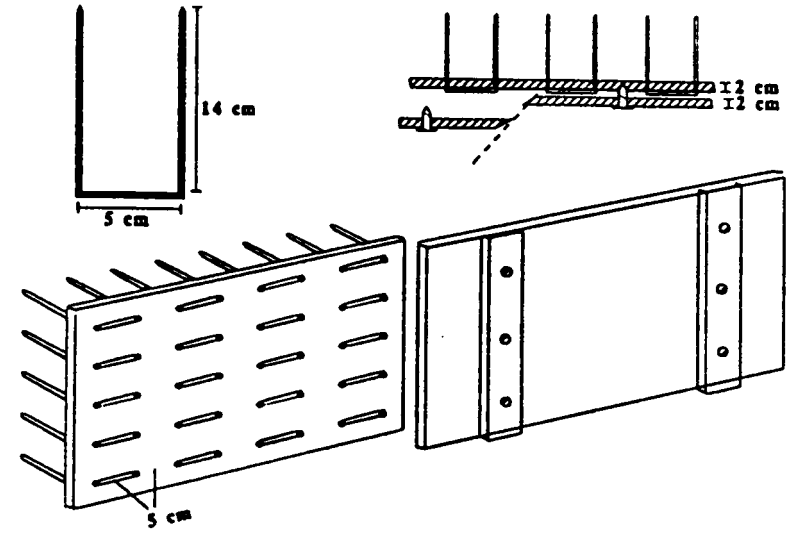

Figure 5.2.2 Pinboard design. U-shaped pins are inserted into a board in order to hold the roots in place when soil is washed from a monolith.

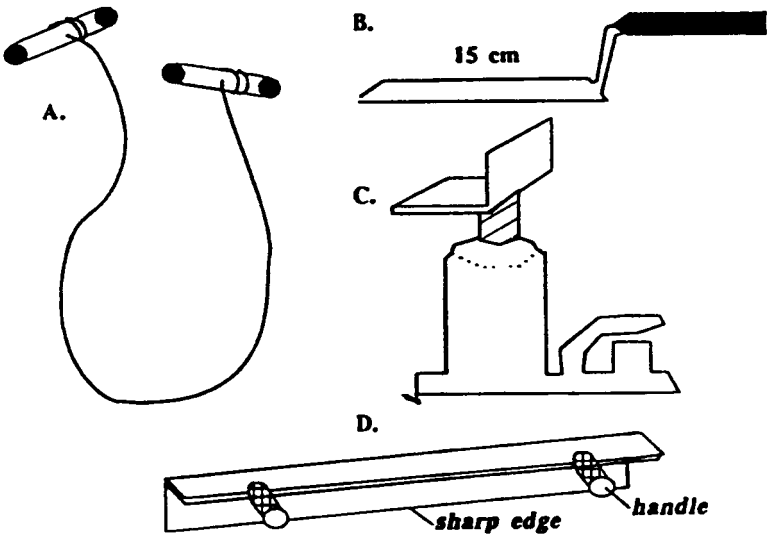

Figure 5.2.3 Auxiliary equipment for taking root samples with pinboards: A. cutting wire, B. Knife, C. Jack to support the pinboard, D. Blade to smoothen a profile wall.

2. Coarse mesh screen, slightly larger than the pinboard
3. Spade
4. Blade
5. Rubber hammer
6. Car jack (Fig. 5.3)
7. Knives
8. String (motorcycle brake) or a steel cable with diameter 2 mm
9. Old sacks (to pack the sample for transporting it)
10. Forceps
11. Thymol

Procedure

1. Select a representative crop stand and note any weed growth surrounding it. Put the mesh screen on the pins and pull it down till reach the bottom of board.
2. Dig a soil pit next to the area to be sampled. The length and depth of the soil pit are determined by the root distribution and rooting depth of the plant to be observed. When plants are in the row, the pit should be dug perpendicular to the crop row. A width of about 0.5 m is required for working. Keep separate heaps for topsoil and subsoil in ortder to reduce long term siote disturbance.
3. Smooth the profile wall where the sample is to be taken with a blade; the wall should be made straight.
4. Describe the soil profile; all relevant information are should be noted e.g. soil horizon, crack, termites hole, or old tree root channel and some soil physical parameters (Up to this stage the method can be combined with root mapping).
5. Place the pinboard vertically with the pins against the profile face, adjust so that the top row of pins is at ground level, and push the pinboard into the soil by hammering the back of the pinboard.
6. Remove about 15 cm (a few centimeters beyond the tips of the pins) of soil underneath the pinboard with a knife.
7. Support the pinboard with a car jack.
8. Cut away soil profile on both sides of the board, also a few centimeters further than the tips of the pins.
9. Put the steel cable along the bottom and up the other sides of board and have two persons draw it up in a sawing movement, so that the monolith is cut away from the soil mass. In the mean time, one person should stand in the soil pit and hold the sample on the car jack when it is cut free (take care when the steel cable emerges form the soil).
10. Pull the board backwards, and support it against the opposite wall of the soil pit; cut away soil untill the level of the pins and any additional soil from the bottom and side of the sample.
11. Carefully lift the monolith out of the soil pit (now you'll notice why you should not make the pinboards too large).
12. Lable the sample and wrap it in old sacks for tranport to the laboratory.

Removing soil and root washing

1. Soak the monolith sample overnight in water.

2. Spray with water gently, start from the bottom and gradually go up to the surface layer; gradually lift the mesh screen so that water can pass underneath.
3. Remove debris and roots of unobserved crops out from the board using a forceps (for total biomass determine their weight).
4. Lift the mesh screen further, so that the root system can be taken out from the pinboard and take a photograph (use on a black cloth as background).
5. Cut the root systems according to thickness of soil horizon and to distance to the plant.
6. Store the root samples in plastic bags filled with water and thymol (a bactericide).
7. Store samples in the refrigerator if available, for further handling.
8. Take the root samples out of the plastic bags, and put into a clear box (25 x 15 x 7 cm) filled with water.
9. Remove all remaining debris and soil, and determine root length (Anderson and Ingram, 1993), root diameter (if needed) and root dry weight (dry in oven at 80°C for 2 nights). Root length density and root diameter measurements are important parameters for study nutrient uptake only.
10. Estimate total biomass per plant by integrating root weight density per zone and depth over the relevant volume of soil.

Disadvantages
1. It takes much time (Labour), especially for washing and cleaning the subsamples; the method is a lot faster, though, than methods based on soil cores.
2. Some roots might be broken and lost during washing.
3. The soil pits disturb the land in long term experiments.

Advantages
1. Quantitative assessment of root biomass with less effort than by coring.
2. Distinction between roots of different plants and between live and dead roots is possible.

5.3 Soil Organic Matter Fractionation

The CENTURY model suggested that soil organic matter should be well defined, as it consists of a wide range of compounds forming a biochemical continuum from cellular fractions of higher plants and of microbial origin to humus compounds. TSBF defined fractions of organic matter are:

a) Light fraction: active soil consisting of microbial biomass and partially humified/cellular organic matter with a short time of 1 to 5 years.

b) Heavy fraction: humified soil comprising physically protected and/or chemical forms of organic matter which are resistant to decomposition with turnover times from 20 to 40 years ('slow pool OM') up to 200 to 1500 years.

For practical purposes the heavy fraction is defined as the organic C and N pool in soil samples after the removal of the light fraction, therefore study on organic matter dynamics, separation on pools of C with a rapid turnover (active fraction) and pools of C with a slower turnover rate is very important. The requirements for TSBF site characterization are the determination of C and N in light and heavy fractions, and determinations on lignin and polyphenolic content in the light fraction absolutely necessary.

Two techniques for separation of light fraction are: (a) based on particle size and (b) based on particle density.

5.3.1 Fractionation of soil organic matter based on particle size: Wet sieving

A simple technique for fractionation of soil organic matter based on particle size (wet sieving technique, see Okalebo *et. al.*,1993) was demonstrated. Using a wet sieving technique, particulate soil organic matter (POM) is defined as the fraction with diameters between 50-250 μm. The assumption is that this POM fraction is the most readily available soil organic matter fraction and determines N mineralization rates, along with fresh organic inputs. With this technique, however, contamination of light fraction with soil mineral components or humified products of the same size is unavoidable.

5.3.2 Density fractionation of Soil Organic Matter using silica suspensions (LUDOX)

Differences on soil texture ans soil structure may effect the decomposition and mineralization of organic matter fractions and microbial turnover. In fine textured soils (clay) a larger part of the organic matter may be physically protected due to its location in small pores and on the surface of clays or organic complexes than in coarse-texture soils (Hassink, 1992). In clay soils a higher proportion of the microbes is physically protected against predation than in sandy soil, by its location in small pores, where their predators can not reach them (Hassink *et al.*, 1993). If we separate soil material, of a specific size, by its physical density, the light fraction will contain purtely organic material, while the heavier fractions contain organic material more closely associated with mineral particles. It seems likely that these heavier fractions represent soil carbon in more stabilized and/or physically protected pools. The fractions with a rapid turnover (active fractions) are assumed to play an important role in soil nutrient dynamics.

Meyboom *et. al.* (submitted) introduced a new and simple method for density fractionation of organic matter using a silica suspension. The light fraction appears to be a more sensitive parameter than total soil organic matter, reflecting differences in management and quality of the organic matter input. Based on this measurement soil organic matter will be divided into three density fractions:

(a) Light fraction, which has particle density < 1.13 g cm^{-3}, and consisting of recognizable plant residues,

(b) Intermediate fraction, which has particle density 1.13 - 1.37 g cm^{-3} and partly is humified material

(c) Heavy fraction has particle density > 1.37 g cm^{-3} and consisting of undefined (amorphous) organic material.

This fractionation is performed in the sand-size organic matter (macroorganic matter; > 150 μm), as that organic-C is more labile than organic-C in the clay and silt size fractions (Tiesen *et.al.*, 1984).

Material and methods

1. Sieves:
   - Top sieve : mesh sieves 250 μm
   - Bottom sieve mesh sieves 150 μm
2. Tray with a mesh screen 150 μm
3. Boxes + 'sieves-spoon'
4. Tissue paper
5. Paper bags
6. LUDOX is an aqueous colloidal dispersion of silica particles produced by Du Pont, it has a maximum particle density 1.3 g cm^{-3}.

Particle Densities (PD) of suspensions needed are:
   - PD = 1.37 g cm^{-3}
   - PD = 1.13 g cm^{-3}

Procedure

First step: Sampling and washing of the samples

1. Sieves fresh soil (< 8 mm), removes all roots, stones, and other bigger debris and samples should be homogenized.
2. Determine the moisture content of subsample
3. Assemble a wet sieving apparatus with mesh sizes 250 μm, and 150 μm
4. Weigh about 500 g of soil, and wet-sieves over two layers of sieves and sprayed with a reasonable pressure of tap water. The top sieve had a mesh size of 250 μm and the bottom sieve is 150 μm .
5. Push soil particle through top sieve while washing, spray with water till the water passing the sieve became clear.
6. Collect all of the organic material present on both sieves, and bring into a bucket of water, and swirl several times those material.
7. Separate organic material and mineral material by decantation.

So the organic fraction recovered from both sieves (> 150 μm and > 250 μm) is called MACRO ORGANIC MATTER, while material retains in the bottom of bucket is called MINERAL FRACTION.

8. The macro organic matter needs further treatments (2nd step), while mineral fraction is discarded.

Second Step: Density Fractionation in LUDOX

9. Put all macro organic matter on a tray with a mesh screen 150 μm, place in Ludox suspension with a density 1.37 g cm^{-3}, and mix it several times.
10. The sinking material fraction call as a heavy fraction (PD > 1.37 g cm^{-3}).

11. Collect the floating material using a 'mesh-spoon' and put on the same tray as used before, place in Ludox suspension with a density 1.13 g cm^{-3}, mix it several time, and also separate between floating and sinking fraction. The floating fraction (PD < 1.13 g cm^{-3}) called as Light Fraction and sinking materials further called as Intermediate Fraction (1.13 < PD < 1.37 g cm^{-3}).
12. Wash the three fractions with tap water for dry weight determination; for chemical analysis that materials should be rinsed with demineralized water.
13. Determine total N, ash and organic-C content.

Note:
- On average macro-organic matter samples were incubated in the Ludox for approximately 10 minutes; standardization of time is necessary to reduce operator variability.
- Difficulties existy in classifying the organic material which is suspended in Ludox solutions (PD 1.13 g cm^{-3}).

5.4 Decomposition rate of organic sources

Decomposition of dead plant material can have a direct effect on crop growth, by mineralization of N, and an indirect one, by build-up of soil organic matter which may increase future efficiency of nutrient use. Rapidly decomposing material of low C/N quotient contributes mainly by N-mineralization and slowly decomposing litters contribute especially to the build up of the soil organic matter pool. Measurements of mass losses from unconfined litter under natural conditions had been demonstrated, by using a standard litter bag designed by TSBF.

Equipment:
1. Litter bag made of exuded polyvinyl with a 7 mm mesh, so its still allow free access to most groups of macrofauna. The sides of litter bag is bent up to retain the shape of shallow box-like container, 30 cm 30 cm by 2.5 deep.
2. Balance

What sort of organic materials should be used?
* Forest studies: mixed samples of freshly fallen leaves, if necessary can be collected from the ground.
* Agricultural plots: crop residues (mixtures of stems and leaves).

How many litter bags are needed?
At least five bags should be observed for every time of sampling, and at least four sets of samplings should be done before 50% of the original mass is lost.

Procedure
1. From the material used for the experiment, total N, C, lignin and polyphenolic concentrations for all sample materials should be analyzed.

2. Fill the litter bag with a known amount plant material equal to normal inputs of that resource per unit area. For a fine plant materials, an extra fine plastic screen materials needs to be placed at the bottom of bags.
3. Place the bags randomly in the field on the soil surface if mulching system is the common practice, or burry the bags if incorporation of residues is the common practice; label the samples and mark their position on a map.
4. At sampling time, lift the bags carefully up, and put into a plastic bag to avoid mass losses during transportation.
5. Take the plant materials out of the bags by flotation and brushing the bags in water.
6. Rinse the materials with demineralized water, dry (oven dry at 80°C) and weigh.
7. Determine concentrations of total C, N, lignin and polyphenolic.

6. SCETSOM: Shifting Cultivation Effects on Tropical Soil Organic Matter, an Experimental Protocol Prepared for the Global Initiative for Alternatives to Slash-and-Burn Agriculture

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6.1 Introduction

Principle

Declines in soil fertility within a few years of forest clearing and burning are often related to the depletion nutrient-rich soil organic matter pools. The Tropical Soil Biology and Fertility Programme proposes that a standardized experiment be conducted at Slash and Burn research sites that assesses the dynamics of soil organic matter during the different phases of the shifting cultivation cycle. Periodic measurement of soil organic matter fractions and their nutrient contents will be measured in bare fallow and cultivated plots and compared to the initial levels within the original forest. When severely degraded soils are available, the same experiment will be conducted. The rate of the SOM decline will be compared in plots with differing clearing and burning managements. A standard "slash and burn management" acts as the complete control. This control will be a plot previously under natural vegetation, cleared, burned and with ash removed. Alternatively, institutes may have previously established long-term sites or experiments in which several of the SCETSOM treatments are currently under study. In this case, the measurements proposed within SCETSOM will be preferentially focused upon those previously established sites because treatment differences are likely to be greater within the broader time span of the different land uses. This study will provide SOM turnover and nutrient availability indices for different S&B soil-climate-vegetation-land management combinations. More specific objectives of this study include:

1. To measure the changes in soil organic matter and nutrient pools resulting from slash and burn agriculture and alternative land-use practices.

2. To determine the effects on soil organic matter dynamics of organic matter inputs to soils following slash and burn agriculture.

3. To test and modify a conceptual and simulation model (CENTURY) of soil organic matter dynamics under slash and burn conditions.

Strategy

TSBF Headquarters staff will identify a minimum data set and experimental design which explores carbon and nutrient dynamics. Cross-site comparison will be facilitated by the use of

standardized methods which will also be provided by TSBF. TSBF's strategy to characterize carbon and nutrient fluxes within S&B follows:

1. *June, 1994.* TSBF will identify the minimum data set and treatment selection for distribution to collaborative institutes in Brazil, Cameroon and Indonesia. The national institutes will nominate an individual scientist to collaborate with TSBF on future activities. This scientist will indicate their willingness to participate in the SCETSOM experiment during July, 1994.
2. *August - November 1994.* TSBF scientists will visit each S&B field site and assist national scientists in data collection necessary to complete the data set requirements and participate in either the installation of the SCETSOM experiment or sample collection/analysis from the previously established long-term experiments. It is anticipated that TSBF scientists will visit Brazil during October, 1993, Cameroon during December 1993 and Indonesia early in 1994.
3. *November 1994 - November 1995.* Scientists in the cooperating institutes will complete the SCETSOM experimental observations according to the schedule which follows and send the completed data report forms to TSBF Headquarters in Nairobi for data base entry. TSBF will distribute preliminary results to all cooperators as these become available. Cooperators who opt to characterize previously established sites will also complete their analyses and report to TSBF during that time.
4. *December 1994.* The final experimental results will be compiled and distributed to all cooperators. The results will be disseminated by joint publication submitted to an international journal. The experimental results will also be used to calibrate/validate the application of the CENTURY Model (Parton *et al.*, 1987) to S&B systems.

While individual cooperators are given the option to either participate in the SCETSOM experiment or to conduct a suite of measurements on existent field sites, it is hoped that all cooperators will be willing to conduct both activities. Furthermore, if when soils of different textures or mineralogies occur within an individual S&B study area, cooperators are encouraged to conduct the SCETSOM experiment at each soil type. The following is a the experimental protocol of the SCETSOM experiment including treatment options and the alternative approach of characterizing existent field sites. Comments by cooperators on these experimental approaches should be sent to: *Paul Woomer, Tropical Soil Biology and Fertility Programme, PO Box 30592, Nairobi, Kenya. FAX +254-2-215991 E-mail TSBF @ CGNET.COM*

6.2 SCETSOM I: Measurement of carbon and nutrient dynamics within a representative slash and burn chronosequence

Principle

Given the short duration of the initial S&B grant, we suggest that the most expedient way to assess the C and nutrient dynamics in S&B is to establish transects which span the range of land uses present in the systems. At a minimum the land uses along the transect will include the original forest, a field shortly after burning, a productive agricultural system and the land at time

of abandonment for fallow. To date, national scientists have notified us of the general locations of their planned research, but no specific transects have yet been identified. Keep in mind that the transects should be as compact as possible (short), the ages of the various land uses be known, and, whenever possible, the transects should include a single, widely representative soil type. One disadvantage is that these chronological sequences along forest margins tend to be progressive and less subject to analysis of variance because the placement of individual plots are not randomized within the overall design. This difficulty may be overcome by establishing replicated transects along the chronosequence and placing greater reliance upon regression techniques for analysis of experimental results. Finally, it is hoped that national cooperators will combine the SCETSOM: chronosequence approach with a more intensively monitored, small plot experiment placed within a recently cleared and burned field of the slash and burn chronosequence.

General approach

A forest-cultivation-fallow sequence along a rainforest margin will be identified by cooperating institutions either along three parallel transects or in collaboration with three farmers (Figure 6.1). The forest area scheduled for clearing will be characterized in terms of standing forest tree and understorey biomass, standing litter and soil organic matter fractions (Anderson and Ingram, 1993). After clearing and burning by the farmers, the measurements will be repeated. This approach measures the magnitude of carbon loss resulting from the clearing and burning event. At each farm, nearby land that had previously cleared and continuously cropped, or cropped and abandoned (recovering fallow) will be dated and identified. The rates of plant productivity and

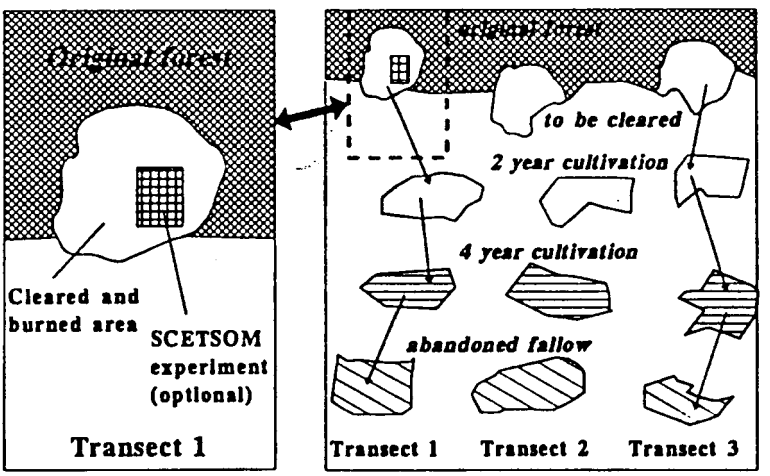

Figure 6.1 Diagrammatic representation of the S&B chronosequence showing different land uses and individual farms/sites as replicate transects.

organic matter dynamics will be measured at six month intervals for one year. These combined measurements will provide a chronological sequence of total system carbon. Attention will be paid to below ground dynamics. The soil organic matter will be fractionated on the basis of particle size as described in Okalebo *et al.* (1993).

Establishing Transects

The selection of the individual transects is at the discretion of the collaborating scientists after several criteria have been taken into account.

1. The study sites along the transect must consist, at a minimum, of the original forest, a recently burned field, a productive agricultural field and a recently abandoned fallow. Additional sites might include a degraded cropland, a plantation, severely degraded/abandoned lands or a recovered fallow. It is important that the ages of each land use, except the original forest, be known.

2. The original vegetation, soil, cropping and fallow systems should be somewhat representative of the predominant conditions of the benchmark area being investigated by other members of the national Slash & Burn team.

3. The soil along the transect should be uniform. The entire transect should fall within the same mapping unit at the sub- to great-group level. Areas of soil associations or dissected terrains are more likely to contain non-uniform soils. Soil texture should remain relatively constant.

4. The design may be viewed as either three replicated transects or a single transect with replicated (x3) land uses. If the latter approach is employed, take care to have different farmers as replicates rather than different small clearings of the same farmer.

5. The transect should be as compact (short) as possible although we realize that these different land uses occur over several km along some forest margins.

Experimental Design and Treatments

Three replicate transects or farms will be selected along the forest margins (Figure 6.1). The natural forest planned for clearing, presently cultivated fields and abandoned fallow areas are identified, dated and chronological sequences established along transects. The carbon pool measurements necessary to characterize the dynamics of a shifting cultivation system are presented in Figure 6.2. A brief description of sampling procedures follows although cooperators are encouraged to sample as individual conditions warrant:

1. **The original forest.** The forest is best measured in the state immediately before burning. Large woody vegetation may be measured by either the circular quadrat (less dense forest) or belt transect methods (very dense forest) and each site should

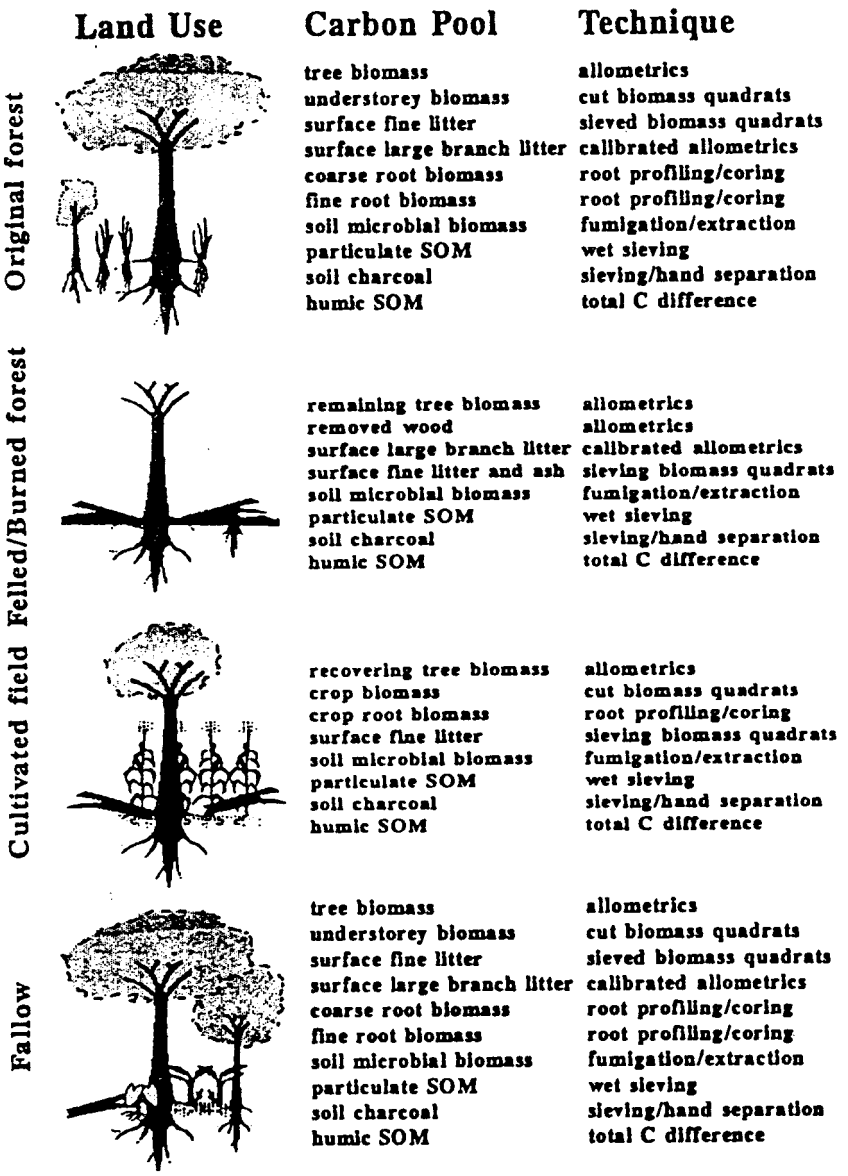

Figure 6.2. The carbon pool measurements and approaches necessary to characterize the dynamics of a shifting cultivation system.

contain at least 100 trees (Anderson and Ingram, pp 22-27). The diameters at breast height should be measures and the tree heights estimated and the equation for either dry (>1500 mm/yr), moist (<4000 mm/yr) or wet (>4000 mm/yr) forests utilized as is appropriate. Understorey vegetationand litter is destructively measured from at least 3 1 m x 1 m subplots (see Anderson and Ingram, pp 27-31). Root biomass is destructively harvested from a 25 cm x 25 cm x 25 cm volume from each understorey subplot. Roots are washed, chopped, fresh weight recorded and a subsample of known fresh weight recovered for air drying and analysis. Soils are collected from the entire forest biomass plot to 20 cm (assumed to be the depth of later hand cultivation). Alternatively, soils may be collected and labelled by depth from their diagnostic horizons if these are known although this sampling strategy adds to the number of analyses.

2. **Recently cleared and burned fields.** The greatest changes in biomass and certain soil properties occur as a result of forest clearing and burning. In many cases, all trees are not felled, the biomass of, and land area occupied by, these trees must be measured allometrically (see above). In most cases understorey biomass will be completely burned, but if not should be measured from 1 m x 1 m subplots. Of greatest interest are the incompletely combusted woody material, surface ash and charcoal, and changes in soil properties. Surface ash and charcoal are collected from three (3) 1 m x 1 m subplots. Soils are sampled from the entire burned plot to 20 cm. If the plots have already been tilled, collect to the depth of tillage. Alternatively, soils may be collected and labelled by depth from their diagnostic horizons if these are known.

3. **Cultivated lands.** It is the productivity and duration of cropping that occupies the greatest overall importance to the Alternatives to Slash & Burn Project. At the same time, the cropping pattern within the cultivation phase of S&B is often extremely complex, with the initial annual crops being no longer cultivated in favour of perennials during the later stages of cultivation. At the same time, net productivity declines with time leading to the farmer's decision to abandon cultivated land in favour of additional forest tillage. We propose to characterize the cropping systems as follows:

   a. First season productivity. Scientists return to the site of the cleared, burned area characterized above later during the cropping season when the first cropping cycle is at peak biomass (shortly before harvest maturity of the principle crop). We may assume that the initial C and nutrient stocks are equal to that measured in the cleared, burned forest (above). The different crops present and their coverage is described. Crop biomass is measured from three (3) 1 m x 1 m subplots. Standing litter is recovered from the subplots. Crop root biomass is destructively measured from 25 cm x 25 cm x 20 cm soil volumes. The dates of establishment of perennial species should be noted. The growth of remnant tree species may be approximated allometrically by their change in height. A composite soil sample is recovered by coring from the entire plot to tillage depth. Alternatively, soils

may be collected and labelled by depth from their diagnostic horizons if these are known.

b. Second season productivity. Preliminary results and a review of the literature suggest that maximum productivity often occurs during the second cropping cycle. If this point is included within the transect, it may be characterized at a time and in a manner similar to the first season cropland except that the coverage and productivity of the establishing perennials also needs to be measured. Scientists should be aware of, and collect samples of, any key indicator species that either exhibit nutrient deficiency symptoms, or become excluded from the cropping system as soil fertility initially declines.

c. Degrading croplands. The transect must include cropland shortly prior to abandonment. The C and nutrient stocks of the degrading croplands at time of abandonment serves as a baseline for the soil depletion during cropping, and as the starting point of fallow recovery. It is extremely important that the age of these croplands be known, as well as the farmers intention to abandon the lands to fallow during the next cropping season. Often the crops present will bear little resemblance to the earlier system and consist of the remaining perennials established earlier during cropping. The stature of the perennials may require that biomass subplots be larger, and special attention needs to be paid to accumulating litter stocks and the early establishment of recovering fallow species. Otherwise, sample the biomass, litter, roots and soil as described above.

4. **Recovering fallows/degraded abandoned lands.** The end product of a single cycle of slash and burn is land abandonment. These abandoned lands may either revert to rapidly establishing and succeeding fallow or enter into a grassy or shrubby delayed succession. In the case of the recovering fallow, nutrients are rapidly re-accumulated and system biodiversity is enhanced, in the case of the delayed succession this does not take place. It is an important objective of the Project to determine where and when the latter situation is likely to occur and how to avoid this condition. Whenever possible, the transects should include both fallow conditions in close proximity for comparison. Again it is important to know the age of the fallows, the length of the previous cropping cycle (which should equal the cropping duration of the degraded cropland, above). Recovering fallows are characterized similarly to the original forest, although special attention should be placed on remnant crop species from the cropping cycle. Degraded, abandoned lands often must be characterized combined coverage estimates along a transect and destructive subplot sampling because few trees have achieved sufficient stature for allometric approaches to be applied. Pastures derived from forest clearing may be measured in a similar fashion. Again, special attention must be placed on standing litter stocks, root biomass and representative soil sampling.

5. **Plantation forestry.** One of the recognized alternatives to slash and burn agriculture is the establishment of plantation forests. In this case, economic tree species are planted following forest clearing, or sometime into the cropping cycle. If such a land

use occurs along the transect, we encourage that this point be included for detailed study. Tree biomass is measured allometrically. Ground cover, litter stocks and root biomass measured using the subplot technique. Representative soil samples are recovered as described above.

Analytical methods of plant and soil samples

The field and analytical procedures to measure the various C and nutrient pools may be obtained from Anderson and Ingram (1993) except for C fractionation, which is presented in Okalebo *et al.* (1993) and the recovery of soil charcoal, which for the time being must be recovered by hand sorting and then analyzed for C and nutrients.

Data analysis and data sharing

The initial site characterization will be used to develop a CENTURY Model (Parton *et al.*, 1987) site data file at TSBF headquarters and subsequent research results used to validate the model within a shifting cultivation system. A data base will be prepared by TSBF which compares the transects and the results obtained from them. Cooperators from the national institutes representing the AS&B benchmark sites are encouraged to compile and analyze the results of their studies as well as publish those results. TSBF is charged within AS&B to compile and report upon the organic matter and nutrient dynamics resulting from slash and burn, and will process the data report forms returned by the collaborating scientists. TSBF plans to prepare a report to AS&B as a whole, as well as publish the synthesized, cross-site-comparative research results in the international literature. TSBF collaborators will be given the opportunity for co-authorship in these publications.

6.3 SCETSOM II: Repeated measure of SOM and nutrient decline

Principle

In some cases transects may have been previously established and researchers may be interested in acquiring a more detailed understanding of the processes which lead to land depletion by forest disturbance. We suggest a replicated field experiment that is established in recently felled and burned forest and monitored for one year. We suggest that this be considered an optional experiment and one that is conducted in conjunction with, rather than an alternative to, SCETSOM I in which SOM and nutrient dynamics are being measured in a broader context.

Experimental approach

The traditional slash and burn treatment serves as a control and compared to the effects of ash removal and organic matter (forest slash) additions (three managements). The effects of nutrient mineralization on plant productivity are evaluated by comparing planted and unplanted plots. Care must be taken to control soil erosion so that losses due to run-off are not confounded with decomposition processes. The experiment is to be replicated across Slash and Burn Project sites

in Brazil, Cameroon and Indonesia, and it is hoped that cooperators will conduct separate experiments on each soil type present at their research sites. The experimental results provide a standardized data-base for the comparison of SOM dynamics under shifting cultivation.

Hypotheses

1. The stability of tropical soil organic matter following clearing and burning is a function of soil type, climate, land management and the nature of the organic matter in the soil.

2. The three-pool functional model of soil organic matter (Active, Slow and Passive functional pools) accurately predicts changes in soil organic carbon, nitrogen and phosphorus over time following the cessation of organic matter inputs to the soil.

3. Changes in organic matter contents in soils subjected to slash and burn agriculture are determined by specific management practices and need not decline.

Experimental design

There are six treatments placed within cleared and burned forest plots as a randomized complete block design:

1. **BURNSOM.** Forest cleared and burned, surface ash and non-combusted organic matter removed and no additional organic inputs with exclusion of adjacent roots.

2. ASHSOM. As BURNSOM, but with ash and incompletely combusted organic materials retained. This treatment most closely resembles current slash and burn practices.

3. ADDSOM. As BURNSOM, but known quantities of a known quality litter are added, equal to the amount of forest litter that would have otherwise been present prior to burning.

4, 5, 6. **BURNSOM, ASHSOM and ADDSOM** plots that are planted with rice **(BURNSOMP, ASHSOMP and ADDSOMP).**

There are 6 treatments. The size of the plots is 4 x 4 m and the number of replicates is four. Therefore, a minimum area of 384 m^2 is required for the experiment, although additional area should be allocated whenever possible to pathways separating blocks (Figure 6.3). It is important that the experimental site be homogeneous with respect to soil (especially texture), previous vegetation and land use. All the replicates need not be in one contiguous block in order to satisfy these conditions. All treatments are to be hand tilled to 20 cm. Weeds and fallen litter must be continuously removed from all plots. All rice straw and grain is removed following each successive crop. The below-ground inputs are accounted for by measurement of root biomass

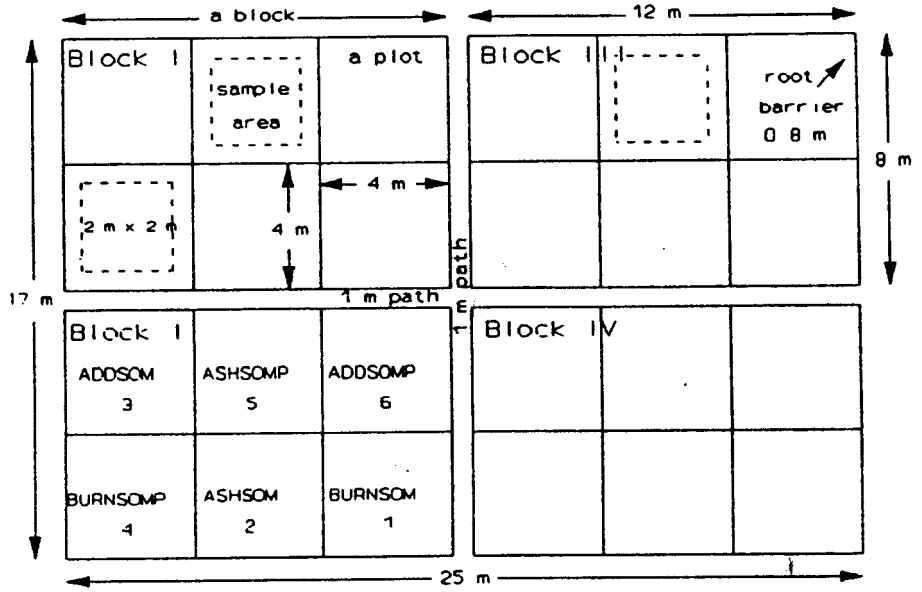

Figure 6.3 The experimental design of the SCETSOM experiment is a Randomized Complete Block with six treatments and four replicates.

from the original forest vegetation and root biomass at the conclusion of each cropping cycle. In this way the necessity of root barriers is eliminated.

Possible supplementary treatments

1. SAMESOM is the same or a similar improved land management practice currently under study by the national institute is installed.

2. BUILDSOM in which a perennial ground cover is planted in one treatment with the objective of conserving or accumulating soil organic matter.

3. SLASHSOM in which forest understorey slash is incorporated into the soil at the ADDSOM rate prior to each cropping cycle.

Procedure

1. **Initial conditions.** After felling, but before burning, all plots are defined using metal stakes. Care is taken to uniformly distribute litter across the experimental area. Surface litter is measured from 1 quadrat (0.5 x 0.5 m) in each plot. This is weighed,

250 g sub-sample taken and the remainder returned to the plot. Soil samples are recovered from each plot by combining 16 core samples/plot to 20 cm, mixing, removing a 500 g sub-sample and returning excess soil. If unburned sites are not available, the initial condition may be established by characterization of adjacent forest. Unless indicated, treatment preparation for the bare fallow and crop plots (e.g. BURNSOM and BURNSOMP) is identical.

2. **Burning.** The plots are burned by igniting the centre of each block and then the perimeter of the entire experimental area.

3. **Ash removal and measurement.** Surface ash is recovered from a 0.5 x 0.5 m quadrat of all plots and weighed. Soil samples are recovered from each quadrat (to 15 cm) after recovery of ash by combining 4 cores. The remainder of the surface ash is removed from the BURNSOM and ADDSOM plots. Ash from these plots is applied to the sample quadrats in the ASHSOM sample quadrats equal to the amounts previously removed. All samples are oven dried and ash and charcoal separated using a 2 mm sieve. The C, N, P, K and Ca contents of all samples are measured.

4. **ADDSOM plot establishment.** Unburned forest litter from adjacent cleared but unburned areas is evenly distributed across the ADDSOM plots at the overall mean rate of initial litter biomass.

5. **Tillage coarse root and large wood removal.** The plots are hand tilled to a depth of 20 cm. Coarse roots should be removed from the plot. The root biomass between 0-20 cm is measured by recovering four replicate cores/plot, washing and hand sorting. It is assumed that all roots present will become belowground organic inputs when tillage is completed. All plots are hand tilled to 15 cm. Large unburned logs are dragged beyond the experimental perimeter.

6. **Rice establishment and measurement.** Locally adapted upland rice cultivars are sown at recommended spacing in the BURNSOMP, ASHSOMP and ADDSOMP plots. A 1 x 1 m plant biomass sample is recovered after 8 weeks and a 2 x 3 m sample recovered at harvest maturity. Samples are separated into grain, stems and roots, roots are washed, all plant components oven dried at 60°C, weighed and the C, N, P, K and Ca contents of each component of yield measured. The exact date of the 16 week soil sample is altered to coincide with the final crop harvest (see 7 below).

7. **Soil sampling.** Soil samples are taken at 0, 2, 4, 8, 16, 26 and 52 weeks following burning. Each plot should be sampled at 0-20 cm using a small-diameter (40 mm or less) soil coring device or auger; sub-samples should be recovered from four random locations within each plot, protected from direct sunlight to avoid extreme temperatures and returned to the laboratory for analysis. Sample holes should be backfilled with soil from adjacent border areas. A strict record of sampling position should be kept (for instance by placing a non-decomposable marker at each location) to prevent resampling.

Table 6.1. Soil carbon measurements, recommended methods of analysis, corresponding CENTURY model pools and model parameter codes necessary to initialize the CENTURY model.

Measurement	Method	CENTURY pool	Parameter code
surface litter (TSBF[1] p. 27)	0.5 x 0.5 quadrats metabolic surface litter (carbon)	Structural and METABC(1)	STRUCC(1)
surface microbial biomass (TSBF p. 68)	fumigation/extraction	Surface microbe C	SOM1C(1)
soil litter (Apppendix 2;TSBF 63-68)	>250μm sieving/C analysis and metabolic C	Root litter structural METABC(2)	STRUCC(2)
soil microbial biomass (TSBF p. 68)	fumigation/extraction	Active soil C	SOM1C(2)
particulate soil C (Okalebo *et al.* p. 66-68)	50-250μm sieving/C analysis	Slow soil C	SOM2C
humic substances	by difference where [Total C - (soil litter C + soil microbial biomass C +particulate C)]	Passive soil C	SOM3C
leachable soil C	under review[2]	Leached soil C	STREAM(5)
soil charcoal	under review	Not applicable	Not applicable

Notes:
[1] TSBF, in: Anderson J.M. and J.S.I. Ingram. 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International. Wallingford, UK. 221 pp.
[2] TSBF would appreciate if cooperators that have identified methods for soil charcoal and leachable SOM contact our headquarters in Nairobi.

8. **Soil handling.** Upon return to the laboratory, the samples from each plot are passed through a 2 mm sieve and the large organic materials recovered, dried, weighed and their carbon, N and P contents measured. A 250 g soil sub-sample is stored under refrigeration (4°C) for no longer than one week prior to chloroform fumigation/extraction. The remainder of the soil sample (approximately 750 g) is air dried and stored for chemical analyses.

9. **Soil analyses.** Analyses to be conducted on these samples are listed in Table 6.1. The analyses are to be conducted as described in the TSBF Handbook of Methods (Anderson and Ingram, 1993) except for the carbon fractionation procedure which is explained in Appendix 1. The dry mass of soil sampled over each depth interval at each sample time must be recorded, along with the dimensions of the sample hole, to allow the bulk density of the soil to be calculated.

10. **Data analysis.** The experiment is analyzed as a randomized complete block design within individual sampling times. The effects of different treatments over time are analyzed using linear and nonlinear regression techniques.

Table 6.2 SCETSOM analyses over time[1].

Initial Conditions		Sample time (weeks)					
Cleared	Burned	2	4	8	16	26	52
MicBio	MicBio	MicBio	MicBio	MicBio	MicBio	MicBio	MicBio
PCF	PCF	PCF	PCF	PCF	PCF	PCF	PCF
TotC	TotC	TotC	TotC	TotC	TotC	TotC	TotC
TotN	TotN			Crop	TotN		TotN
TotP	TotP				TotP		TotP
ExtK	ExtK				ExtK		ExtK
ExtCa	ExtCa				ExtCa		ExtCa
ExtAl	ExtAl				ExtAl		ExtAl
DisC	DisC				Crop		DisC
	CC						CC

[1] analyses codes are as follows: MicBio = Microbial carbon and nitrogen (microbial phosphorus is optional); PCF = Carbon fractionation based on particle size (>2mm, 2mm-250μm, 250μ-50μm, <50μm, see Appendix 1); TotC = Total organic carbon; TotN = Total nitrogen; TotP = Total phosphorus; ExtK = Extractable potassium; ExtCa = Extractable calcium; ExtAl = Extractable acidity; DisC = Leachable dissolved C; CC = Charcoal (>2mm diameter, hand sorted); Crop = rice harvesting procedure.

7. Impressions of the Bungo Tebo site

The second part of the workshop was held at the field campus of Gadjah Mada university (UGM), close to Muara Tebo in Bungo Tebo district, Jambi. The site (1° 31.926' S, 102° 22.481' E) is located along the Tebo river, which joins the Batanghari river in Muara Tebo. The field campus is called Wanagama-2 (Wanagama 1 is in Java) and the surrounding forest is used for Education and Training. It is part of a forest concession privately operated by PT Sylva Gama, covering an area of 30,000 ha (originally 100 000 ha). In this site University staff and students can conduct their research and practical courses on natural tropical forest management. The forest, which is officially classified as production forest, has been selectively logged in the past decade and currently is in a regrowth stage.

Dr Suryo Hardiwinoto, the research manager of the site explained the history of the field and the ongoing activities. Since April 1993 a collaborative research with a Japanese company, Kansei Electric and Engineering Company (KEEC) was formed with the main task to find out the appropriate reforestation technique for logged-over forest. The UGM group has a number of ongoing forest experiments:
- Strip enrichment planting of Dipterocarp trees
- Forest regeneration in simulated gaps, with and without mycorrhiza enrichment
- Nutrient balance of regenerating forest

Part of the concession is classified as HTI (industrial forest plantation), but now still carries a logged over forest. A tree nursery has been started. The area borders on the Kuaman Kuning transmigration area. Soil survey maps made at the time the transmigration area was laid out include both the remaining forest area and the new villages. Around Kuaman Kuning *Imperata* grasslands have developed; in the village intensive homegardens can be found, as in other transmigration villages. Oil palm is being introduced as commercial crops.

Most of the original Jambi villages are located along the rivers, as river transport used to be dominant, and soils tend to be better along the river. Part of the forest close to the field campus appears to be old 'jungle rubber' stands.

Along many of the logging roads, spontaneous settlers ('forest squatters') have opened 'ladangs' in the forest. During our visit many plots were freshly slashed and burnt. Most of the squatters apparently plant rubber on all the land and only few food crops (cassava), mostly close to the house. Damage by wild pigs, monkeys and honey bears was given as the main reason for doing so in 'roadside' interviews with some farmers. In other ladangs banana is intercropped with rubber. Forest squatters as well as farmers from the transmigration village collect rotan and damar in the remaining forest. We also saw some ladangs made by Jambi people near Muara Tebo, who had fenced off the area in order to plant upland rice in between the rubber.

In the remaining forest a number of Kubu families (the real indigenous people) still try to continue their hunting-gathering life style. They have contact with some of the newcomers in the area, but are not easily contacted.

Dr Husin Sawit (CASER) and Dr Thomas Tomich (ICRAF) made a separate reconnaissance survey in the vicinity of the forests among the settlers. They reported and discussed their observation with the participants concerning the characterization of the socio-economic and institution aspects.

In general, in the Bungo Tebo District and especially in the Pelepat and Rantau Keloyang Sub-districts the population may be grouped into four main categories:

1. Jambi people (Malay),

2. Kubu people (Anak Dalam tribe),

3. Government-sponsored transmigrants (Javanese, Sundanese), and

4. Spontaneous migrants.

Slash and burn agriculture has been practiced by the first groups for hundreds of years. Initially, the spontaneous transmigrants came to this area as latex tappers, then they managed to rent or even buy the lands for their own activities. It was observed that slash and burn agriculture is associated with poverty and degradation of land resource.

Future studies should be focused on Malay, government-sponsored and spontaneous transmigrants, since access to the Kubu people is rather difficult. A proposal was developed to select villages/ farmers of each of these strata in an area of broadly similar soil and vegetation. As a first indication of topics which may emerge from the characterization and which may merit further research in Phase 2, we came up with:

socio-economic

* land tenure status (legal, actual and perceived) as determining factor in land use choices (contrasting extensive 'jungle rubber' of farmers with traditional access to the land and intensively managed rubber by newcomers ???)
* life histories of spontaneous settlers to clarify the range of options from which they choose and the family networks used for risk avoidance and resource exploration

biophysical

* scope for diversifying rubber/banana systems with other perennials: rotan, fast growing trees (*Paraserianthes falcataria, Acacia mangium* and/or others), slow growing Dipterocarps for damar and timber. A range of management regimes with different intensities can be envisioned as a buffer zone between the forest and the villages,
* extending the Dipterocarp + mycorrhiza technology to smallholders,
* comparing C and nutrient budgets between forests (on-going KEEC project) and other land use systems, as part of a SCETSOM transect.

8. Plan for covering biophysical aspects for ASB phase 1

During the workshop we discussed the planning for research on biophysical asapects during phase I of the ASB project. Table 8.1 summarizes the plans.

Table 8.1 Characterization tasks for ASB phase I in Indonesia, as discussed during the workshop

Benchmark zone, extrapolation domain	Peneplain, Forest margin and Recently converted forest, Low population density		Peneplain, Degraded Lands, High population density	National Park Buffer zone, high elevation
Study sites for primary data collection	Bungo Tebo Jambi	Sitiung, SumBar	Lampung Utara	Air Dingin, Sungai Penuh, ?
1. Climate	CSAR	CSAR	CSAR	CSAR
2. Soils	CSAR	CSAR	CSAR/ UniLa	CSAR
3. Vegetation	BIOTROP	BIOTROP	BIOTROP	BIOTROP
4. Biomass quantification:	FRDC/		UniLa-	
a. Above ground	UGM	CRIFC	UniBraw	FRDC
b. Below ground	UGM/ UniBraw	CRIFC/ UniBraw	UniLa- UniBraw	?
5. Greenhouse gas emissions	IPB	IPB	UniLa	IPB

Notes on characterization activities

General
All work should cover 3 aspects:
A. Review existing data,
B. Make existing data available for a Geographical Information System (GIS),
C. Collecting new data (if needed).
For some aspects (e.g. climate) or sites (e.g. Sitiung) a wealth of data exists already and the emphasis can be on aspect A and B rather than C.
Wherever possible, data should be geo-referenced using a GPS (geo positioning system).

1. *Climate.* Climate compiled (or re-analyzed) from existing data at CSAR, in combination with site-specific data where available.

2. *Soils.* Maps of 1: 250 000 exist, more detailed studies (1: 50 000) needed for the study sites (specific transsects).

3. *Vegetation.* Vegetation changes need to be linked to the land use studies.

4. *Biomass.* Biomass measurements (parameters for the Century model) are needed for relevant vegetation types, in conjunction with studies of land use (6) and vegetation (3).

5. *Greenhouse gases.* C balance linked with (2), (3) and (4); CH_4 and N_2O direct measurements. So far, no analysis on N_2O was demonstrated since the Gas Chromatograph is under service. However, there is a possibility to do it at IPB in the future. New attachment such as Gas Sampling Valve is definitely required because so far the equipment was only used for analyzing liquid samples. Another urgent supporting material is N_2O standard gas which usually requires at least two upper and lower limits of ambient concentration, like 300 and 1000 ppm.