

Alternatives to Slash-and-Burn

Above ground biodiversity assessment
working group summary report 1996–99

*Impact of different land uses on
biodiversity and social indicators*



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Alternatives to Slash-and-Burn

ABOVE-GROUND BIODIVERSITY ASSESSMENT WORKING GROUP SUMMARY REPORT 1996-99

Impact of different land uses on biodiversity

Compiled by A.N. Gillison¹ (Coordinator)

Part A: Executive summary

Part B: Above-ground, ecoregional benchmark surveys

**Part C: An intensive biodiversity baseline study in Jambi
Province, Sumatra, Indonesia**

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This report is one of a series detailing results from the Alternatives to Slash-and-Burn (ASB) Programme, a system-wide initiative of the Consultative Group on International Agricultural Research (CGIAR). The ASB programme, initiated in 1994, seeks to reconcile agricultural production and development with mitigation of the adverse local and global environmental effects of deforestation. Research sites are located in humid tropical forest margins in Cameroon, Brazil, Peru, Indonesia and Thailand. The global coordination office is located at the headquarters of the International Centre for Research in Agroforestry (ICRAF).

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Printers:	Signal Press
Cover photo:	Debra Lodoen

Printed August, 2000. Please do not cite this report without permission of the authors.

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Part A: Executive summary

This report covers the contractual requirement of ASB to the Global Environment Facility (GEF) to meet Goal 2 “*Assessment of the impact on biodiversity of different land uses*” as outlined in the aims and objectives of Phase II². It also meets the broader goals of the ASB consortium to explore the dynamic linkages among biodiversity, carbon sequestration and productivity for human needs. The approach has been to establish a series of ecoregional biophysical baselines to first identify and then to evaluate, via intensive field studies, some of the key predictive relationships among plant and animal species and functional types and the physical environment. The size of this task required that it be tackled at two levels: first, to identify broad distributional patterns of key plant groups along gradients of land use at the ecoregional scale, as these are usually closely associated with both plant and animal performance overall; and second, to explore finer scale patterns of both plant and animal performance along an intensive land-use gradient within a specified ecoregion. The assumption has been that the information derived from the intensive study could reveal indicators of biodiversity response to land use that could be extrapolated and subsequently tested within the broader spatial ecoregional framework. Once identified, such indicators would be examined to assess their potential use by managers and planners in ongoing assessment and monitoring of biodiversity and as an aid to decision support for adaptive management. While this report deals mainly with above-ground biodiversity according to the TOR of the GEF contract, close attention has been given as well to below-ground elements in the intensive study in order to better understand the dynamic between biodiversity and land use. Funding for additional survey work in Cameroon and Indonesia was supplied by DANIDA and more recent, ongoing work exploring linkages between biodiversity and profitability in Thailand and Indonesia has been funded by ACIAR.

The study was conducted along a series of land-use gradients in the Western Amazon basin, Cameroon, Thailand and Sumatra, Indonesia. For each study area, digital elevation models were constructed and coupled with all available biophysical information relating to climate, land use, land cover, geology, soils, road and stream networks, and human population distribution. Clusters of sites were then located to span environmental variability to the extent of available logistic support. In-country teams of ASB partners then collected field data using a rapid survey technique for vegetation and site physical features. In the intensive study, the same technique was supplemented by recording associated animal and additional physical data, including soil physico-chemical attributes and above-ground carbon. This gradient-based approach produced several new outcomes that are of both scientific and practical significance and extend beyond the immediate GEF requirements. For the first time, the combined use of plant taxonomic and plant functional attributes (PFAs) has shown marked improvement in our capacity to predict biophysical response and thus, biodiversity, to land use impact. *These response characteristics include (a) richness patterns in certain key plant and animal groups, (b) above-ground carbon and (c) soil nutrient availability – (and, by association, productivity potential for human needs).*

From this point of view the study has met the needs of the GEF TOR in that we have established an improved theoretical and empirical basis for forecasting the impact of land use on biodiversity along defined environmental gradients. This now has the capacity to be translated into a toolkit for managers to rapidly assess the comparative biodiversity *status quo* within tropical, lowland forested and agroforested landscapes and their land-use potential and

² Under GEF grant for Phase II of the ASB project.

then to use the acquired information to select appropriate options for sustainable management. In the course of data analyses and, at the request of the ASB social scientists, a vegetation index (the “V” index) was derived from a minimum set of plant-based variables known to be highly correlated with land-use type, plant and animal richness and soil nutrient availability. Together with a species/plant functional type-richness ratio measure, this has been incorporated into a Policy Analysis Matrix and into a bioeconomic simulation model developed by ASB partners. Recent surveys in Northern Thailand and Central and South Sumatra have established a framework for exploring linkages between biodiversity and profitability (total factor productivity). These suggest that correlations between readily observable, plant-based attributes and soil nutrient availability may be closely associated with, and thus predictive of, productivity for human needs. Information of this kind may be vital in generating and testing models of options for appropriate trade-off between biodiversity and profitability. The studies provide, for the first time, a scientific basis for generating and testing hypotheses about the role of biodiversity in productivity and related profitability in tropical forested lands.

A significant finding from the survey is that in a number of cases, plant and animal richness in early fallows and in late secondary forests and agroforests (especially jungle rubber and jungle Cacao) may exceed that of nearby intact or old-growth forest. The implications from this are that, together with certain fallow systems, certain agroforests can contribute significantly to overall biodiversity at the landscape level. The study also suggests that the influence of so-called dominant fallow weeds, e.g. *Chromolaena* and *Lantana*, should be investigated more closely, as in certain circumstances they may contribute rather than detract from biodiversity and soil nutrition. Highly significant correlations between certain sets of readily measurable, plant-based attributes and above-ground carbon suggest that the rapid survey approach may be appropriate for rapid assessments of above-ground carbon, and, under certain circumstances, below-ground carbon, where this is required to estimate actual and potential rates of carbon sequestration under different land use scenarios.

The methods used in the study have also provided a new and wholly quantitative, generic technique for profiling plant and animal habitats. Initial comparisons between similar land-use types in different countries reveal relatively consistent profiles when this method is used. A testable, cost-efficient, generic tool is now available for rapidly comparing ecosystem response in different parts of the lowland tropics where, for example, in similar physical environments in which species differ, plants and animals may possess similar adaptive traits. This development underscores the generally poor predictive capacity of plant species alone and without the benefit of complementary functional types. It also highlights the importance of including the genetically-based functional component of both plants and animals in the biodiversity equation. For management, this is significant as it opens the way to characterising individuals using non-species-based methods. For example, more than one plant functional type may occur within a species and *vice versa*. *It is clear that biodiversity assessment cannot be meaningfully implemented in isolation from other landscape facets. Because many taxa and functional types range across different land-use types, biodiversity must be assessed within the context of gradients of land-use intensity and type.* The predictive models and plant-based indicators are specific only for tropical, lowland environments; further study is required before these can be developed and tested for both lowland and upland ecosystems.

Specific software was developed in the course of the project to support both potential mapping of species (DOMAIN) and field collection and analysis of data acquired using the rapid survey vegetation proforma (PFAPro). The DOMAIN mapping software originally developed by CSIRO has been re-compiled to run under a user-friendly Windows environment. Both

software programs have been extensively used in training programs for above-ground biodiversity assessment in the three ecoregions. They are available *gratis* via the CIFOR web page and registered downloads of the DOMAIN program have been recorded from 45 countries since its release in August 1997. Although the PFAPro package has been used widely in both training and field operations, it is still in the beta-testing phase and new upgrades, including multilingual versions, are planned pending adequate funding.

Apart from the development of new biodiversity assessment survey tools, a significant outcome of the study thus far is the evident need for improved coordination of multidisciplinary field activities, in particular, the co-location of study sites. Despite early setbacks in planning and coordination of Phases I and II, the ASB program has now developed a very robust and productive research structure where devolution of research responsibility to in-country teams and partners is proving highly profitable. It is very evident from the dynamism inherent in almost all phases of land use in tropical forested lands that there is no one set of universal 'best bet' alternatives to slash and burn. Phase II has clearly shown that, at best, simple, generic tools based on sound scientific principles are likely to be more appropriate for managers to rapidly and cost-effectively assess and monitor the natural resource base than 'one-hit' land-use prescriptions developed in areas remote from the situation at hand. In a climate of largely unpredictable and stochastic biophysical and economic events, it will be necessary to have access to such tools in order to assess, compare, analyse and implement management with a greater awareness of biodiversity impact and economic outcomes. Research that targets such needs will produce a more efficient 'bang for the buck' by allowing managers and land owners to adapt to changing circumstance and to better control their livelihoods.

Future needs include a re-definition of research targets and a careful examination of knowledge gaps. The results of the above-ground biodiversity study suggest the methodology is now reasonably well worked out and requires further testing in upland and coastal environments as well as wetlands. While much more remains to be studied in the context of biodiversity and profitability, the recent improvements in research coordination indicate the real future challenge for developing sustainable options for management lies in understanding the dynamic linkages between biophysical and socio-economic elements of land use in forested and agroforested landscapes. Provided we can gain some understanding of these processes, this will open the way to appropriate policy intervention.

Part B: Above-ground, ecoregional benchmark surveys

Personnel:

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1. INTRODUCTION

These surveys were conducted as part of the research program of Alternatives to Slash and Burn consortium. It was designed to address Goal 2 of ASB Phase II, to "*Assess the impact on biodiversity of different land uses*". The extreme logistic constraints associated with the ecoregional baseline studies in different countries meant that detailed, replicative sampling of ecoregional gradients had to be replaced with an approach that was logistically feasible but, at the same time, could be used to adequately sample key patterns of land-use impact. Because the ASB program is highly multidisciplinary, it was important to co-locate study sites wherever possible. Although sampling strategies differed between disciplines, sites were centered around a common spatially-referenced sampling point (a 40 x 5m vegetation plot). Wide-ranging surveys along distances of several hundred kilometers in some cases meant that sampling was often superficial, resulting in frequently poor correlates between different data sets. In areas without an effective calibrational baseline study, it was, therefore, not possible to establish any useful models of the impact of land use on biodiversity. Another major constraint was the lack of an acceptable operational definition of biodiversity. At the time of this study there was no model or sampling system that was available to help identify useful predictors of change in biodiversity due to land use.

For the purposes of this study, a two-tier approach was selected. The first approach aimed to select, as far as possible, a representative range of land-use types in each of four ecoregional benchmark areas (Western Amazon Basin Brazil and Peru, Sumatra, Thailand and Cameroon). In each of these study locations, a rapid survey was conducted along regional gradients of land-use intensity using a vegetation and site proforma to characterise key aspects of land cover. The assumption was that vegetation would reflect overall patterns of biodiversity. Within this broad framework, a second tier of sites were placed with a much more intensive study at a finer environmental scale, employing a range of above-ground animal groups as well as an examination of soil physico-chemical variables and soil macrofauna. The relationships derived between patterns of biodiversity and the physical environment at this fine scale are now being extrapolated at a wider ecoregional scale, using the spatio-environmental framework acquired using the first tier approach. From these two approaches, an attempt was made to identify

indicators that can be used to forecast the impact of land use on biodiversity and thus provide a basis for decision making for adaptive management under changing circumstances. Because of the highly complex dynamics of landscape management and different ecoregional cropping systems, indicators have been derived that are not based so much on species but rather on adaptive features of individuals – in the present case, plants. Such indicators can now be translated into species equivalents for specific regional and local conditions. For example, the jungle rubber ‘best bet’ in Sumatra might be equivalent to ‘jungle cocoa’ in Cameroon or Brazil in terms of similar richness patterns in plant species and functional types, but it may not necessarily have the same taxonomic composition.

2. INPUTS

2.1 Research aims:

- To develop a cost-efficient method for the rapid survey of above-ground plant biodiversity.
- To identify, calibrate and test cost-efficient indicators of biodiversity for use in rapid survey and monitoring at the landscape level.
- To identify linkages among biodiversity, soil nutrient availability, above-ground carbon and profitability and related impacts of different land-use practices.
- To develop testable, analytical models to couple above and below-ground biodiversity with respect to the above.
- To provide a scientific basis for cost efficient toolkits that can be used by managers and planners to acquire data about biodiversity as an aid for decision support for adaptive management and sustainable alternatives to slash and burn.

2.2 Summary of survey design criteria and field methods:

Purposive selection of biophysical gradients or benchmark sites was applied in three continental ecoregions. These covered a wide range of land use types using a gradsect-based survey design³ that employs as a sampling framework, those key environmental gradients that are either known or assumed to determine plant and animal distribution. At each site, the same procedure was used to collect biophysical data including site physical characteristics, vegetation structure, all vascular plant species and unique functional groups (*modi*) in a 40 x 5m plot. At each location, after consultation with in-country partners, a representative gradient of land-use types was selected for study. These were co-located as far as possible with other studies of below-ground biodiversity, carbon stocks and greenhouse gases. Each ecoregional benchmark contained a similar range of land uses from closed forest, tree crops, subsistence gardens and degraded grassland or pasture. While most surveys were necessarily superficial due to logistic constraints, they were supplemented by an intensive baseline study in Jambi province, Central Sumatra. In that study, a team of national and international specialists in plant and animal survey collected data that could be used to seek underlying patterns of plant and animal distributions along a readily distinguishable land-use gradient. The results from that survey (see Part C) have enabled the identification of the most efficient indicators of biodiversity habitat and provided the necessary platform for extrapolative mapping of key species and

³ Gillison and Brewer (1985). The use of gradient-based transects or gradsects in natural resource surveys. *J. Environ. Manage.* 20, 103-127.; Wessels, K.J., Van Jaarsveld, A.S., Grimbeek, J.D. and Van der Linde, M.J. (1998). An evaluation of the gradsect biological survey method. *Biod. Conserv.* 7, 1093-1121.

functional groups. In Mae Chaem, Northern Thailand (see Part D) plants and birds were sampled along land-use intensity gradients with mixed results, suggesting the need for a re-examination of the sampling technique for birds. The Cameroon study (Part E) was restricted to plants due to logistic and funding constraints. Overall, these indicators facilitated the analysis and interpretation of limited data from the non-intensive study sites. Details of the plant-based methodology can be found in the report of the 1997 Sixth Annual Review Meeting for ASB. Techniques for sampling animals are explained in the relevant surveys (Parts C and D) In order to assess the value of new locations, CIFOR supported the reconnaissance of additional sites in Mexico and Madagascar.

2.3 Above - and below-ground site locations and summaries:

Of the 162 plots located for above-ground (AG) biodiversity assessment, 92 were co-located with below-ground (BG) sites (including 16 intensive baseline plots from Sumatra). A wide range of land-use types from pasture to different agroforestry to forestry systems were sampled in Brazil (21 plots in Rondônia/Acre), Perú (36 plots in Pucallpa and Yurimaguas); Yucatan (9 plots in Zona Maya and Campeche); Indonesia (47 plots, Jambi); Cameroon (21 plots Mbalmayo/ Yaounde). (Annex 1, Table 2); Thailand (28, Part D). For carbon stocks and greenhouse gases, 50 sites were co-located (see Annex II, Figure 1a and refer Climate Change WG report).

2.4 Data storage, distribution and access:

Data were recorded in hard copy in the field and later transcribed into a computer using the FUNDAT computer program developed in CIFOR (now replaced with the more recently developed PFAPro). All data were spatially referenced using a Global Positioning System and stored in a Microsoft Access (*.mdb) format. In this way, data from all benchmark sites can be accessed in a uniform way and analysed both separately and *in toto*. This method of data acquisition was developed after close consultation with field teams in each country. Team representatives from each country were supplied with a set of diskettes, each containing a complete data set from all ecoregional sites. The core data set has been archived in magnetic media and hard copy at CIFOR, Bogor, Indonesia. Additional backups have been made on 3.5" diskettes and IOMEGA ZIP diskettes. Graphic files and data catalogues have been transferred to the office of the ASB Coordinator in Nairobi. A comprehensive data catalog is available in Annex III Table 13. Data from the recent Thailand study are yet to be included in this catalogue (but see Part D for details).

2.5 Analytical methods and models:

Preliminary regression and multivariate cluster analyses (multi-dimensional scaling) have been applied to data from all sites. Limited spatial modeling of the potential distribution of plant species richness has been completed for Jambi province, Central Sumatra. At present, all data analyses are being conducted at CIFOR.

3. OUTPUTS:

The following items highlight some of the key outputs of Phase II thus far. A more comprehensive list of achievements both in line with and outside the GEF contract is outlined in Tables 1 & 2 below.

3.1 Above-ground pattern of plant taxonomic and functional features within and between benchmark sites:

There is a consistent trend across all benchmarks between the pattern of plant functional types and types of land use. Richness in vascular plant species and richness in plant functional groups are highly correlated. [See report on 'V' index and conclusions below.]

3.2 Indicators of above-and below-ground taxonomic and functional or trophic groups:

Taxonomic identification of above and below-ground collections of fauna have been completed. A major constraint to the selection of useful correlates is the wide variation in range distribution and ecological behavior between different groups of biota such as mammals, birds, plants and microfauna in cryptic habitats. It is no surprise, therefore, that there are no obvious linear trends between, for example, nematodes (see Below-Ground report) and plant species or plant functional richness. For the many cryptic fauna the lack of taxonomic identification has meant closer reliance on characterisation of functional or trophic groups.

Nonetheless, several key plant-based indicators have emerged from the multi-disciplinary baseline study conducted in Sumatra. Two examples drawn from termites and birds illustrate the potential value of plant vascular species richness and richness of plant functional types as indicators of these groups. An intensive, co-located study of ground-dwelling termites and vegetation plots revealed significant correlations between termite species richness, plant species richness and plant functional type richness. The highest correlation was found by using the ratio of plant species richness to plant functional type richness. Using this ratio measure a similar improvement was found for above-ground carbon, Collembola, Termites and Birds (see Part C, Annex II, Figures 1a,b,c,d). The ecological explanations for these correlates are not entirely clear but the results suggest that at least some animal groups may be responding to gradients of overall heterogeneity of vegetation, expressed as a function of variability in both plant taxa and functional types and reflected in soil nutrient availability. This finding is a new and promising tool for estimating species richness in certain key groups such as the '*ecosystem engineers*' represented by termites.

The combined use of richness values in plant species, plant functional types (or *modi*) and the species/*modi* ratio can also be used to characterise a profile using cumulative values along 5x5m quadrats of each 40x5m transect (Annex I, Figure 1).

3.3 Linkages between soil substrate, land-use pattern and above-ground biodiversity:

A highly significant, statistical relationship ($r^2 > 95\%$) between plant species richness and plant functional types (PFTs or *modi*) can be related to gradients of land use in

Jambi. Annex I, Figure 7 illustrates the pattern derived using multi-dimensional scaling of Plant Functional Attributes (Species-weighted summary of individual elements of PFTs) with Land Use Type overlays in which a suggested area of 'best bets' is identified. At least for the Jambi baseline study along land use patterns in differing soil conditions, highly significant correlations have been established between PFTs, plant basal area, mean canopy height and certain soil attributes such as bulk density, total soil nitrogen, cation exchange capacity and pH. These attributes provide key indicators of land use impact on site biodiversity and productivity for human needs. Annex I, Figure 3 illustrates a close predictive relationship between patterns of richness in plant species, plant functional types and land-use types. While the correlations are not so high for the Mae Chaem study in Northern Thailand, they are nevertheless significant (Part D).

3.4 Linkages between greenhouse gases, carbon stocks and above-ground biodiversity:

Data analyses of GHGs are yet to be finalised. A total of 50 AG plots were co-located with those of the carbon sequestration group. (Cheryl Palm). The data have been analysed for correlates between certain plant variables and above-ground carbon. (Annex I, Figure 2). While there is no clear statistical relationship (ref: Climate Change WG Report) there are obvious patterns between AG carbon stocks and land-use types and associated PFTs. Data acquired from the intensive Jambi baseline study have revealed a significant correlation between carbon stocks (Hairiah and van Noordwijk, Sect.10 Part C) and the ratio of plant species richness to PFT richness. (Annex II, Figure 1a)

3.5 The "V" Index: A potential indicator of land use impact on biodiversity and profitability, based on key vegetation structural, plant taxonomic and functional types (PFTs):

From the Sumatra baseline study, it has been possible to extract key vegetation indicators of impacts of land use and environmental change. These are: *mean canopy height, basal area ($m^2 ha^{-1}$), total vascular plant species, total PFTs or functional modi and a ratio of plant species richness to PFT richness*. Multi-dimensional scaling analysis (available in a wide range of exploratory data analysis packages) can be used to extract the single best set of values (eigenvector scores) for a specified set of sites characterised according to these variables. When standardised, the values can be used as a relative index of vegetation that, in the present study, corresponds closely with observed impacts of land use on biodiversity, crop production and associated 'time since opening' (e.g. clearing for cropping or harvesting). (Annex I, Figures. 4,5,6). This set of values is termed a "V" index. *While there are close correspondences with plant and animal biodiversity, the V index is more a habitat or site characterisation indicator than an actual index of biodiversity*. The method can be used at any scale, thus facilitating the comparative analysis of site data for scaling-up or scaling-down purposes. While the index is relatively crude and very simplistic, it has the novel advantage that, because of the high correlation with observed land use pattern, it may be a useful variable in econometric models (e.g. FALABEM – S. Vosti pers. comm.) and in assessing potential 'profitability' (total factor productivity) for a specified land use or set of land uses within a landscape context. (See 3.6 below). CIFOR has acquired funds to address this possibility in association with ASB (Ref: successful bid to ACIAR re: 'Above-ground biodiversity and productivity assessment for Alternatives to Slash and Burn;') (A.Gillison, T.Tomich and D. Thomas) and this is currently being investigated

in Northern Thailand (Mae Chaem) and Central and South Sumatra (Lampung). The multi-dimensional scaling approach used to derive the “V” index can also be used to graphically display a zone of “best bet” characteristics for which specific values of plant-based variables can be identified (Annex I, Figure 7).

3.6 Linkages with the developing ASB Policy Analysis Matrix:

There are few established criteria for identifying appropriate vegetational or other biodiversity-based variables that can be used directly to help construct a meaningful policy analysis matrix (PAM). Because the five vegetational variables used to construct the ‘V’ index above appear to correlate better than others with faunal habitat, soil nutrients and carbon stocks, they may be useful albeit, indirect, indicators of profitability and agronomic sustainability (see other WG reports). For this reason complete data sets have been generated for each of the benchmark sites and added to the PAM currently under development (ref: separate input by D. Thomas, T. Tomich, S. Vosti and J. Witcover).

3.7 Thematic maps of biodiversity pattern in central lowland Sumatra and progress in spatial data compilation in Latin America, Cameroon and Thailand:

Digital, spatially-referenced data are essential for constructing spatial models and for providing a common multidisciplinary platform for multidisciplinary, scientific discussion. A digital elevation model (DEM) has been completed for Jambi, Sumatra and Pucallpa, Peru. An additional DEM for the Mbalmayo transect in Cameroon was extended by about 200 km to include the northern savannas near Bafia (05° 02' 40" N.Lat.). Electronic media copies of the DEM and other spatially-referenced data have been placed with each country partner. The DOMAIN potential mapping software program has been used to generate preliminary maps of biodiversity pattern in Sumatra (Jambi). Unlike the other ecoregional sites, the Jambi study includes data acquired from CIFOR's additional sites throughout Central Sumatra (about 147 in all). The ICRAF team in Chiang Mai has produced a comprehensive DEM of the Mae Chaem watershed (Part D Map 1). These provide an expanded context of land use gradients that will facilitate extrapolative modeling and field testing of biodiversity patterns at the landscape level.

3.8 Remote sensing applications:

Models of ecosystem behaviour, including the response of biodiversity to land use impact, can be developed via intensive baseline studies such as the one conducted in Jambi. However, their use is likely to be severely limited unless they can be readily extrapolated to the landscape level. For this reason, CIFOR has acquired both airborne and satellite radar imagery of the Jambi study area (via the Government of Indonesia and Netherlands Government INDREX program). These data are being investigated using ground-truthing methods based on the PFA proforma. Further studies are planned for the next phase of ASB, using high resolution SPOT image over a 2000 km² template that includes the Jambi baseline location. Other sequential Landsat imagery has been acquired from 1983 to 1995 for lowland Jambi to explore patterns of forest retreat associated with documented land use. These data are also being examined to ascertain their indicator value for above-ground (and possibly below-ground)

biodiversity. If indicators are detected then the spectral signatures may have value in extrapolating patterns derived from ground surveys and from thematic maps generated via DOMAIN. This activity is being developed further in association with GCTE and BIOTROP (ICSEA), as there are potential linkages with climate modeling.

3.9 Identified 'best bet' alternatives to slash & burn:

For most locations, there will be no single 'best bet' alternative; but the methods described here can be used to help identify a range of options or 'best bets' for specified land uses. These aim at providing acceptable trade-offs between defined land uses and related profitability and their impacts on biodiversity. Overall, these were represented by the richest multistrata agroforestry plots. In the case of Brazil these were plots in 'Nueva California' that were composed of Peach Palm, Acerola, Cupuaçu, Coffee and other minor crops. In Sumatra, indications are 'jungle rubber' is a preferred option, whereas in Cameroon it is 'jungle Cacao'. It is important to note that although as many representative land use types were sampled, there were significant omissions, for example rubber and oil palm in Cameroon. Nonetheless, the same general principles appear to hold across all sites. The most depauperate plots for biodiversity and possibly some of the least productive were on Alang Alang (*Imperata cylindrica*) and Cassava (*Manihota utilissima*) in Jambi and Mbalmayo and degraded pastures in Perú and Brazil. While the value of establishing 'high biodiversity' complex agroforests is relatively clear, what is not clear is the ecological role of some early fallow systems such as those dominated by *Chromolaena odorata* and other 'daisy fallows' dominated by such genera as *Baccharis* and *Vernonia*. Preliminary results suggest these may play an important role in facilitating habitat rehabilitation under certain circumstances (see below).

3.10 Training workshops:

Training workshops in above-ground biodiversity assessment techniques have been completed in all benchmark areas. For the Western Amazon Basin, a workshop was completed in Pucallpa Peru with 26 participants from Mexico, Bolivia, Brazil and Peru. In Cameroon a workshop was conducted in July 1997 with 21 participants and a regional S.E. Asian workshop with 26 participants from Indonesia, Malaysia, Thailand and the Philippines was completed in December 1997.

3.11 Publications and software:

3.11.1 Publications:

- Gillison, A.N. (1997). Mapping the potential distribution of plants and animals for wildlife management: The use of the DOMAIN software package. In: K. Romimoharto, S. Hartono and S.M. Soenarno (eds.). Proceedings of the National Seminar on *The Role of Wildlife Conservation and its Ecosystem in National Development*. pp. 114-119 + two maps. The Indonesian Wildlife Fund. (IWF), Jakarta.
- Gillison, A.N. and Carpenter, G. (1997). A plant functional attribute set and grammar for dynamic vegetation description and analysis. *Functional Ecology* 11, 775-783.
- Gillison, A.N., Liswanti, N. and Arief-Rachman, I. (1996). Contributors. In: *Final Report, Rapid Ecological Assessment in HPH Pt Serestra II and HPH Pt Bina*

- Samaktha. Pre-implementation, Integrated Conservation and Development Project, Kerinci Seblat National Park.* World Wildlife Fund for Nature, Indonesia Program. Bappenas, The World Bank. (Published 1997).
- Gillison, A.N. *et al.* (1999) Overview report of the ASB Intensive biodiversity baseline study Nov.-Dec. 1997. Ca. 65 pp. 12 Tables, 5 Annexes and 4 Maps. CIFOR Working Paper (in prep.).
- Gillison, A.N. (1997). In: Catherine Kenyatta, ed. Summary report of the above-ground biodiversity working group. Annex II *Alternatives to Slash and Burn, Report of the 6th Annual Review Meeting*. 17-27 August 1997, Bogor, Indonesia. Pp. 52-64 (ICRAF, Nairobi).
- Vanclay, J.K., Gillison, A.N. and Keenan, R.J. (1997). Using plant functional attributes to quantify site productivity and growth patterns in mixed forests. *Forest Ecology and Management* **94**, 149-163.

Note: At the time of writing several manuscripts have been submitted to scientific journals and more are in preparation with in-country co-authors.

2.11.2 Software:

- Carpenter, G. and Gillison, A.N. (1997) DOMAIN Version 1.3 for Windows. A software package for mapping the potential distribution of plants and animals [*Since its availability on the CIFOR web page in August 1997, downloads have been registered from users in 45 countries*]
- Carpenter, G. and Gillison, A.N. (1998,99). PFAPro – a data-entry and meta-analysis package for the PFA field proforma. Designed for field recording of site physical attributes, plant taxa and plant functional attributes. A second beta test version is available at time of writing [see above]. This package replaces the former FUNDAT package also developed by CIFOR in association with ASB.

Table 1

ABOVE-GROUND BIODIVERSITY ACHIEVEMENTS - 1996-99*

- Field protocols finalised, tested and disseminated at field and landscape levels in all benchmark sites [2.1.1]
- Plant-based indicators for certain above- and below-ground faunal groups identified and others under study. [2.1.2]
- Generic procedure determined to identify alternative best-bets (e.g complex agroforests) via an index derived from key vegetation variables. [2.2.1]
- Spatially-referenced databases completed for all benchmark sites [2.2.2]
- Methods established for selection of plants for sustainable enrichment. [2.3.1]
- Implementation of field management practices for degraded lands not undertaken (models must be developed first) [2.3.2]
- On-site training in assessment protocols completed for all benchmark sites and all ecoregional centers [2.4.1]
- Preliminary training in the use of spatially-referenced data sets completed in South-East Asia [2.4.2]

* GEF contracted Phase II activity in brackets.

Table 2

ABOVE-GROUND BIODIVERSITY ADDITIONAL ACTIVITIES - 1996-99*

- New measure of functional diversity and functional complexity (This complements the standard Shannon-Wiener and Simpson diversity indices commonly used for species: *mss* in preparation).
- Preliminary fieldwork completed for Yucatan Peninsula (Campeche, Zona Maya) in S.E. Mexico; Sites identified for Thailand (Chiang Mai); Madagascar econnaissance completed in September 1997.
- Intensive baseline study of above-ground plant and animal species in Jambi along a land use gradient completed in November 1997.
- A recent study in Lampung, S. Sumatra has just been completed (Sept. 1999) exploring relationships among coffee-based agrosystems, biodiversity, profitability, above and below-ground carbon and soil nutrient availability.
- An intensive, biodiversity baseline study was completed in Mae Chaem, Northern Thailand, exploring relationships between land use type, biodiversity (plants and birds), soil nutrient availability and profitability (July 1999).
- Digital Elevation Models completed for Indonesia, Peru (Pucallpa) and Cameroon. Brazil to be determined. Comprehensive DEMs are available for Mae Chaem via ICRAF, Chiang Mai.
- ASB sites in Indonesia analysed within the context of other non-ASB, CIFOR ecoregional study sites.
- Analysis of remotely-sensed imagery of Jambi Land Use Types (LUTs) (radar and Landsat) is underway.

- Computer-based software (DOMAIN) upgraded for potential mapping of plants and animals. Data-entry software (PFAPro) to support use of the Plant Functional Attribute proforma was completed in May 1998 with recent upgrades in August 1999. Applied at international training course in biodiversity assessment conducted by Smithsonian Institute & Man and Biosphere, USA.. Used in training courses in Cameroon, Thailand and Vietnam.
- Preliminary development of common database format for all Working Groups has been established in Indonesia (ICRAF & CIFOR).
- Initial spatial model of '*zone of extrapolation*' completed for tropical regions based on benchmark studies (ref: extended WG report)

* Most of these activities were funded directly by CIFOR and although complementary, were external to the GEF contract.

4. Findings thus far:

- ***Intensive baseline studies along gradients of land use are necessary to identify and calibrate biodiversity indicators.*** Sampling methods must be designed to accommodate, as far as possible, the highly complex interactions between biota and their physical environment. The data acquired and the predictive models developed must also be capable of extrapolation and verification at the landscape level. For these reasons it is necessary to first design a sampling structure that includes a representative range of land-use gradients in any region under study. Second, intensive, co-located studies of above- and below-ground biota and their abiotic determinants (soil, climate, land use, etc) are needed to construct initial correlative models of the distributional relationships of both along natural and modified resource gradients. These correlates can then be coupled with spatial models and patterns of biodiversity extrapolated for specific environments. Thematic maps of biodiversity pattern can then be tested via ground survey and remotely sensed imagery. Information acquired in this way can be used to frame process-based research where this is needed. The Phase II study has shown clearly that this is the very minimum required to develop a requisite knowledge base for constructing sustainable models of options for managing forested and agro-forested lands. Using this approach, a two-week, intensive multidisciplinary, baseline study conducted in Jambi, Central Sumatra produced far more effective information than 2.5 years of largely uncoordinated, rapid surveys of sites by different scientists across regional environmental gradients. In addition, the products of carefully designed, intensive, gradient-based studies are far more likely to generate more productive insights into ecosystem behaviour and publications in peer-reviewed scientific journals. With this in mind, the cost-efficiency of survey design should be a key consideration in planning and budgeting for future work.
- ***Biodiversity cannot be meaningfully estimated in terms of species alone.*** Species richness and composition must be coupled with functional richness and composition in order to better understand land-use impacts on farming and natural systems. While plant-based estimates of species richness are the most commonly used indicators of overall biodiversity pattern, predictive value may be significantly enhanced by using a ratio of plant species richness to functional group richness as an indicator.

- ***Isolated, single-point samples of biodiversity can be misleading.*** Biodiversity must be sampled within a representative range of key land-use types if dynamic models of land-use impact are to be developed. Knowledge of range distributions of key taxa and functional groups is critical to developing performance models and to estimating thresholds of sustainability.
- ***Peaks of richness in both species and functional groups do not necessarily occur in pristine forest.*** In lowland tropical humid vegetation, frequently occurring 'highs' are most likely to be found in late stage secondary forests and frequently on base-rich soils, especially in 1-3 year old 'daisy fallows' following slash and burn gardening. This finding tends to run counter to conventional concepts of richness patterns in vegetation where greatest richness is assumed to be in tropical, humid, lowland rainforest.
- ***The importance of early fallows dominated by members of the Asteraceae (Compositae) (here termed the 'Daisy fallow') may be seriously underestimated in terms of their associated biodiversity value and contribution to nutrient pools, soil structural improvement and ecosystem dynamics.*** Mayan agriculture treats these fallows as highly significant components in overall land-use planning. Results across all ASB benchmarks seem to confirm that the 'daisy fallow' (variously dominated by large Asteraceae, *Baccharis*, *Chromolaena* (*Eupatorium*), *Tithonia*, *Vernonia* etc.) should be considered potentially beneficial in agroforest 'best bets'. Priority research is indicated to examine the impact of their inclusion and exclusion in agroforestry systems.
- ***Indicators of 'best bet' agroforests.*** Records of total vascular plant species and unique plant functional types or *modi* collected via the rapid survey technique can be used to estimate 'best bet' alternatives by identifying those conditions where species and functional richness are maximised. When matched against a newly developed index that characterises plant functional groupings per plot, a highly robust statistical model can be used to compare values of plant biodiversity in terms of species and functional richness.
- ***More complex estimates of plant functional diversity and plant functional complexity that compare evenness and composition of groups.*** These have already been developed by CIFOR for forests and will be applied to the ASB sites.
- ***New global records of plant species and functional richness:*** Data collected to date from the tropical lowland agroforested landscapes of Cameroon, the Western Amazon and Indonesia reveal some consistent trends. While some Cameroonian forests are relatively rich (50 -100 vascular plant species per 40x5m plot), they tended to be poorer than those in the Western Amazon basin (typically 70 –100 per plot), which in turn fall well below many in Sumatra that frequently exceed 150 per plot. Density patterns appear to vary with disturbance history and type of manipulation. While in mature, relatively undisturbed forests, individuals and species may be relatively widely spaced, a managed 'Durian' forest in lowland Sumatra revealed a staggering 62 woody vascular plant species in the first 5x5 m of a 40x5m plot. This is by far the highest species density record documented thus far for all forest types in the new and old-world tropics using this recording technique. Density of species and individuals usually varies with the nature and frequency of disturbance. This phenomenon may have implications for ecosystem management that could differ considerably from that developed for better known forested landscapes with far fewer species.

- ***Correlations between plant-based attributes and above-ground carbon and soil nutrient availability:*** In the Sumatran study, high correlations have been established between sets of plant-based features, especially those involving Plant Functional types, certain vegetation structural attributes, and above-ground carbon and soil nutrients. These highly predictable relationships and the relative ease of measurement of the plant-based features suggests there may be a potentially useful set of indicators for rapid assessment of carbon stocks where this is required in complex, tropical forested landscapes. In the Thailand study, soil nutrients were less well-correlated with vegetation and avifauna. The Phase II studies have at least provided a valid basis for testing hypothetical relationships between carbon dynamics and land use that may be relevant for scaling up for climate modeling purposes. The high correlation with soil nutrients indicates this will be potentially useful in estimates of productivity for human needs expressed as profitability.

5. Gaps in knowledge; funding priorities; training needs:

- Additional study sites and funding support are needed to provide a more comprehensive knowledge base for developing models of sustainable management for biodiversity especially that related to estimating trade-offs for profitability. (See Table 3.)
- The extrapolative capacity from existing and future sites can be examined via the use of DOMAIN software. (Annex I, Figures 8, 9)
- Funding priority should be given to intensive, multidisciplinary, ecoregional baseline studies rather than to independently coordinated research activities.
- A large knowledge gap in a global understanding of the generic potential of output from the ASB project requires a more uniform approach to ecoregional methodology involving data acquisition, data storage and the development of spatial models.
- Training of trainers to facilitate technology transfer.
- Follow-up training for in-country teams, in particular training in elementary data analysis and spatial modeling.
- Multi-lingual manuals for using the field proforma and the associated data-entry software programs.
- Electronic networking to facilitate transfer and analysis of data.
- A need for national agencies and NGOs to be more self-reliant in field operations, data analysis and interpretation and in advising management on best bet options.

Table 3

SUGGESTED ADDITIONS TO BENCHMARK SITES: PHASES II & III

EXISTING BENCHMARKS (Extensions to Phase II)

Indonesia:

Additional sites to include wetland and upland sites and fallow systems (?30).
Funds permitting, a second intensive baseline study in upland Jambi (ca. 1500m a.s.l.)

Cameroon:

Additional 35 sites in the now extended Mbalmayo transect to Makam III

Peru:

Additional 55 sites to create a transect from Iquitos through Tarapoto to Chanchamayo.

Brazil:

Additional 13 sites extending the present Rondonia – Acré transect to include additional fallow systems and community managed forests.

Thailand :

Mae Chem watershed with seasonal savannas and Pinus forests.

PROPOSED NEW BENCHMARKS (Phase III)

Mexico : Yucatan – Petén

Africa : Madagascar: Ranomafana and Masoala
Nigeria and Ghana (Proposed EPHTA sites)

6. Future needs – Phase III

6.1 A more systematic approach to site location and intensive, co-located multidisciplinary studies along key environmental gradients:

As argued in 4. above, there is a need for a more intensive research focus to better understand the interrelationships between biodiversity and land-use impact. Using global, public domain data, spatial models of pantropical gradients of climate and resource substrate can be readily used to identify gaps in the knowledge base. Rather than have loosely coordinated working groups operating more-or-less independently, it would be far more cost-effective to focus joint activities in a common resource area and with a clear perspective of the research problem at hand. Such intensive activity will require a higher-than-usual funding and logistic support per unit time but would result in fast turnaround of outputs, publications and technology transfer with a better capacity for research coordination and communication than existed in the earlier phases of ASB.

6.2 Additional features to existing methods of characterisation:

The results of studies so far indicate that the characterisation of sites by vegetation alone may be insufficient for studies of land use impact on biodiversity. Additional, parallel surveys of key animal indicators (e.g. birds) may need to be more carefully investigated. Further studies of plant-based indicators of carbon dynamics may require a re-examination of the minimum attribute set currently applied via the rapid survey vegetation proforma.

6.3 Synthesis and models:

Considerable uncertainty surrounds the synthesis of existing AG and BG data and the development of synthetic models that can be used to provide a set of options for sustainable management. A prime need is the standardisation of data collection and data storage, and there remains a need for a data hub within the ASB consortium that would serve as a common platform for data access. The recent synthesis meetings in Nairobi and Brasilia have highlighted the need for a cross-disciplinary framework for developing and testing models of sustainable land use at the landscape level. A fundamental aspect of this development will be the continuing need for baseline studies that can be used to parameterise and calibrate such models. Output will need to be carefully examined to ensure a seamless connection with predictive spatial models.

6.4 New Benchmark sites:

As listed in Table 3, proposed new benchmarks include the sites targeted by EPHTA (ref. Stephan Weise), Madagascar (A. Gillison) and Thailand (D. Thomas). These additions will be necessary to achieve requisite representativeness of tropical regions and agroecological zones. At the time of writing, reconnaissance of Madagascar has been completed (A. Gillison), in addition to which, data from agroforestry systems in Papua New Guinea have been obtained using the standard vegetation assessment techniques. The results from the Mae Chaem study in Thailand indicate that a more representative set of land use types is needed for that ecoregion.

6.5 Training the trainers:

With the expansion of activities in biodiversity assessment it will become necessary to train teams and, in particular, team leaders who can pass on the necessary technology. Whereas the previous series of workshops were successful, it will be more efficient to undertake longer and more intensive training sessions with fewer personnel. While vegetation aspects of AG are generally adequate, these new training sessions might require additional features to include assessment of productivity for human needs. Such additions would require new training techniques. It is planned to conduct a joint training course in Indonesia in late 1999 (T. Tomich pers. comm.) in order to provide potential managers with an integrated approach to natural resource assessment that combines both the socio-economic and biophysical components.

Part C: An Intensive Biodiversity Baseline Study in Jambi Province, Central Sumatra, Indonesia

Preliminary Report

Compiled by A.N. Gillison and N.Liswanti¹

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SECTION 1: SUMMARY AND OVERVIEW

1.1 Summary:

This section reports the preliminary results of an intensive biodiversity baseline study that was undertaken to establish an improved scientific basis for selecting indicators for biodiversity assessment. The sampling framework centred around a series of 16 (40x5m) plots that were established along a gradient of increasing land-use intensity. While these plots were designed for a vegetation survey, they formed a focal point for co-located surveys of various animal groups and analyses of soil physio-chemical properties and above-ground carbon. A team of 23 national and international specialists in biodiversity assessment undertook the survey in an area of lowland Sumatra that included land-use types ranging from intact rain forest through various logged-over and secondary forests, mixed agroforests and plantations, to degraded grasslands. The survey produced several outcomes that are significant to both science and management. These include the identification of a greatly improved set of plant-based indicators of biodiversity, soil nutrient status and above-ground carbon. The indicators are based on combinations of richness of vascular plant species, Plant Functional Types (PFT) and a ratio of species richness to PFT richness. To these can be added vegetation structure (mean canopy height, basal area in square meters per hectare) that improve the prediction of certain site physical features, and some animal taxa. The combination of plant species, functional types and structure can also be used to generate an overall vegetation index (the "V" index outlined in Part B) that is itself highly correlated with various animal taxa and site physical conditions. A statistical analysis shows that many correlations are non-linear, maximum variance being accounted for by second order polynomial regressions. Exploratory data analysis confirmed that specific combinations of these indicators can be used to identify 'best bet' conditions such as jungle rubber, where biodiversity (expressed as richness of taxa and functional types) may in some cases exceed that of pristine forest. The study has established a scientific basis for exploring linkages between plant and animal taxa and functional types, soil nutrition (and thereby potential site productivity) and carbon sequestration. The results provide a ready means of approximating biodiversity patterns across a range of land-use types that typify much of the lowland tropics around the world. This illustrates how plant and animal species richness varies with land use impact. This information provides an improved basis for forecasting the impact on biodiversity of forest conversion to different land uses. The methodology can be readily adapted for use by management where rapid assessment of site conditions is needed, and where site-based information is critical to support adaptive management under changing environmental and socio-economic conditions. The information acquired at this sub-regional scale is generally consistent with that for similar land-use types in other countries. Spatial extrapolation of biodiversity patterns can be readily tested using DOMAIN potential mapping software and the digital environmental data acquired for the Sumatran benchmark site. The survey has generated a series of scientific papers authored by national and international participants. The study also provided invaluable material for case studies that are being included in a multi-media training manual for rapid vegetation assessment as a component of biodiversity.

1.2 Introduction:

This survey was conducted as part of the research program of the ASB consortium. It was designed to address Goal 2 of Phase II of ASB, which is to "*Assess the impact of different land-use practices on biodiversity*". The extreme logistic constraints associated with the ecoregional baseline studies in different countries meant detailed, replicative sampling of ecoregional

gradients had to be replaced by an approach that would be logistically acceptable but at the same time could adequately sample key patterns of land use impact. (See survey design below). Because the ASB program is highly multidisciplinary, it was important to co-locate study sites wherever possible. Although sampling strategies differed between disciplines, sites were centred around a common spatially-referenced sampling point (a 40 x 5m vegetation plot). Wide-ranging surveys along several hundred kilometers meant sampling was often superficial, resulting in frequently poor correlates between different data sets. In the absence of an effective calibrational baseline study, it was therefore not possible to establish any useful models of the impact of land use on biodiversity. Another major constraint was the lack of an acceptable operational definition of biodiversity. At the time of this study there was no model or sampling system that was available to help identify useful predictors of change in biodiversity due to land use.

It was clear that in order to develop any useful, testable model of land use impact on biodiversity, the ASB above - and below-ground teams had to start from scratch. Sumatra is known to contain some of the world's highest levels of richness in plant and animal species. Unfortunately, it is suffering major impacts from poorly planned land use arising from land clearing for oil palm and rubber plantations. Because these conflicts typify much of the lowland tropics and because information was already available from earlier CIFOR surveys of representative Land Use Types (LUTs) (A.N. Gillison and N. Liswanti), Sumatra was chosen as the focal area for an intensive biodiversity baseline study. The aim was to first locate a representative gradient mix of LUTs and physical environments and second to sample these according to site physical characteristics, specific vegetation features designed to reflect taxonomic variability as well as adaptive features, and a range of animal taxa (birds, mammals, insects, molluscs). It was assumed the resulting data sets would be adequate for developing testable models of plant and animal response to land-use impact. This procedure would help identify indicators for use in subsequent rapid assessments of impact in similar tropical lowland forested landscapes, thus reducing the need for intensive and costly surveys.

Without some ready means of extrapolating (mapping) findings, results from any survey are of limited use for management. An important focus for this operation was to ensure all data were spatially referenced as accurately as possible. High quality GPS readings (Trimble Scoutmaster using the Acculock system) were obtained mostly with a conservative accuracy of $\pm 70\text{m}$. The aim of this approach was to establish adequate spatial data for modeling the potential distribution of plants and animals under different LUTs and physical environments. If shown to be successful, such models would be potentially useful for coupling biophysical interactions with socio-economic models being developed by other ASB groups. It is assumed that by constructing integrated models of biophysical-socio-economic interactions it will become possible to generate options for adaptive management to cope with unexpected variations in climate and market forces triggered, for example, by episodic El Niño and La Niña events.

Multidisciplinary surveys are costly in time, money and coordination. If carefully designed, they can be enormously cost-effective. Forward planning is essential in order to acquire the right mix of international and national specialist for the different plant and animal groups. Planning for the present survey began a year before, and extensive reconnaissance was needed to establish the most suitable location. The assistance of BIOTROP was sought initially, as this Indonesian-based NARS possessed a research station centred in lowland Jambi Province in Central Sumatra with adequate accommodation and electrical power to serve most of the needs of different specialists. Further, CIFOR had established a close working relationship with life-scientists from BIOTROP and ICSEA. For biodiversity surveys, timing is critical as seasonal

variations can have a major effect on the nature of the data collected for different plant and animal taxa. Towards the scheduled start of the survey, Jambi was gripped in an El Niño drought that threatened a postponement to the following year. Fortunately a weather change with heavy rain ten days beforehand created near-perfect conditions for a baseline survey. The field operation was conducted between 16/11/97 and 2/12/97. Most taxonomic identifications were completed by mid-1998 via contracts arranged through research institutions in the UK and Australia.

1.3 Budget:

Complete costs are difficult to estimate given that certain salary costs of CIFOR and ICRAF staff and in-kind assistance from partner institutions are not included. The bulk of the in-field survey costs contract fees for specialists and subsequent contracts for taxonomic identification at various research institutes was approximately USD\$98,000. Funding was covered in part through ASB (60%) with the remainder from USAID and DANIDA. In retrospect, given the results of the survey, the number and quality of the participants and the high level of infrastructure support, the operation could be regarded as relatively low-cost. A parallel study in more remote and less well supported lowland tropical region such as parts of Kalimantan or West Irian would have been twice as costly.

1.4 Participants:

A detailed list of participants is available in Annex 1, Table 3. A total of 27 scientists and support staff participated in the survey. International specialists were drawn from the British Museum of Natural History, the Institute for Terrestrial Ecology, UK, Oxford University (Depts of Geography and Plant Science), and the University of Malaysia. National scientists from Indonesia were from LIPI (Herbarium Bogoriense, Zoology Museum), SEAMEO BIOTROP, University of Brawijaya and the University of Gadjah Mada. The survey was coordinated by CIFOR (A.N. Gillison) with assistance from Ms N. Liswanti (CIFOR) and Dr D. Sheil (University of Oxford, Plant Sciences Department).

1.5 Collecting permits:

In accordance with existing Government regulations, prior arrangements were made via LIPI to permit staff from each of the international institutions to collect and curate taxonomic collections of plants and animals. In accordance with GoI regulations, all scientists who take collections overseas for identification are to return type specimens and a representative set of identified specimens to the respective partner institutions in Indonesia, in particular the Herbarium Bogoriense and the Zoology Museum. At the time of writing, all specimens have been returned together with their identifications by the overseas institutions.

1.6 Site location and description:

The survey site was located at Pasir Mayang in Jambi Province, Central Sumatra (Annex III; Maps 1,2,3,4). The area includes 900ha of a forest reserve set aside for research by SEAMEO BIOTROP located within the Barito Pacific logging concession. The survey team was based at the BIOTROP research station (with several members also located at the nearby Barito Pacific guest quarters). The area sampled is a mosaic of pristine forest, logged-over secondary forest, softwood plantations, rubber and jungle rubber with secondary mosaics of subsistence gardens and fruit orchards. While the forest is rich in plant species, the dominant tree genera are from

the Dipterocarpaceae family. Vegetation is supported by a mixture of relatively low nutrient, gibbsitic, kaolinitic and ferrallitic soils over recent alluvium, acidic pumice tuffs, tuffaceous sandstones and carbonaceous mudstones siltstones and sandstones and conglomerates. The area is drained by the Batangahari river that is used to float log rafts down to Kota Jambi. Site locational and physical data including vegetation structure are listed in Annex III, Table 1a. Soil analytical data are contained in Annex III, Table 2.

1.7 Survey design:

1.7.1 General:

To forecast the effects of land-use on biodiversity at the landscape level requires an adequate sample of land-use intensity and land-use types. To set the bounds and system parameters in order to model ecosystem response to human impact requires a specific physical environmental context for land use. With this in mind, the present survey was preceded by a ground reconnaissance of a series of representative land use types (LUTs) in the lowland forested landscapes centred on Pasir Mayang in Jambi Province, Central Sumatra. Although only a limited number of LUTs could be sampled due to logistic constraints, these represented a range of extremes from pristine lowland tropical rain forest through logged-over forest and tree plantations to degraded *Imperata* grassland. Some specialist groups were restricted to only very limited samples (e.g. about 7 x 100m transects for termites alone) in the ten days available for fieldwork. It was therefore necessary to ensure these limited samples were effectively bracketed within a representative subset of vegetation and LUTs.

1.7.2 Gradient-based transects:

For surveys where the purpose is to recover as much information as possible about the distribution of plants and animals it is appropriate to use gradsect sampling (gradient-oriented transects) that rely on the purposive selection of sample sites arranged within a hierarchy of key environmental gradients (Gillison and Brewer, 1985) (Box 1). In the present case, these were rainfall seasonality, soil drainage patterns and time since harvest, or time since 'opening' (e.g. clearing rain forest). For this survey, LUTs were chosen primarily because of the nature of the land use and secondly according to environmental gradients in descending importance. At each LUT a pair of 40x5m strip transects was laid out along the contour where possible. The plot size was pre-determined from assessing results from range of plots elsewhere. As the results show, for most LUTs the 40x5m size is adequate. For very species-rich sites additional plots were added until the cumulative species curve reached a satisfactory (subjective) asymptote. The relatively small 40x5m plot makes it possible to sample animal habitat with a level of sensitivity frequently unobtainable with larger plots. Partly in preparation for this survey, CIFOR had produced a comprehensive digital elevation model (DEM) for Jambi Province compiled from 1:250,000 mapping scale topographic maps. These were supplemented by nested contour sub-maps compiled at 1:50,000 scale for focal survey areas surrounding the BIOTROP research site at Pasir Mayang (Annex III, Maps 1,2)

1.8 Database structure, storage and access:

Data from all collections of plants and animals were cross-referenced with the benchmark site numbers. All data are catalogued (Annex III, Table 15) and are stored on hard disk and as hard copy at CIFOR, as well as being backed up on 100mb Zip diskettes (IOMEGA). The data have been compiled in Microsoft Access and Excel formats. Field data were compiled on-site using

the newly developed CIFOR *PFAPro* software. This software facilitates direct transfer of data to MSAccess. All data collated from the survey have been distributed to partner institutions, in line with ASB policy.

1.9 Data analyses:

The PATN exploratory data analysis package (Belbin, 1992) was used to detect patterns in the data sets by both classification and ordination (Multi-Dimensional Scaling), using Gower metric and Bray-Curtis measures. Linear correlations between all attribute values were calculated using the Minitab software package. Second order, polynomial regressions were also used to seek improved fits for those attributes with linear 'r' values >0.500 and where indicated by data distribution. These procedures helped identify the most efficient predictors of taxa and functional types and set the scene for further analyses using multiple regression.

Box 1

Gradient-based methods of survey design and data collection

The gradsect method of Gillison and Brewer (1985) employs purposively selected physical environmental gradients as a framework for survey. Sites are located along gradients according to a hierarchy of decreasing physical environmental influence and, usually, spatial scale (e.g. rainfall seasonality, temperature, parent rock type, slope, aspect, soil catena etc). This allows clusters of sites to be located to sample the maximum possible range of environmental variability that is responsible for species distribution and performance. Where the intent is to capture as much environmental variability and species distribution in the area, the method has been found more efficient than surveys based on purely random or purely systematic grid designs (see also Wessels *et al.*, 1998). For plots (of 40 x 5m size) located along gradsects, a rapid survey proforma is used to record site, physical variables (georeference by GPS; elevation (m), slope (%), aspect (deg.), soil type (and subsequent physio-chemical analyses), parent rock type, and land-use history. Vegetation structure is recorded according to mean canopy height (m), percent crown cover, litter depth, furcation index, and basal area ($\text{m}^2 \text{ ha}^{-1}$). All vascular plant species are recorded where possible (Family, Genus Species) and voucher specimens taken for subsequent taxonomic confirmation. Plant Functional Attributes (mainly features that indicate adaptations to environment) are recorded by in-country teams trained in the proforma method. The software package *PFAPro* developed by CIFOR to facilitate data entry and analysis was used to record data using a standard protocol to ensure compatibility and uniformity of data collection.

1.10 References:

- Gillison, A.N. and Brewer, K.R.W. (1985). The use of gradient directed transects or gradsects in natural resource surveys. *Journal of Environmental Management* **20**: 103-127
- Wessels, K.J., Van Jaarsveld, A.S., Grimbeek, J.D. and Van der Linde, M.J. (1998). An evaluation of the gradsect biological survey method. *Biodiversity and Conservation* **7**: 1093-1121.

SECTION 2: RAPID VEGETATION SURVEY

By A.N. Gillison

2.1 Introduction:

Evidence for the need to conserve biodiversity is well established in the literature and is reflected in the international Convention on Biological Diversity that has addressed a series of issues for attention by its signatories (CBD 1994). Despite the agreed urgency to develop a framework for biodiversity conservation, there is, as yet, no operational definition for biodiversity. According to Weitzman (1995), the implementation of any plan to preserve biodiversity is hampered by the lack of an operational framework or an objective function, and *"We need a more-or-less consistent and useable measure of the value of biodiversity that can tell us how to trade off one form of diversity against another"*. Miller and Lanou, (1995) also maintain *"The value of biodiversity is determined largely by the interaction between human society and biodiversity"*. This implies that among other things, there should be a dynamic link between biodiversity and productivity for human needs. The World Bank (1995) asserts it is necessary to integrate biodiversity concerns into national decision making, but the mechanisms for this remain elusive. In Indonesia, the Government recognises a lack of scientific and management expertise in biodiversity conservation (Government of Indonesia, 1993), that is further hampered by the current regime of property rights on public lands and waters, and the failure to use much of the financial returns from exploiting the country's living resources to support biodiversity conservation (Barber *et al.* 1995).

These pressures highlight both the need for a working definition of biodiversity and a cost-efficient, generic tool for its assessment that can be used in turn to inform policy planners and managers. While the species remains the sole currency unit for biodiversity assessment (Heywood and Baste 1995) there will be little progress (*cf.* Wulff 1943). Species richness and abundance used alone and without other attributes of behaviour and performance can seriously misinform and impede biodiversity assessment. Parity in richness does not guarantee equivalence in either genetic composition or response to environment. Partly for this reason, an emerging school of thought now considers assessment should include functional features or types as well as species. (Box 1981, Gillison 1981, 1988, Nix and Gillison 1985, Cowling *et al.* 1994a,b, Huston, 1994, Collins, S.L. and Benning, T. 1996, Martinez 1996, Woodward *et al.* 1996). Varying definitions of functional types are so far most commonly associated with guilds (Bahr 1981, Gillison 1981, Huston 1994, Gitay and Noble 1996, Mooney 1996, Shugart 1996, Smith, 1996, Smith *et al.*, 1996, Gillison and Carpenter 1997), but as Martinez (1996) asserts *"..the functional aspects of biodiversity are a broad and vague concept that needs substantial added specification in order to become scientifically more useful."* Cramer (1996) also feels the task of screening all the world's species for functional types is impossible and that for a global model, a breakdown of the world's vegetation can only be done based on major physiognomic or otherwise recognisable features. Recent global ecoregional studies (Gillison and Thomas, unpublished) suggest that, to the contrary, broad physiognomic and structural features can mask important functional and taxonomic differences in biodiversity. Gillison and Carpenter (1997) and Gillison (1997) and Gillison and Alegre (1999, unpubl.) have also shown it is possible to use generic functional or adaptive morphological attributes to characterise and quantify vegetation response to environmental change such as land use, climate and soil.

A new quantitative method has been developed for characterising vascular plants according to a set of 35 Plant Functional Attributes that describe a plant as a three component 'coherent' (*sensu* Vogel 1991) or functional model. This consists of the photosynthetic envelope, modified Raunkiaerean life form (Raunkiaer 1934) and above-ground root system. The method uses a semantic rule set and grammar (Gillison and Carpenter, 1997) to generate a theoretically finite set of unique PFA combinations for the world's vascular plants. Any one combination is termed a functional *modus*. Using this rule set, about 7.2 million combinations or *modi* are possible, although it is thought that in reality the number is closer to 4,000. There is no *a priori* interdependence between *modi* and species; as the mapping is many-to-many, i.e. more than one *modus* can occur within a species and *vice versa*. The advantage of functional over solely species-based methods is that the former can be universally applied by observers with limited botanical and ecological experience. It can be used to compare functional characteristics of individuals and sets of individuals independently of species, e.g. where taxa may be geographically disjunct but may possess similar adaptations to environment. In a comparative study of methods of characterising site productivity and growth patterns in North Queensland rain forests, Vanclay *et al.* 1996 showed the PFA method outperformed traditional methods of site characterisation. The method is now undergoing further tests by the Forestry Department, Qld DPI (Keenan, Woldring pers. com.). Gillison *et al.*, (1996) has shown consistently high correlations between total numbers of species and total numbers of unique *modi* recorded from 40 x 5m plots across a wide range of environments (Annex II and *cf.* Baskin 1994). The implications from this are that in surveys where botanical expertise is lacking, *modi* can be used to predict species richness with a high degree of confidence. This may also benefit rapid assessment of plant biodiversity and improve correlations between plant and animal biodiversity (*cf.* Gillison *et al.* 1996). A field proforma specifically designed for rapid survey (see section 2.4) can now be used by observers with minimal training to characterise site physical features, vegetation structure, species composition and *modi* to rapidly describe a specific habitat for a taxon or set of taxa.

Richness in species and unique *modi* can be a useful complementary descriptor of habitat. But while these contribute to characterising biodiversity, they do not by themselves reflect evenness or dominance of individuals per species such as the frequently used diversity indices of Shannon-Wiener and Simpson (Magurran 1988). Many diversity indices have been developed, but the search goes on (Cousins 1991, Majer and Beeston 1996). The great majority are based on species abundance and at best are usually regarded simply as another species-based, stand attribute. A problem for survey in tropical forests is that to generate such indices requires time-consuming counts of individuals which is not cost-effective. To help circumvent this problem, Gillison *et al.* (Appendix 2.1) have developed a complementary measure of *functional diversity* based on the numbers of *modi* per species for each plot. This differs from approaches by others (e.g. Martinez 1996) and has the advantage that in rapid survey it is only species rather than numbers of individuals of species that are counted. A measure of *functional complexity* has also been developed by the same authors based on a computed functional 'distance' between *modal* assemblages derived from a table of weighted 'transformation' values between specific PFAs (Gillison and Carpenter 1997).

It is one of the tenets of RBA that for practical purposes there should be indicators or surrogates of more complex plant and animal assemblages. Whether this is a realistic assertion is a continuing source of debate (Cranston and Hillman 1992, Reid *et al.* 1993, Pearson 1995, Howard *et al.* 1996), and there is often questionable theoretical support for targeting so-called keystone species (Tanner *et al.* 1994). There is nonetheless an increasing need for reduced attribute sets that can be used to carry other information such as the status of key pollinators

and seed dispersers that may not be available at the time of survey (Miller *et al.* 1995). To demonstrate indicator efficiency requires calibration from very intensive baseline studies of taxa and functional types at a comprehensive range of spatial, temporal and environmental scales. Such baseline studies are almost non-existent in complex tropical environments. Ongoing studies within the context of ASB show varying correlative trends. In a baseline study of Sumatran rain forests, Gillison *et al.* (1996) showed that while plant biodiversity increased with elevation from 500 to 900m asl, the converse was true for insects and birds. While such confounding effects can be accommodated by appropriate regression models and multiple discriminant formulations, predictive models of biodiversity based on environmental correlates such as elevation clearly need to be carefully evaluated before being used by managers. It follows that environmental context and scale are important in designing field studies of biodiversity (see also He, *et al.*, 1994.).

Most practitioners now concede the landscape matrix is critical to supporting biodiversity (*cf.* Forman and Godron, 1986, Franklin 1993), and this has been central to survey design and data collection across all the ASB and CIFOR ecoregional benchmark sites. Because disturbance is a critical determinant of biodiversity (Petraitis *et al.*, 1989, van der Maarel 1993, Phillips *et al.* 1994), factors such as agriculture, shifting cultivation and forest fragmentation (Grime 1979, Bierregard *et al.*, 1992, Sayer and Wegge 1992, Margules and Gaston 1994, Brooker and Margules 1996) should be considered when designing a survey. For this reason, the ASB sites have been located specifically to sample a range of dynamic conditions, along successional gradients of land use from pristine rain forest, logged-over forest, plantations to degraded grasslands. Although the issue of plot size is a continuing source of debate in plant ecology, recent studies show that for plant diversity, useful information can be recorded from plots as small as 50 x 2m (Parker and Bailey 1992, Parker and Carr 1992, Parker *et al.* 1993) and 40 x 5m. (Gillison *et al.* 1996). The advantage of 'small and many' vs. 'few and large' is that the former is more cost-effective when sampling variation in biodiversity at landscape level (*cf.* Keel *et al.* 1992). Variation of this kind demands cost-effective survey techniques (*cf.* Margules and Haila 1996). Because the distribution of plants and animals is determined mainly by environmental gradients, gradient-based techniques using the gradsect approach offer one means of sampling such variation (Gillison and Brewer 1985). With gradsects, sites are located according to a hierarchical nesting of assumed physical environmental determinants such as climate, elevation, parent rock type, soil, vegetation type and land use. This approach has been shown to be more cost-efficient than purely random or purely systematic (e.g. grid-based) survey design (Gillison and Brewer 1985, Austin and Heyigers 1989). As gradients themselves are being sampled, this will enhance the efficiency of extrapolative spatial models.

Issues of biodiversity conservation inevitably raise important questions of site representativeness. For a programme involved in the selection of 'best-bet' options for biodiversity and productivity, a manager may need to choose between different locations to ensure optimal management. For this a range of sophisticated computer-based solutions already exists. These are based mostly on species occurrence but may include environmental features such as land classes (Nicholls and Margules 1993, Pressey *et al.* 1996, Csuti *et al.* 1997, Pressey *et al.* 1997). Other species-based approaches use additional levels of higher taxa (Prance 1995) or a measure of 'phylogenetic distance' to include taxic richness or genealogical relationships as embodied in taxonomic classifications, typically by a weighting of the relative number of species per genus, genera per family etc. (Vane-Wright *et al.* 1991, Williams *et al.* 1992, Faith 1992, 1993, 1995). A problem with species-dependent approaches of this kind is that for many tropical lowland forests, species identification is difficult and time-consuming. In addition, the majority of these algorithms require expertise that is frequently lacking in

developing countries. For this reason, and because functional types can be more easily identified than species, Gillison *et al.*, (unpublished 1998) developed an analogous concept of 'functional distance' based on *modi* (outlined in Annex I). The algorithm is being incorporated in a new data-entry software package PFAPRO designed to run on a PC as a Windows application (Carpenter and Gillison, unpublished 1998). When data from a series of plots containing functional *modi* have been entered, PFAPRO has the facility to generate a distance matrix on demand. By this method, managers can readily identify levels of similarity between plots or landscape units.

Data collected during this project will be used to generate and test spatial models of key sets of taxa and functional types and to couple these with productivity patterns based on land use. For this purpose a potential mapping software package DOMAIN (Carpenter *et al.* 1993) will be used. Unlike other packages such as BIOCLIM (Busby 1991) or CLIMEX (Sutherst and Maywald 1985) that are either climate-dependent or require detailed, process-based knowledge about the species in question, DOMAIN uses any georeferenced data that are considered important in influencing performance of an individual. This may include environmental data used to construct a gradsect-based survey. DOMAIN then accepts known distribution points for specific taxa or functional types and constructs an environmental envelope for these using environmental correlates and a distance measure based on the Gower metric. It then computes a grid-based distribution map of according to the similarity matching of each pixel or grid with the original environmental domain. DOMAIN has been used in previous baseline studies in Sumatra (Gillison *et al.* 1996) and has been modified by CIFOR to run as a user-friendly, Windows based package on a PC. The software is available *gratis* from the CIFOR home page on the internet. Since its installation in August 1997 CIFOR has recorded downloads from users in 35 countries. Because DEMs were constructed for each of the ASB benchmark sites in Phase II, it is anticipated DOMAIN will be used for generating and testing spatial models of biodiversity and related productivity. The effective extrapolation of data will depend to a large degree on the availability of georeferenced environmental data. These data have been compiled at CIFOR using mapping sources from within Indonesia (Laumonier *et al.* and other sources from within the GoI Ministry of Forestry). Remote sensing of tropical rain forest vegetation has been used elsewhere with some success (Tuomisto *et al.* 1994) and is expected to play a significant role in DOMAIN applications. Data for normalized difference vegetation index (NDVI) are available and can be used in DOMAIN. NDVI is commonly used with AVHRR (advanced very high resolution radiometer) data for which appropriate calibrations are necessary (Roderick *et al.*, 1996a,b).

Most vegetation classification and survey methods incorporate a combination of broad structural variables coupled with seasonality (deciduousness) and a list of dominant species, e.g. 'Very tall evergreen Dipterocarp forest'. While this is useful for many geographic purposes it is insufficiently diagnostic for management purposes. In addition, structurally similar vegetation types are usually annotated by regionally different plant species. Within a region, vegetation described according to vegetation structure may be adequate for describing animal habitat but similar structure in separate global ecoregions are not necessarily ecologically equivalent. For ecologically sensitive classifications additional, response-based attributes such as adaptive features or plant functional attributes (PFAs) provide added value. As PFAs are generic and largely independent of species, they can be used to make ecological comparisons between geographically remote areas where environments and adaptive features may be similar but where species differ.

2.2 Methods:

The Plant Functional Attribute proforma (modified from Gillison, 1988 and updated by Gillison and Carpenter, 1997) was used to record site physical features [georeference by GPS in degrees, minutes and seconds; slope percent (clinometer); elevation (m) (digital aneroid altimeter); aspect in degrees (compass); parent rock type; soil type; vegetation structure, (mean canopy height (m), crown cover percent, basal area (m^2ha^{-1}); litter depth (cm); Domin scale cover-abundance estimates of wood plants <2m tall and Domin estimates of bryophytes; all vascular plant species and plant functional types (PFTs)]. As described by Gillison and Carpenter (1997), Plant Functional Types or PFTs or functional *modi* are combinations of essentially adaptive morphological or functional attributes (e.g. leaf size class, leaf inclination class, leaf form and type (distribution of chlorophyll tissue), coupled with a modified Raunkiaerean life form and type of above-ground rooting system. PFTs are derived according to a specific grammar or rule set from a minimum set of 35 functional attributes. An individual with microphyll-sized, vertically inclined, dorsiventral leaves supported by a phanerophyte life form would be a PFT expressed as MI-VE-DO-PH. Although they tend to be indicative of a species, they are independent of species in that more than one species can occur in one PFT and more than one PFT in a species. PFTs allow the recording of genetically determined, adaptive responses of plant individuals that can reveal infraspecific as well as interspecific response to environment (e.g. LUTs) in a way that is not usually contained in a species name. They have a major advantage in that, because they are generic, they can be used to record and compare data sets derived from geographically remote regions where, for example, adaptive responses and environments may be similar but where species differ. The data are recorded along a 40x5m strip transect located along the contour.

The data were compiled in a laptop computer using a recently developed software package, PFAPro (Gillison and Carpenter, unpublished). PFAPro facilitates compilation according to the rule set developed by Gillison and Carpenter (1997). It also facilitates the summary analysis of meta-data as well as producing graphs of relationships between different plant and vegetation variables. Using PFAPro, data logged for each 5x5m quadrat allow the generation of cumulative species and PFT totals per unit area and this allows the subjective inspection of asymptotic curves that can indicate whether or not a plot is an adequate sample of the vegetation or LUT (See Annex 1, Fig.1).

In addition to site physical data, simple totals of species, PFTs and vegetation structural variables, PFAPro can be used to generate a range of diversity indices for PFTs (Shannon-Weiner, Simpson and Fisher's alpha). The calculations are not trivial as, unlike diversity indices for species that are based on abundances of individuals per species, the PFT indices are derived on the number of species per PFT. Since the species to PFT relationship is many-to-many, this must be taken into account when calculating diversity. The method is described more fully in Appendix 2.1.

Four observers (ecologist and assistant, botanist (x2) and two laborers) collected plant voucher material later identified and curated at the *Herbarium Bogoriense*. A complete set of identified species and associated PFTs is listed in Annex III, Table 3. This method facilitated sampling even the most complex rain forest plot of 177 species in less than three hours. Photographic records were made of each plot. A sub-set of these has been scanned and will be cross-referenced with the data set.

2.2 Results:

The data were analysed according to the methods described above and in Part B. The most useful interpretations came from multidimensional scaling in which a two vector solution was extracted from plot data (Part B, Annex I, Fig. 7). This graph shows a zone of maximum biodiversity richness that is associated with jungle rubber. The peak in richness can be explained in part by the greater variety of available ecological niches in this agroforestry system compared with pristine rainforest. The analyses are based on a minimum data set of mean canopy height, basal area, species richness, PFT richness and a ratio of species numbers to numbers of PFTs or *modi*. Cumulative species, modi and species/modi richness area curves per 40x5m plot are indicative of vegetation type per LUT (Part B, Annex I, Fig.1 (1-7)). More detailed results from analyses of combined sets of taxa and functional types are described in the synthesis (Section 11). Other analyses dealing with variations on compositional structure of species, PFTs and vegetation structure and their relation to LUT will be dealt with in a later report. Plant taxa and functional types for each LUT are listed in Annex III Table 3. Summary data are listed in Table 2.1 and estimates of green biomass are given in Table 2.2 below. Relationships between vegetation and LUTs are described briefly in Section 3 below.

Table 2.1.
Summary of Taxa and Plant Functional Types (*Modi*) per LUT

No.	Site	Family	Genus	Species	Uniq Sp/Plot	Modi
1	BS1	44	82	103	102	37
2	BS2	43	81	104	100	36
3	BS3	32	48	50	50	20
4	BS4	45	83	111	108	39
5	BS5	43	82	117	112	38
6	BS6	26	35	42	42	27
7	BS7	25	43	48	46	33
8	BS8	37	60	68	65	37
9	BS9	31	52	58	54	30
10	BS10	53	97	115	111	47
11	BS11	49	89	100	97	41
12	BS12	6	10	11	11	10
13	BS13	6	7	7	7	5
14	BS14	7	12	15	15	12
15	BS15	8	19	19	19	13
16	BS16	22	40	43	42	34
	Total	477	840	1011	981	459
	Unique Total	91	320	—	557	216

Table 2.2.
Green biomass per Land Use Type*

Site.no	LUT	Av.kg/m2	stdev	coefvar	SEM	C-t/ha
BS01	NF	0.133	0.079	0.594	0.028	0.533
BS02	NF	0.000	0.000	*	0.000	0.000
BS03	LOF	0.000	0.000	*	0.000	0.000
BS04	LOF	0.045	0.083	1.854	0.029	0.179
BS05	LOF	0.007	0.020	2.828	0.007	0.028
BS06	HTI	0.247	0.159	0.642	0.056	0.987
BS07	HTI	0.092	0.131	1.424	0.046	0.368
BS08	RUB-P	0.107	0.126	1.178	0.044	0.426
BS09	RUB-P	0.083	0.093	1.121	0.032	0.331
BS10	J_RUB	0.033	0.400	1.194	0.014	0.133
BS11	J_RUB	0.018	0.035	1.913	0.012	0.073
BS12	IMP	0.227	0.057	0.252	0.033	0.908
BS13	IMP	0.180	0.008	0.045	0.004	0.719
BS14	CAS	0.207	0.028	0.136	0.016	0.829
BS15	CAS	0.288	0.089	0.308	0.051	1.150
BS16	CHROM	0.335	0.143	0.427	0.082	1.340

*Source M.Van Noordwijk and K.Hairiah

NOTE: Additional results from the vegetation survey are described in Section 11

2.3 References:

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Appendix 2.I

Unpublished measures of functional diversity and functional complexity used in this project

(extracted from Gillison, A.N. Carpenter, G. and Thomas, M., *Plant functional diversity and complexity: two complementary measures of species diversity*.)

Functional diversity

Concepts of functional diversity vary; according to Martinez (1997) (see also Steele, 1991 quoted by Martinez), functional diversity is defined as “*..the variety of interactions with ecological processes*” and can be quantified by determining the nature and extent to which functional groups are represented in an ecological system. Functional diversity can also refer to the number of such groups in a community each of which contains one or more species (Smith and Huston, 1989; Scott and Benning 1996). Whatever the nature of the functional groups it is generally accepted they will be fewer than the species under study, (Mooney 1997). In this sense functional ‘diversity’ is simply a measure of group richness rather than an estimate of evenness or dominance based on the abundance of individuals per group.

As with species diversity, it would seem reasonable to derive a parallel measure of functional diversity based on the abundance of individuals per functional type or *modus* but without species-weighting. While logically viable, this is likely to be limiting in practice as to record all individuals, (e.g. in an epiphyte-rich, rain forest) can be excessively time-consuming and counterproductive if the aim is rapid assessment, and if the functional types or groups are likely to be significantly fewer than the species. Depending on the scale and purpose of the investigation, the additional effort may not be worth the gain. For these reasons, we explore the possibility of using species instead of individuals to serve as a ‘higher-order’ measure of abundance by deriving a species-weighted, rather than a spatial or density-driven, measure of Functional Diversity based on abundances of individuals. A species-weighted form of Functional Diversity (SFD) can therefore be defined as: ***The diversity of functional types expressed as a function of the number of species per type***. While the definition can be compared with that of Huston (1994) for species diversity where “*The total species diversity of a community is described by the number of functional types multiplied by the average number of species per functional type*”, this approach is more sensitive to evenness and dominance. We achieve this in the same way that species abundance is used to calculate species diversity but with the important difference that counts of species per functional type are used instead of counts of individuals per species. For this we apply the Shannon-Wiener formula to estimate evenness and that of Simpson to estimate dominance. Another difference is that, unlike the ‘one-to-many’ species to individual relationship, the mapping between species and *modi* is

many-to-many' (i.e. more than one species can exist in one *modus* and *vice versa*) (Fig. 1). Both formulae have been modified to accommodate these multiple relationships.

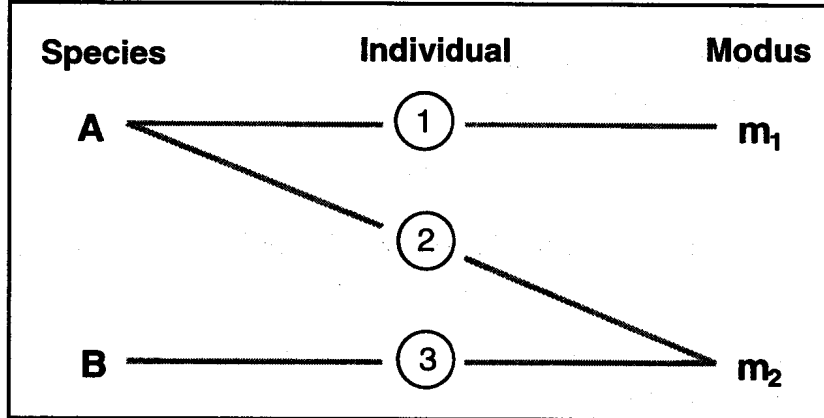


Fig. 1 An example of multiple linkages (many-to-many mapping) between Linnean species and functional types or *modi*. Species A occurs in *modi* m_1 , m_2 ; species B in *modus* m_2 , while m_1 occurs in species A, and m_2 in species A and B. An individual is recorded once if it satisfies any one of these relationships – duplicates are omitted.

Shannon Wiener Index

The Shannon-Wiener index is calculated from the equation (ref.):

$$H' = - \sum_{j=1}^{Nspp} p_i \ln p_i$$

where quantity p_i is the proportion of individuals found in the i th species, and is estimated using the maximum likelihood estimator:

$$p_i = \frac{n_i}{N}$$

Where n_i is the number of individuals in the i th species. For species/population data, each individual in the sample belongs to exactly one species. And N is the total number of species recorded. However with *modus*/species data, a species may be attributed to more than one *modus* if that species is present in multiple functional forms. To accommodate this difference, the maximum likelihood estimator is modified to divide the proportional count for a species evenly between the *modal* types in which that species is present. The equation for p_i , the proportion of species in the i th *modus* becomes:

$$p_i = \sum_{j=1}^{Nspp} \frac{n_{ji}}{n_j \cdot N}$$

Where $Nspp$ is the number of species,
 n_{ji} is the number of records for species j , *modus* i (either 0 or 1)
 n_j is the number of records for species j ,
and N is the total number of records.

Because the species to *modus* mapping is a many to many relationship N may be greater than both the number of species N_{spp} and the number of *modi* in the sample.

Simpson's Index

The same modified form of the maximum likelihood estimator is used in the calculation of the Simpson index which is usually formulated as:

$$D = \sum p_i^2$$

The Simpson index produces higher values for lower diversity, and is often expressed as $1 - D$

Limits

Diversity values for the Shannon-Wiener index become progressively smaller with increasingly uneven distribution of species between *modi* where, for example, a small number of *modal* forms dominate the sample. Given the number of species and the number of *modi* in the sample, the absolute minimum index value possible can be found by computing the largest possible value for maximum likelihood estimator (P_0) for one *modus*, while minimizing the remaining $Nm-1$ estimators ($P_{i>0}$). The minimum estimator value occurs when only one species occurs in a *modus*, and that same species occurs in all other *modi*. The minimum is formulated as:

$$p_0 = 1 - \frac{Nm - 1}{Nm \cdot N_{spp}}$$

$$p_{i>0} = \frac{1}{Nm \cdot N_{spp}}$$

$$H'_{\min} = -[p_0 \ln(p_0) + (Nm - 1)p_{i>0} \ln(p_{i>0})]$$

The maximum value of the Shannon-Wiener index is generated when the species are evenly distributed between all *modi*, such that $P_i = 1/Nm$, yielding as a final form:

$$H'_{\max} = \ln(Nm)$$

The same proportion values determine the limits of the Simpson Index. This index returns smaller values for increasing diversity.

$$D_{\min} = \frac{1}{Nm}$$

$$D_{\max} = p_0^2 + (Nm - 1)p_{i>0}^2$$

Interpretation and Examples

When interpreting species-weighted functional diversity measures it is important recall that the measure describes the distribution of species between functional *modi*, not the distribution of individuals between functional types.

The values generated by of these species-weighted functional diversity measures, when applied over a broad range of sites, are typically higher than the equivalent measures from species/population data. This reflects the reduced likelihood of dominance of any particular functional type, and a similar degree of discriminatory resolution (or granularity) between functional types and species. The consistently high correlation between species counts and *modal* counts at the global level is explored elsewhere (Gillison, submitted for publication – see Annex II)

Functional complexity

Two approaches were adopted for the analysis of *modal* composition. The first was an exact mirror of the analysis of species composition. Instead of an analysis of species incidence, the incidence of each *modus* was used to generate a between-site Jaccard distance. This distance matrix was then input to the same multidimensional scaling procedure.

The second approach attempted to take account of the inherent similarity or dissimilarity between different *modi*. It was based on the syntactic distance between *modi* of Gillison and Carpenter (1997).

We consider sites X and Y , such that site X contains the set of *modi* $\{X_i, i = 1 \dots m\}$ and site Y contains the set of *modi* $\{Y_j, j = 1 \dots n\}$. Now let $f(a, b)$ be the distance between *modi* a and b . We define the dissimilarity between sites X and Y to be:

$$d_{X,Y} = \frac{\sum_i \min_j f(X_i, Y_j) + \sum_j \min_i f(X_i, Y_j)}{m+n}$$

This index will be zero only if sites X and Y contain the same set of *modi*. In particular, it will be non-zero if *modi* at one site are a proper subset of *modi* at the other. It should also be noted that the dissimilarity index is not a metric.

The expected value of the dissimilarity index depends on the number of *modi* at each site. If the *modi* present at each site are generated by random sampling from a set of available *modi*, then the distance between two sites will decrease as the number of *modi* at each site increases. In the absence of any other aspect of pattern, we would expect sites with many *modi* to be very similar, whilst sites with few *modi* would be dissimilar - both to other sites with few *modi* and to sites with many *modi*. Ordination of such a dissimilarity matrix would result in a hyper-sphere - with *modi* rich sites at the centre, and *modi* poor sites at the periphery. Analyses of data from a range of global environments tend to confirm the utility of this procedure (Gillison and Thomas, unpublished).

SECTION 3: VEGETATION AND LAND USE TYPES

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3.1 Background:

The forested lowland in Sumatra is a highly complex ecosystem that is of great interest for research. Compared with other natural ecosystems in Sumatra, perhaps the forest lowland ecosystem is the most comprehensively studied so far. In Sumatra biodiversity is highest in lowland vegetation. For instance, in the valley surrounding the Ranum river in North of Sumatra, for vegetation which has diameter 15 cm has Simpson Index diversity 0.96 and 0.94 on Bangka island hill (from result study by Tim PUSLIT SDL-USU). Some studies on the phytosociology of forest of the pamah land use type have been done in Sumatra (Mogea 1980; Mirmanto 1986; Abdulhadi *et al.* 1989, 1991; Abdulhadi 1991 and Mirmanto dkk. 1992). Nonetheless the structure and composition of vegetation vary from one to another place depending on habitat condition. Human activity in forestland use will greatly influence changes in vegetation composition.

3.2 Aims and objectives:

- To provide baseline data for above-ground biodiversity assessment based on vascular plant species, plant functional types, vegetation structure and key site physical attributes.
- To provide a biophysical baseline and sample reference point for other multidisciplinary input.
- To identify the best sub-set of plant-based variables that be used to estimate distribution in other biota.

3.3 Personnel:

Dr A.N. Gillison, Plant Ecologist (CIFOR)
Ms N. Liswanti, Research Assistant (CIFOR)
Drs Suhardjono, Botanist (LIPI, *Herbarium Bogoriense*)
Mrs Afriastini, Botanist (LIPI, *Herbarium Bogoriense*)
Mr Edi Purnomo, Botanist (BIOTROP)

3.4 Methods:

Based on radar satellite and remote sensing of lowland forest in Jambi, there were 8 land use types in Pasir Mayang, Pancuran Gading village, and Kuamang Kuning. They are primary forest, secondary forest, selectively -logged forest 1983, *Paraserianthes* plantation 1993-1994, rubber plantation, jungle rubber, *Chromolaena* fallow, *Imperata* and Cassava garden. For each land use type we recorded the spatial coordinate using GPS, elevation, slope, soil depth, soil type, canopy height, using a 40x5 m strip transect. In each plot we recorded all the vascular plant species, life form, leaf size, leaf inclination, and herbarium specimen for identification at Herbarium Bogoriense, Balitbang Botany, Puslitbang Biology-LIPI, Bogor.

3.5 Discussion:

The results of herbarium identifications from the survey are 765 species. There are 83 families, 276 genera and 428 species (Annex III, Table 2). Selective logged forest (1983) contained the highest species recorded during the survey, followed by jungle rubber, intact rain forest, rubber plantation, secondary rain forest, *Paraserianthes* plantation, *Chromolaena* fallow, Cassava plantation, and *Imperata* grassland. The diversity of vegetation on this study is higher than land use forest in Riau. In other studies of the pamah land use type in Bukit Tigapuluh, Riau, Sumatra on secondary forest (belukar) within 0.25ha sample plots, Mirmanto (1993) recorded 19 families, 30 genera and 45 species. In disturbed forest within 0.25ha sample plot, there were 27 families, 48 genera and 57 species. In primary forest, there were 20 families, 37 genera and 60 species (Annex III. Table 3).

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SECTION 4: BIRDS

By P. Jepson¹ and Djarwadi²

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4.1. Introduction:

This report presents preliminary analyses and conclusions of the bird survey component of the Jambi base-line study. The analysis is largely descriptive and aims to provide an overview of the data to facilitate comparisons with findings from other disciplines and generate ideas for more detailed and multidisciplinary analysis. The conclusions section flags some areas which may merit further investigation. A brief discussion on the sampling protocol suggests that for birds, an approach drawing on a landscape ecological framework may be more suitable for Rapid Biodiversity Assessment that aims to assess the impact of land use change.

4.2. Aims and objectives:

- To provide baseline data for above-ground biodiversity assessment based on bird species richness and functional (guild) type.
- To investigate the changes in bird diversity across a disturbance gradient from natural forest to agricultural habitats.
- To provide a sample reference point for other multi-disciplinary input.

4.3. Personnel:

Paul Jepson, Ornithologist (University of Oxford)
Djawardi, Ornithologist (IPB, Bogor)

4.4. Methods:

4.4.1 *Review of existing methods:*

For the purpose of measuring and comparing bird diversity there are two broad groups of methods: those which generate a species list, perhaps with an approximation of abundance, and those which generate a species list with a quantifiable measure of abundance.

For birds, abundance is enormously difficult to measure with any precision. A key problem is the difference between observed and real abundance. This can be a factor of a species' habits and the openness of a habitat (distance at which birds can be seen and/or heard). The latter variable differs between habitat types and must be accounted for if the aim (such as in this study) is to compare diversity between habitats. A group of methods called Distance Sampling [Reynolds, 1980] which are supported by a sophisticated analytical statistics package (DISTANCE2) are available for comparing abundance in different habitats. One of these methods (Variable-circular Plot) has been employed by the BirdLife International-Indonesian Programme in Nusa Tenggara and Maluku to compare biodiversity values of different habitat types with proposed reserves. Although distance sampling is highly compatible with a plot-

based protocol, it was not considered appropriate for the survey because BirdLife's experienced has revealed that:

- while a density can be calculated with five contacts for a species, twenty contacts are usually required to generate densities within 5% confidence limits; this requires planning for at least 8 days sampling for each habitat type;
- data analysis is complicated and time consuming;
- it is questionable if the assumptions of Distance Sampling methodology are justified in tropical rainforest.

"Rapid" as defined by the time horizon of this study, constrained the choice to *presence-absence* methodologies and those which could yield useable data in one day's sampling per division. Species accumulation curves were selected. This method is well known in Indonesia because it was described by John MacKinnon in his popular field guides. Counts of species are made during successive sampling units, and the cumulative number of species plotted. The rate at which the curve flattens gives an indication of total number of species and whether all species in the habitat have been observed.

MacKinnon defined the sampling unit as the first 20 species and envisaged an observer walking. This introduces a rough measure of relative abundance and increases the likelihood of meeting rare species. The need to link bird observations to a plot, as well as time constraints, required a variation of this methodology - observers stayed with the immediate vicinity of the plot and the sampling unit was a five minute time period. With this protocol an abundance measure is not possible, and rare species are likely to go unrecorded.

4.4.2 Field Methods used on this survey:

Twelve plots were sampled using a species accumulation methodology. A species list of contacts was compiled for each five minute period between 16.30hrs and 18.00hrs and between 06.30 hrs. and 08.00 hrs. Audio-visual species contacts were made by the two observers named above in 'wooded' land use types and by a single observer in 'open' land use types. The observers roved within 30m of the plot centre.

Bird species contacts were scored: "H" = heard, "L" = seen, "T" = fly-over. In open habitats a list was made of species actually recorded in the land use.

Data were entered into a spread-sheet after each morning count. Entering data while a count is within immediate memory is an integral part of the overall methodology, because it:

- a) assisted with learning\confirming identity of calls;
- b) ensured both observers gave the same name to the same contact.

In addition to the above, bird species lists were compiled for three landscape elements of the logged forest land-use not sampled in the plots, namely : access road edge; camp; and log pond.

4.4.3 Analysis:

4.4.3.1 Data storage and access:

The following two data sets are annexed to this report and contained in the Excel file name 'Jambird.xls':

1. A matrix of species recorded in each 5-min count.
2. A total species list by plot and also by additional “landscape elements”. (Annex III, Table 4)

Data set 1 is a combined and agreed record taken from the field notebooks of the two observers. The second data set is compiled from the first. Additional values attributed to each species in order to facilitate investigation of the data sets are as follows:

- Species number code according to [Andrew, 1992 p.147];
- Species number code specific to this study. i.e. the number of the species in the total species list for the study ordered according to [Andrew, 1992 p.147];
- Status i.e. resident (R), migrant (M);
- Diet guild *sensu* [Thiollay, 1995 p.199]
- Feeding site guild *sensu* [Thiollay, 1995 p.199]
- Body size category *sensu* [Thiollay, 1995 p.199]

4.4.3.2 Data analysis:

The methods used resulted in a *presence-absence* data set. Although species were recorded by five minute count, it is not possible to analyse for relative abundance because counts are not independent, i.e. a bird recorded in one count may or may not be the same bird recorded in subsequent counts.

Three species flying over the plot and unlikely to utilise the LUT in which the plot is embedded, were omitted from the analysis (see Appendix 4.1 for list).

To explore the question of the impact of disturbance on forest bird diversity the following analyses were made:

- a) **Species richness.** Species accumulation curves were plotted to compare species richness between plots. The intention is to re-analyse this data using the British Museum program “Curves” which optimise the curve. This analysis will be submitted as an update to this report.
- b) **Functional diversity.** Species were assigned to diet guilds, foraging site guilds and body size classes *sensu* [Thiollay, 1995 p.199]. Counts of number of species per class are graphed. Unidentified species were omitted from the analysis. A table of number of species according to taxonomic family is also presented.
- c) **Resident\migrant status.** A simple count of migrant species by plot was made to ascertain whether numbers differed between plots.
- d) **Differentiation in β diversity between sites.** Sørensen’s similarity indices were calculated using the Multivariate Statistical Package (MVSP), 1987. This is a simple measure suitable for presence and absence data; it treats all species as equal irrespective of whether they are abundant or rare. [Magurran, 1988 p. 200]
- e) **Clustering of sites.** A nearest neighbour cluster analysis was performed on the Sørensen’s similarity indices with randomised data input.

4.5. Preliminary results:

4.5.1. Descriptive analysis:

4.5.1.1 Species richness:

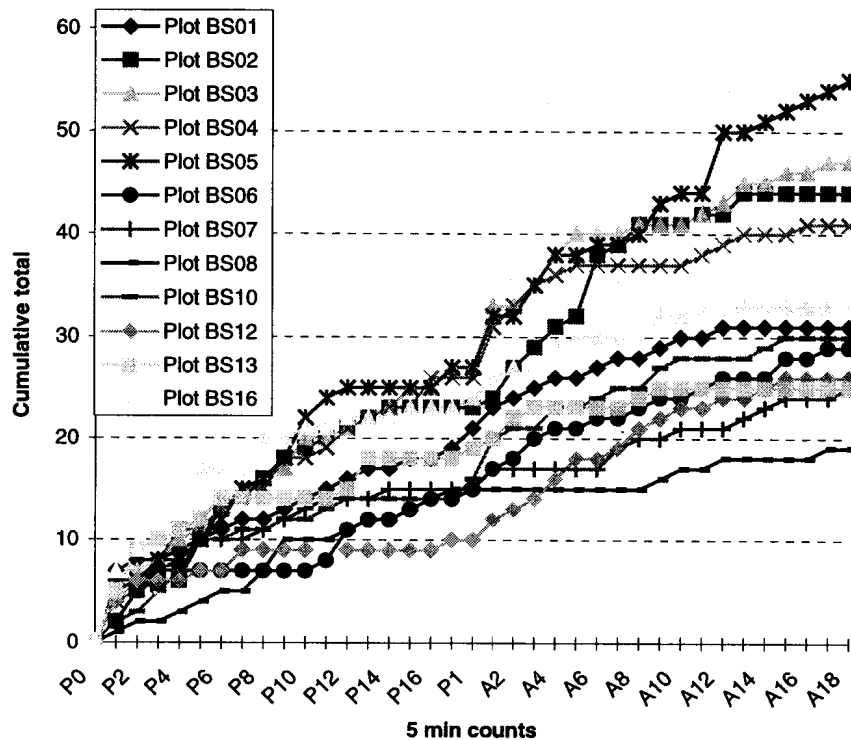


Figure 4.1 Species accumulation curves

Figure 4.1 shows species accumulation curves for each plot. The rate at which the curve flattens is crucial to comparing such curves, and it is regretted that it is not possible as yet to present smoothest-fit curves.

The richest plots were the natural forest plots (BS2 & BS5) and the heavily disturbed logged forest plot (BS3). The two industrial plantation plots (BS7 & BS8) were the most depauperate. The 'wooded' plots appear to show increasingly depauperate sub-sets with increased intensity of management. The 'non-wooded' plots have a largely open-country species assemblage distinct from the 'forest' plots. The *Chromolaena* plot (BS16) has some forest species and represents the change-over point.

4.5.2.1 Trophic diversity:

4.5.2.1.a Proportion of diet guilds:

Figure 4.5.2.1i. Percentage of species diet guilds

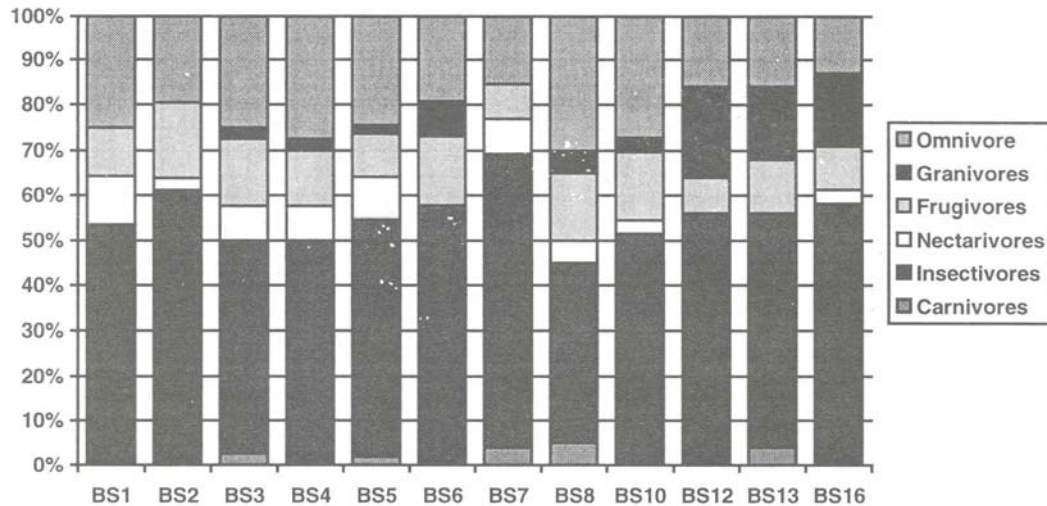
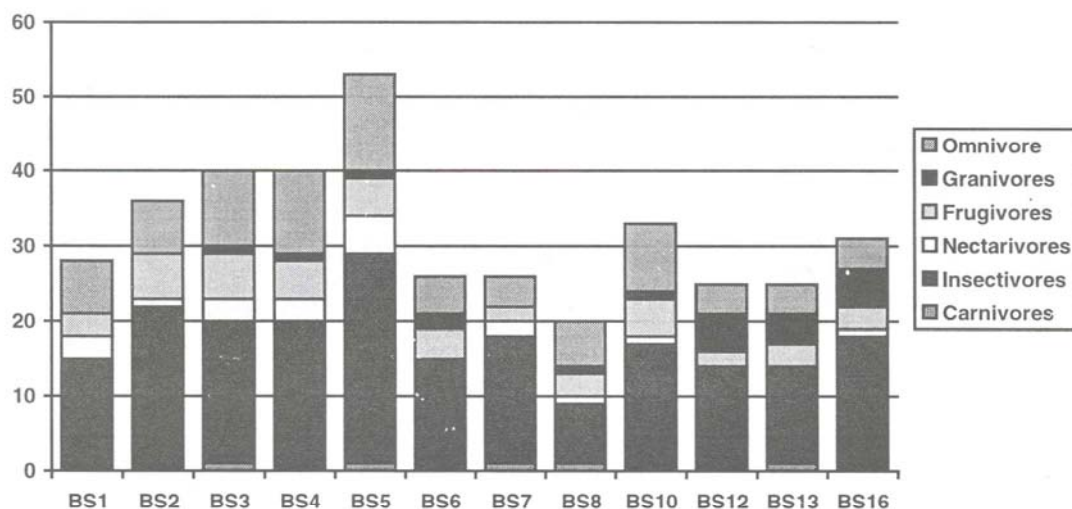


Figure 4.5.2.1b. Number of species diet guilds



The granivore guild is represented in disturbed forest habitats and constitutes the largest percentage of species richness in the most highly modified habitats: *Imperata*; *Cassava* and *Chromolaena* (plots BS12, BS13 and BS16). Plantation rubber (BS8) and jungle rubber (BS10) have similar proportions of each guild, as do the three logged forests. The two *Paraserianthes* plots are dissimilar - BS6 has granivores and no nectarivores, whereas for BS7 it is the reverse (species numbers are low).

4.5.1.2b Proportion of feeding site guilds:

Figure 4.5.1.2i. Percentage of species in each feedings site diet guilds

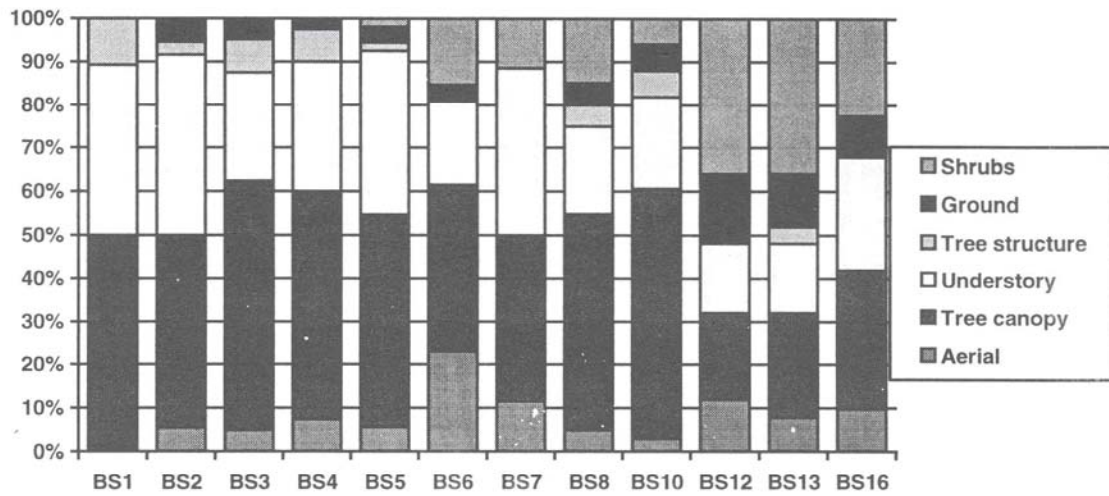
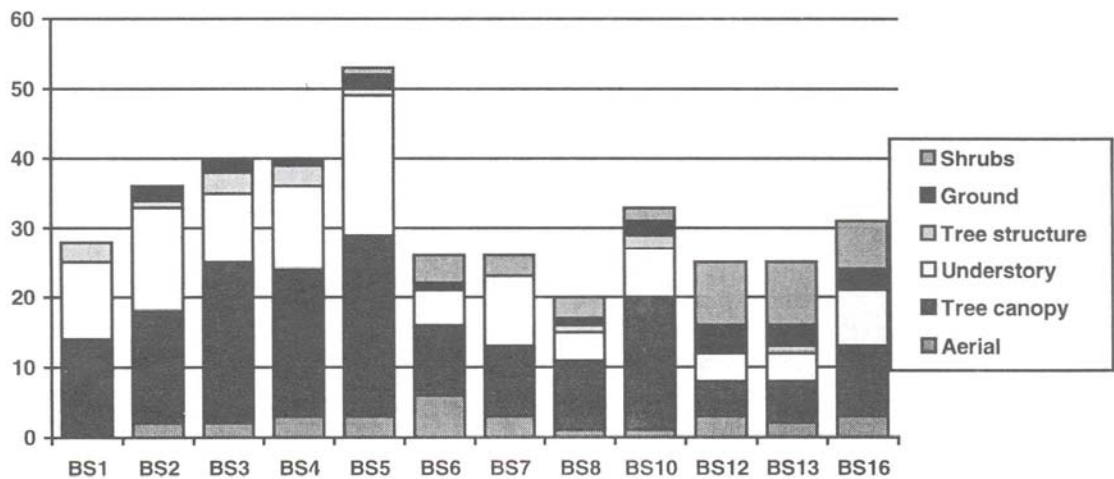


Figure 4.5.2.2a. Number of species in each feedings site diet guilds



The tree canopy feeding guild constitutes over 45% of species in natural forest plots (BS1-BS5) and in the jungle rubber (BS10) and plantation rubber (BS8). The proportion of this guild is less than 35% of species total in all other plots. Species adapted to feeding from grasses and shrubs are present in all non-natural forest plots, but not in natural forest plots (with the exception of one species in Plot BS5).

4.5.2.3 Proportion of body size classes:

Figure 4.5.2.3 a. Percentage of species by size class

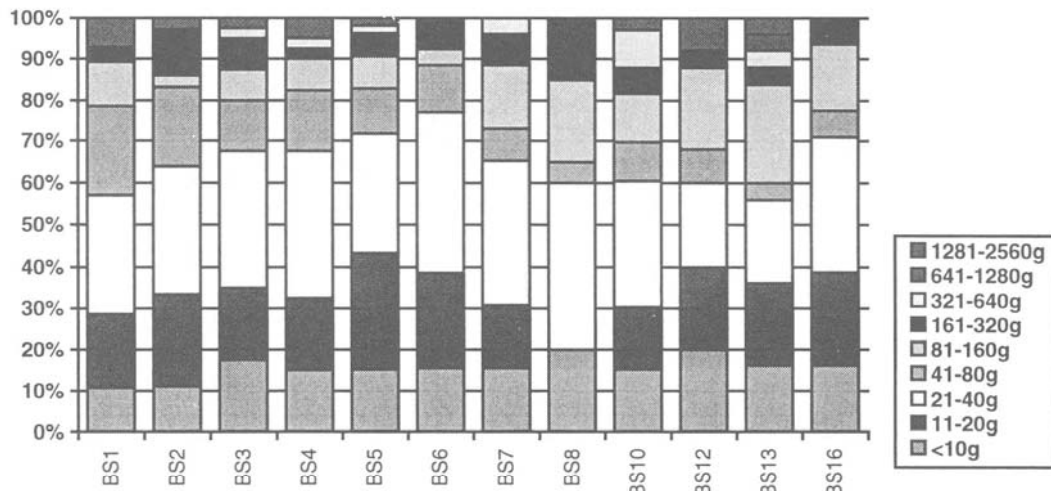
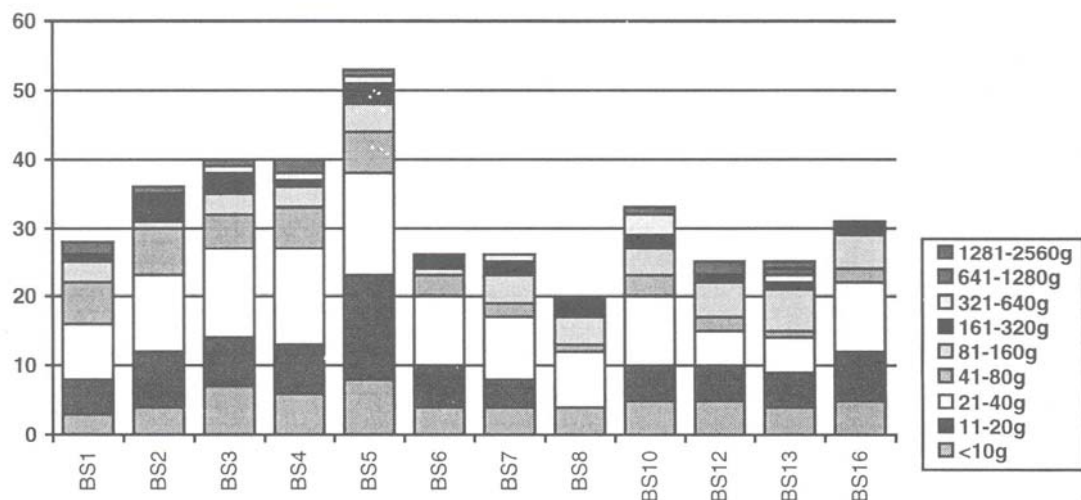


Figure 4.5.2.3 b. No of species by size class



No clear patterns differentiate the plots. Both the unlogged natural forest site (BS1) and *Imperata* (BS12) have the largest percentage of species in the heaviest weight class.

4.5.1.4 Species diversity by taxonomic family:

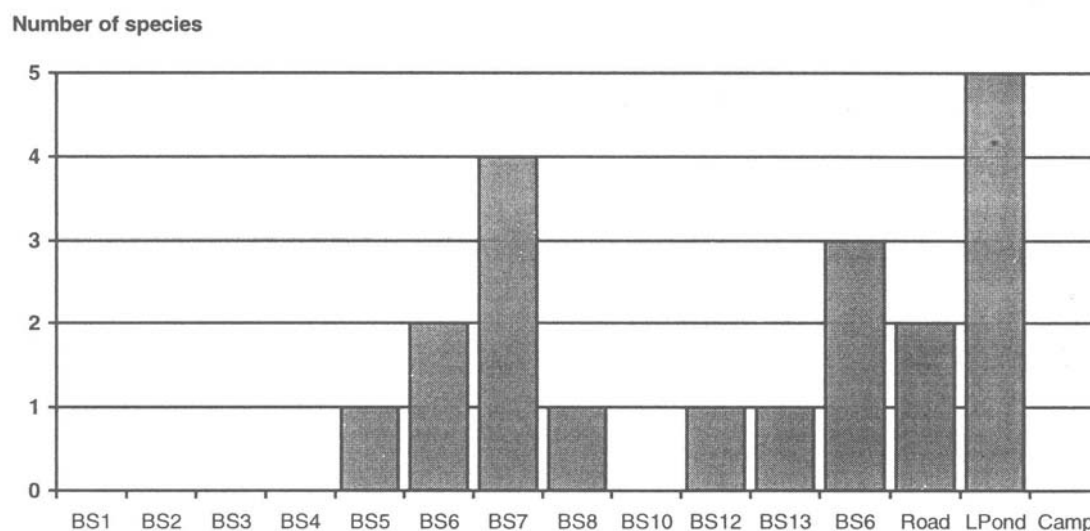
Natural forest plots are characterised by higher numbers of bird families and passerine bird families, compared with non-natural forest families (with the exception of BS1), see Table 4.1. Five families are only present at natural forest plots, namely: Hemiprocridae; Trogonidae; Muscicapidae; Monarchidae; Zosteropidae.

Table 4.1
Summary of species in each taxonomic family by plot

	Natural Forest Plots											
	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	BS10	BS12	BS13	BS16
Ardeidae											1	
Accipitridae			1		1		1	1				
Falconidae						1	1					
Anatidae										1		
Phasianidae										1	1	
Turnicidae						1				1	1	1
Rallidae											1	
Charadriidae												
Scolopacidae												
Giareolidae												
Columbidae		1	1	1	1			1	2	3	2	3
Psittacidae	2	2	2	2	2	2		2		1	1	
Cuculidae	1			2	3	2	3	1	4	2	2	4
Strigidae												
Caprimulgidae												
Apodidae			1	1		3						
Hemiprocnidae												
Hemiprocnidae		1	1	1	1							
Trogonidae	1	1		1	1							
Alcedinidae	1	1			1		1	1		1	1	
Meropidae		1		1	2	1	1	1	1	1	1	1
Capitonidae	1	1	2	2	1				2			1
Picidae	3	1	3	3	1			1	2		1	
Eurylaimidae			2	1	1		1	1	1			
Hirundinidae					1	1	1			1	1	1
Campephagidae	1	2	2		1							
Pycnonotidae	2	2	3	4	3	3	2	3	4	2	2	2
Irenidae	1	2	2	1	2	1						1
Laniidae												1
Orthonychidae		1										
Timaliidae	4	6	3	3	6	1	2	1	3	1	1	3
Sylviidae	1	3	3	3	3	5	4	2	3	6	5	5
Muscicapidae	2	1	1	1	2							
Monarchidae		2	1	1	4							
Dicaeidae	1	1	2	2	2			1	2			1
Nectariniidae	3	1	3	3	6		2	1	1			1
Zosteropidae			1		1							
Estrildidae						1				2	2	2
Ploceidae												
Sturnidae	1	2	2	1	2	1	1	1			1	1
Oriolidae				1	1				1			
Dicruridae	1	1	2	1	2		1		1			1
Corvidae		1				1	1	2	1			
non-passeriformes	6	8	7	9	10	6	5	7	5	8	10	5
passeriformes	10	13	13	12	15	8	9	8	9	5	6	11
Total Families	16	21	20	21	25	14	14	15	14	13	16	16

4.5.1.5 Migrant species:

Figure 4.5.1.4i Number of migrant bird species by plot and landscape element



Migrant species are more frequent in non-natural forest plots and in disturbed landscape elements within the natural forest.

4.5.2 Exploratory (pattern) analysis

4.5.2.1 Differentiation in β diversity (Sørensen similarity indices=Dice's Coefficient)

Table 4.2. Similarity indices

	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	BS10	BS12	BS13	BS16
BS1	1	0.535	0.389	0.423	0.381	0.107	0.143	0.080	0.159	0.036	0.036	0.164
BS2	0.535	1	0.482	0.390	0.442	0.269	0.239	0.197	0.162	0.091	0.121	0.167
BS3	0.389	0.482	1	0.578	0.563	0.235	0.206	0.258	0.320	0.060	0.090	0.219
BS4	0.423	0.390	0.578	1	0.568	0.299	0.299	0.295	0.486	0.121	0.121	0.306
BS5	0.381	0.442	0.563	0.568	1	0.225	0.275	0.270	0.299	0.101	0.127	0.235
BS6	0.107	0.269	0.235	0.299	0.225	1	0.615	0.391	0.271	0.510	0.549	0.491
BS7	0.143	0.239	0.206	0.299	0.275	0.615	1	0.435	0.407	0.431	0.471	0.561
BS8	0.080	0.197	0.258	0.295	0.270	0.391	0.435	1	0.453	0.222	0.267	0.275
BS10	0.159	0.162	0.320	0.486	0.299	0.271	0.407	0.453	1	0.172	0.172	0.375
BS12	0.036	0.091	0.060	0.121	0.101	0.510	0.431	0.222	0.172	1	0.840	0.571
BS13	0.036	0.121	0.090	0.121	0.127	0.549	0.471	0.267	0.172	0.840	1	0.536
BS16	0.164	0.167	0.219	0.306	0.235	0.491	0.561	0.275	0.375	0.571	0.536	1

Undisturbed forest plots (BS1 & BS2) are highlighted in grey and all natural forest plots enclosed within the dotted line (Table 4.2). These constitute a group with similarity indices greater than 39%. Outside this group dissimilarity increases markedly. A second group: *Chromolaena* (BS16), Jungle rubber (BS10) and *Paraserianthes* (BS7) exhibit between 14% and 16.5% similarity. Then there is a gradient of increasing dissimilarity (10.7% to 3.6%) from *Paraserianthes* 1 (BS6), plantation rubber (BS8) to *Cassava* and *Imperata* (BS12 & BS16). The *Cassava* and *Imperata* plots are the most similar, and the more mature *Paraserianthes* plot shows greater similarity with natural forest than the younger *Paraserianthes* plot.

5.2.2 Cluster analysis:

The analysis resulted in two main groupings: natural forest plots and mono-dominant plots. The natural forest plots are all quite dissimilar. The logged and unlogged plots are included in separate sub-groups. Plantation rubber is grouped with natural forest plots although it is the most dissimilar. *Paraserianthes* is grouped in the mono-dominated 'agricultural plots'. Of all the plots, *Cassava* and *Imperata* are the most similar.

4.6 Discussion:

4.6.1 Review of methods: costs in time and effort per plot (?per taxon):

4.6.1.1 Cost effectiveness:

The protocol employed in this study lends itself to a range of simple descriptive analysis as well as similarity indices. It is not suited to more detailed statistical analysis. As such, the method produces an initial indication of changes to bird diversity caused by increasing degrees of forest modification.

It is highly cost-effective. For each forest plot, two observers could collect data and enter it in to a spreadsheet ready for analysis in one day. In open habitats one observer was sufficient. It is an excellent technique for producing quick results. But it depends closely on the identification skills of the observer; for example in the natural forest plots (BS1-BS5) more than 85% of bird contacts were by call. This generates the need for experienced field ornithologists (who are often quite expensive). Furthermore, if the observers are unfamiliar with the avifauna, they should spend 3-4 days practising identification before starting counts.

4.6.1.2 Limitations and recommendation for modifications to the sampling protocol:

In the case of birds, the protocol had two important limitations: a) variation in sampling area and b) selection of the landscape element to be sampled. The question under investigation concerned the effects of different levels of disturbance on avian diversity. The distance at which birds could be detected varied significantly between plots and species. For example, in primary and secondary forest and jungle rubber plots, sight records were all within 30m but some vocal species could be heard up to 500m or more. In the *Cassava* and *Imperata* plots, species could be seen and heard for 1 km or more. Obviously, among the latter there is a greater chance of detecting thinly dispersed species.

Other disciplines sampling at the plot can assume that habitat is homogenous for their sample. This assumption is difficult to meet for birds. Sampling within a fixed area (e.g. 30 m from the plot) would produce very few contacts and as a result increase the required sampling time. Sampling (as we did) all contacts made from the plot overcomes the time consideration, but introduces bias because habitat heterogeneity increases with size of sampling area. Increased habitat heterogeneity correlates strongly with increased species diversity.

The argument that this does not matter because we are sampling the land use is also problematic. It assumes that the plot vegetation type is crucial to defining bird diversity in the land use concerned. This may be true for mature forest, but is not the case for birds in the highly modified sites. For example, in the *Cassava* plot only 7 of the 25 species were actually recorded in the *Cassava*. At resolutions below 500m², scrub and trees associated with access tracks and field edges were important elements, adding species such as *Prinia familiaris*;

Cocomantis merulus; *Copsycus solaris* and *Macronus gularis*. At a wider resolution, woodland patches around homesteads and rivers probably accounted for the presence of *Psitacinus* and *Gracula religiousus*.

A way round these problems could be to base sampling design on landscape ecological principles [see Forman, 1986 p. 201]. This would involve identifying first landscape units (LUTs) and then landscape elements within each landscape unit. A possible protocol could be to establish plots in the principal vegetation type of each landscape unit (as we did). The time-consuming sampling disciplines (plants, termites, insects, etc.) could confine themselves to these, but those disciplines sampling groups with larger home ranges and greater dispersive abilities would combine standardised sampling of plots with non-standardised sampling of other landscape elements (e.g. searching).

Some benefits of this approach are:

- it maintains the benefit of data comparability across groups provided by the plot reference point;
- through knowing what occurs in all landscape elements it enables discussion of the influences of these elements on the plot-based species set, i.e. it accommodates source-sink theory which is expected to become more important with increasing habitat modification and ;
- it enables the identification of landscape elements that are critical to maintaining biodiversity values in the overall landscape or land use;
- policy interventions arising from studies such as these will have impact at the land use or landscape level.

If we consider the Jambi surveys in this framework, we sampled four landscape types: managed natural forest (primary and logged forest plots); commercial plantation forestry (rubber and *Paraserianthes* plots); traditional agro-forestry systems (jungle rubber and *Chromolaena*); and 'frontier' agriculture (*Cassava* and *Imperata*). These constitute a gradient of landscape change. Taking the two ends of this gradient as an example, I have summarised in Table 4.3 the variety of landscapes elements represented. It is constructive to think of the functional contribution of each of these elements to the overall biodiversity value of the landscape.

Table 4.3
Landscape elements in Natural forest and Frontier agriculture landscapes

Natural Forest		Frontier agriculture	
Element	Sampled?	Element	Sampled?
Pristine forest (various types)	Plot	<i>Cassava</i>	Plot
Logged forest (various age classes)	Plot	<i>Imperata</i>	Plot
River	-	Track with scrub	from plot
Access road;	Bird count	Stream with vegetation	
Extraction tracks	-	Woodlot/Fruit tree grove	birds in flight
Log pond	Bird count	Marshy pond	Ducks in flight
Camp	Bird count	Scrub	

In the natural forest LUT, we sampled three landscape elements according to the protocol suggested above. These were the logging road and forest edge the log camp, and the log pond. Each of these landscape elements characterises a managed forest estate.

Table 4.4
Species record in key habitats outside the sampled landuse types

Landscape element	Species	
	Total	Cum. total
Logged Forest	74	74
Unlogged Forest	45	88
Road	35	101
Log pond	12	112
Camp	21	119

Sampling the logging road added 13 species not recorded in the forest interior, and the two highly modified landscape elements accounted for 15% of species in the overall landuse. These added mainly non-forest species, migratory shorebirds in the case of the log pond and garden and night birds in the case of the logging camp (Table 4.4).

4.6.2 Relevance of study at regional and global levels:

The lowland, evergreen, mixed dipterocarp forests of the Sunda-shelf are among the most bird diverse habitats on earth; 291 species of which 164 are Sunda endemics, breed mainly or exclusively in this biome [Wells, 1985 p. 202]. They are also among the most threatened; large areas are being converted to agriculture with the remaining areas being modified by commercial timber extraction. Understanding the effects of this process on the distribution and status of bird species is crucial for planning and prioritising conservation action. This study is an important contribution in this field of investigation.

4.6.3 Relevance to Rapid Biodiversity Assessment:

A World Bank review of Integrated Conservation and Development Project (ICDPs) in Indonesia, identified a lack of clear linkages between the conservation importance of a reserve and rural development activities as a key factor in the under performance of these projects. This is a growing recognition of the need for spatially-referenced biodiversity information during the preparation phase. The protocol employed in this study would appear ideal for providing an understanding of relative biodiversity values of habitats represented in an ICDP area.

4.7 Preliminary conclusions and discussion of results:

Although natural forest habitats form a group distinct from the 'frontier' agricultural sites, there are quite high levels of dissimilarity between plots. This may be a factor of sampling time. The total number of species recorded in the five natural forest plots and forest edge (see Table 4.3) was 112, and the maximum number of species at any one plot was 56. The dissimilarity is believed to be as much a function of short sampling times and small sampling areas, as a real difference between plots. If the number of replicates was increased we would expect more shared species between plots. This conclusion is supported by the species accumulation curves

which flatten out slowly. In the open frontier agriculture and plantation habitats, sample effort created less bias, and the similarity indices are more robust.

The bird communities of natural forest plots differ significantly from the commercial plantation and frontier agriculture plots. The latter support non-forest bird communities. Typical forest bird families such as hornbills, trogons and tree-swifts are replaced by typical open-country families such as Ardeidae, Turnicidae and Estrillidae. Within families there are also clear differences. There is little overlap in the species composition of, for example, Pycnonotidae, Timalliidae, Sylviidae between natural and non-natural forest habitats. The Jungle rubber has many species in common with natural forest, but species typical of scrub habitats are also represented.

A point of interest in the *Imperata* plots was the co-occurrence of two closely related warbler species occupying the same niche. On Sumatra, *Cisticola juncidis* is typically a species of wet-rice agriculture and is well established. *Cisticola exilis* is a grassland species, typical of *Imperata* grasslands. A possible explanation of this co-occurrence is that *Cisticola juncidis*, already well established on Sumatra, rapidly colonised these new *Imperata* grasslands, and *Cisticola exilis* subsequently moved into the area. Selective logging appears to result in an increase in overall species richness of the forest. This is to be expected because it increases habitat heterogeneity and contrast within the landscape. This is illustrated most clearly by the log pond, which adds migratory shorebirds to the species total. As indicated earlier, the invasive species are widespread and common species of little conservation concern, and the important question is what species drop out rather than how many are added. To properly investigate this question for birds requires more detailed studies. This is because greater mobility (and in some species, longevity) may mask subtle changes in habitat quality.

4.8 References:

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Appendix 4.1 Species excluded from analysis

Number	Species Name English	Scientific	Plot	
			BS6	BS12
626	Silver-rumped Swift	<i>Rhaphidura leucopygialis</i>	X	
633	Whiskered Tree-swift	<i>Hemiprocne comata</i>	X	
701	Wreathed Hornbill	<i>Rhyticeros undulatus</i>		X

SECTION 5: MAMMALS

SURVEY OF MAMMALS ON DIFFERENT LAND USE TYPES

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5.1 Introduction:

Not less than 620 species mammals are found in Indonesia. According to Krebs (1972), the distribution of animal species generally follows, or is commensurate with, changes in the physical environmental pattern. Medway (1972) believes that changes in animal diversity are congruent with elevation changes. Studies of bats from Kitchener *et al.*, (1990) suggest that populations vary inversely with elevation. Habitat type is the other factor which greatly influences animal diversity according to Kitchener *et al.*, (1997) from their study in Tembagapura, Irian Jaya, [see also Kitchener and Maryanto (1997) from the result study in P.Gag Irian Jaya].

To understand the degree to which mammal species vary across similar habitat types, we need to observe their diversity and distribution from primary forest to industrial forest plantation and jungle rubber as well as in areas that have been converted from forest to open areas such as *alang-alang* (*Imperata*) and/ or *Cassava* garden. This is a report on mammal diversity across six different land-use types : primary forest, secondary forest, jungle rubber jungle and rubber plantation, *Paraserianthes* plantation, and open areas under *Imperata* and *Cassava* (LUTs combined). Our observations were made just a week after a drought had broken and after forest fire and dense smoke affected all land-use types in Sumatra.

5.2 Site selection and methods:

5.2.1 Sites:

The sites were established at Pasir Mayang (01° 04' 47'' S, 102° 06' 02'' E), Pancuran Gading (01° 10' 12'' S, 102° 06' 50'' E), and Kuamang Kuning (01° 35' 56'' S, 102° 21' 11'' E), Muara Bungo, Jambi. There were 11 sample plots co-located with the vegetation survey team across six land use types as follows :

- Primary Forest : (BS1, BS2)
- Logged-over Forest : (BS3, BS4, and BS5)
- Industrial Forest Plantation (*Paraserianthes*) : (BS6 and BS7)
- Rubber Plantation : (BS8)
- Rubber Jungle ; (BS10)
- *Imperata* and *Cassava* (Open areas) : (BS12 and BS14)

5.2.2 Data collection:

We surveyed the diversity and ecological status of mammals during the period 19-29 November 1997. (Annex III Tables 5,6,7) We used two observer groups: the first group

observed bats and rats, and the second group observed other mammals, excluding bats and rats. The second group observed direct and indirect occurrences of mammals at the sample plot location.

5.2.2.1 Bats and Rats:

Collecting data for bat and rat diversity was implemented using mist nets and rat traps on six different land use types. We used a specific rat trap design known as “Trap Kasmin” (28x12x12cm) made from wire. In the field we used baits of coconut and peanut butter to attract the animals. We placed traps five metres apart along a transect on each land use type with 15-20 traps every night. From experience of Kitchener *et al.*, (1997) and from our own experience on small mammal research in Nusa Tenggara and Maluku during 1989-1995, traps should be left for three days, except in an open area such as *alang-alang* and *Cassava* (two days only). The total number of traps used for all land use type was 459 (Table 5.1). We trapped bats using a mist net placed to intercept bat flight paths. For each site, we used 2 9x12m mist nets, and left these for three days. We checked the traps every day and night at 08:00 and 20:00hrs (Table 5.1).

The maturity status of bats and rats is based on the basioccipital and basisphenoid bone component (Kitchener and Maryanto 1993; Maryanto and Boeadi 1994). We determined the reproduction status for each bat and rat by direct examination of the position of the testes (abdominal, inguinal, or scrotal), virgin uterus form (nulliparous), the total number of foetuses, and the amount of scars that indicated whether or not an animal had been pregnant.

5.2.2.2 Small and large mammals (excluding bats and rats):

Observations of small and big mammals other than bats and rats were made twice daily; the first between 06.30-08.00 and second between 16:30-18:00. To complete the data, we included an additional observation at night between 20.00-22.00hrs. The types of data recorded were: a) animal species, b) total number of individuals, c) the contact distance between animals and the plot centre, d) contact direction, e) time of contact and f) direct and indirect track from foot, sound, and other tracks.

Table 5.1
The total number of traps and mist nets area for each land use type.

Habitat	Trap	Mist net (m ²)
Primary forest (BS1&2)	60	163,8
Log over (BS 3)	60	117
Log over 1983 (BS3,4 &5)	60	163,8
Paraseriantes (BS6)	60	156
Paraseriantes (BS7)	60	163,8
Rubber plantation (BS8&9)	60	132,6
Alang-alang (BS12&13)	30	31,2
<i>Cassava</i> plantation (BS14&15)	30	23,4
Rubber jungle (BS10&11)	39	109,2
Total	459	1060,8

5.3 Data Analysis:

For all taxa, we made comparisons between diversity from different land-use types and Simpson Index diversity (Simpson, 1949), Shannon-Wiener Index (Ludwig and Reynolds 1988) and cluster analysis using SPSS/PC software.

5.4 Discussion and Results:

5.4.1 Bats:

Mist nets were unsatisfactory. From the total mist net traps with size 9 and 12 meter that were used for three nights on each land use type, there were only a few species captured, which included frugivores such as *Rousettus amplexicaudatus* at the *Paraserianthes* site, *Cynopterus brachyotis* at rubber plantation and *Balionycteris maculata* at logged-over forest. Other species were *Pipistrellus javanicus* at a *Paraserianthes* plantation, *Rhinolophus lepidus* in logged-over forest (an insectivore). The total number of individual of bats per square meter during the survey was 0.0122 with 0.005 and for the total species. (Table 5.2). All female bats were pregnant. Also we found *Pteropus vampyrus* (kalong) that was observed on the flight line in logged-over forest. These animals can fly between islands 60 km apart (Marti Fujita, personal communication).

Compared with our survey of bats in 1991 (before the El Niño smoke disaster in our study area), Maryanto (unpublished data) recorded 0.08 species m⁻² and 0.39 individuals m⁻² in logged-over forest. This figure was greatly reduced with the change to *Paraserianthes* plantation. In 1991 using the mist net with total area 140.4 m², we recorded *Balionycteris maculata*, *Megaerops wetmoreyi*, *Cynopterus brachyotis*, *Macroglossus sobrinus*, *Rousettus amplexicaudatus*, *Nycteris javanica*, *Tylonycteris pachypus*, *Tylonycteris robustula*, *Hipposideros cervinus*, *Megaderma spasma* and *Rhinolophus* sp. (cf. *lepidus*) (Table 5.3). Another comparison with data from logged-over forest at selection cutting in Serestra II, Bangko, Jambi Province, in January 1996 showed that the total number of individual and species for bats per square meter was 0.029 and 0.009 (Maryanto *et al.*, 1996) (Table 5.3). The differences between diversity and abundance may be because of the excessive smoke in the current survey area. The site location in this survey was particularly bad due to smoke that only disappeared one week prior to the survey. We were surprised not to find common species such as *Cynopterus brachyotis* or *Macroglossus sobrinus*. These species are usually very common in all areas of Sumatra with elevation less than 1000m (Kitchener *et al.*, 1990, Corbet and Hill 1992). We conclude that the widespread smoke may have had a negative impact on the bat populations.

Using mist nets should be much more efficient to catch frugivorous bats (Megachiroptera), but on this survey we were unsuccessful. On the other hand for a mist net that usually is not effective to catch Microchiroptera (insect eater), we recorded a higher than usual percentage of 27.27% (3 individuals from a total of 11 bats). The impact of smoke in these area is the main reason why the total population of frugivorous was less, but this did seem to affect insectivores. The high percentage of these bats is related to their feeding behaviour, as they can catch something small without using their eyes. Another possibility is the nature of their habitat. Insectivores usually stay in an enclosed close place such as roof or cave, but this is the opposite for the frugivores, who inhabit open spaces (Kitchener *et al.*, 1990, Corbet and Hill, 1992).

From the total number of bats recored, *Megaerops wetmoreyi* was the only rare species (Micklenburh *et al.*, 1992). This is a common species in Riau and also in Pasir Mayang, particularly in primary forest and logged-over forest, but recently this forest has been converted to industrial forest plantation (*Paraserianthes* /BS7) (Maryanto, unpublished data). We suggest another study should be implemented to examine the impact of both smoke and habitat conversion from logged-over to industrial forest plantation.

The species *Balionycteris maculata* that we trapped in the field indicates that this species is distributed across all primary and secondary forests at elevations below 600m. This might be a new species because it is differs from the one recorded in Kalimantan (Maryanto, unpublished data). To confirm this, we need to compare it with the specimen original recorded in Malaya and now available in the Raffles Museum, Singapore.

Table 5.2

Trapping bats using a mist net for each land use type, individual, individual/trial 100m²*

Land Use Type and plot	Effort	Species	Individual	Ind/effort	Diversity
Primary BS1 &BS2	163,8	-	-	-	-
Logged-over forest (BS 3,4,5)	280,8	2	2	0,7	0,3
<i>Paraserianthes</i> (BS6&7)	319,8	2	4	1,3	0,3
Jungle Rubber	241,8	1	5	2,1	0
Alang-alang	31,2	-	-	-	-
<i>Cassava</i> plantation	23,4	-	-	-	-
Diversity					0,6

* Values are Simpson's diversity index.

Table 5.3

Comparative effort in trapping bats at logged-over forest in Serestra, Bangko, Jambi, January 1996 (Maryanto *et al.* 1996), logged-over forest / primary October 1991 (before conversion to *Paraserianthes* / location BS7/ Maryanto, I. Data unpublished) and at Pasir Mayang research site, Kuamang Kuning, Pancuran Gading November 1997).

Species Name	Bangko (1996)	Logged-over (1991) (Now <i>Paraserianthes</i> /BS7)	Pasir Mayang, Kuamang kuning, Pancuran Gading,1997
<i>Balionycteris maculata</i> ,	x	x	x (BS4,5)
<i>Cynopterus brachyotis</i>	x	x	x (BS8,9,10,11)
<i>Chironax melanocephalus</i> ,	x		
<i>Dyacopterus spadiceus</i>	x		
<i>Megaerops wetmorei</i> ,		x	
<i>Megaerops ecaudatus</i>	x		
<i>Penthetor lucasi</i>	x		
<i>Macroglossus sobrinus</i>	x	x	
<i>Eonycteris spelaea</i>	x		
<i>Rousettus amplexicaudatus</i>		x	x (BS6)
<i>Hipposideros cervinus</i> ,		x	
<i>Nycteris javanica</i> ,		x	
<i>Megaderma spasma</i>		x	
<i>Myotis muricola</i>			x (BS 7)
<i>Rhinolophus lepidus</i>		x	x (BS4,5)
<i>Tadarida mops</i>	x		
<i>Tylonycteris pachypus</i> ,		x	
<i>Tylonycteris robustula</i> ,		x	

5.4.2 Rats:

This kind of animal can be found on different land use types and shows differences in degraded habitats. *Maxomys rajah* usually dominates primary forest and logged-over forest, while *Maxomys whiteheadi* is normally very common in open areas. But in our survey we found this species in the logged-over forest, *Paraserianthes*, and rubber plantation. It is very closely related to *Rattus exulans* that we found also in *Paraserianthes* and rubber plantations. Although rats occurred across all LUTs, abundance was greatest at the *Imperata* site (see Table 5.4).

The reproduction status and ecology for each rat species in different land uses can be explained by the following :

5.4.2.1 Microbiogeography of rats:

The dissimilarity distance between locations based on rat habitat show that there are two groups; primary and logged-over forest in the first group, and jungle rubber, *Paraserianthes* and *Imperata* in the second group. Results based on dissimilarity distances between rats show that *Rattus tanezumi* and *Rattus tiomanicus* tend to share a similar habitat. This is different to

Maxomys rajah, that tends to live separately from other rats. The choice of habitat and associated breeding condition for each species can be explained by the following :

***Rattus tanezumi* (Indonesian black rats)**

During the survey only one individual was found in the *Paraserianthes* plantation. This species is similar to *Rattus rattus*, but there are significant genetic differences between these species (Musser & Carleton, 1993). The reason it is found in *Paraserianthes* plantation is because there is a lot of human activity in that area. We predicted there would be a close relationship between rats at the *Paraserianthes* plantation and the level of human activity within the plantation forest.

***Rattus exulans* (Pacific rats)**

Ecology:

This species has a wider range of distribution in South East Asia, Indonesia, New Zealand and Polynesia and has a specific habitat in Papua New Guinea and Solomon Islands. It is commensal with human activity and can survive up to 3000m above sea level. In paddy fields and gardens this species could become a pest (Maryanto, data unpublished). In this rapid survey the species was found in the *Paraserianthes* plantation, rubber plantation, *Imperata*, and jungle rubber. We did not find it in the *Cassava* plantation, and we suggest that this species might have moved to *Imperata*-dominated areas.

Reproduction:

We caught nine female rats in six different land use types during the survey and they were all pregnant . One female rat found at the *Paraserianthes* site was pregnant with two scars at both sides and uterine horn 1,48mm wide; another female rat found at the *Imperata* site was also pregnant with 5 foetuses in the left side and 1 at the other. Dwyer (1975) mentions that this species will breed during the wet season and produce a large litter.

***Rattus tiomanicus* (Malayan field rats)**

Ecology:

This species was found at both the *Paraserianthes* plantation and *Imperata* and it prefers a bushy place (Payne *et al.*, 1985). From nine rats found during the survey, 8 occurred in *Imperata* , and one at a site similar to *Paraserianthes*. Corbet and Hill (1992) argue that this species is mutually incompatible with *Rattus tanezumi*.

Reproduction:

Six out of nine rats were male and ready for breeding. From 3 female rats, 2 were pregnant with one soon to be pregnant. About 5-7 babies will be born from each rat.

***Maxomys rajah* (Brown spiny rats)**

Taxonomy:

Two sub-species of these rats are widespread in Sumatra (Van Strien 1986) : *M.r. pellax* and *M.r. similis*. At our site location we are not certain whether it is *M.r. similis*, so we need to repeat our effort by making a comparative sample from Aceh (Chasen 1940).

Ecology:

This species tends to live in secondary forest or primary forest with sandy soil (Payne 1985). In this survey, even though the soil type between *Paraserianthes* and rubber plantation was similar (ultisol) and the sites closer to each other, in this survey we did not find *Maxomys rajah* in both sites. It was predicted that besides soil type, the litter depth at primary and logged-over forest would exert a major influence over the presence of this species.

Reproduction:

Seven mature rats were found in the field from the total specimens. There were 4 male *Maxomys rajah* from both primary and secondary forest ready for breeding (Scrotal). One female rat had been pregnant twice with the six scars on the right and five on the left (on the logged-over area), and another 2 female rats were found in the primary forest, one pregnant and the other still young but ready for breeding.

Maxomys whiteheadi (Whitehead's rat)

Ecology:

This species can be found near the forest. Payne *et al.*, (1985) mentions that this species can attack paddy rice, especially where paddy fields are surrounded by forest. It is associated with *Rattus argentiventer*, *Rattus exulans*, *Rattus tiomanicus*, *Rattus tanezumi* (Maryanto, data unpublished). In this survey, we found this species in *Paraserianthes*, logged-over forest, rubber plantation, and *Imperata*.

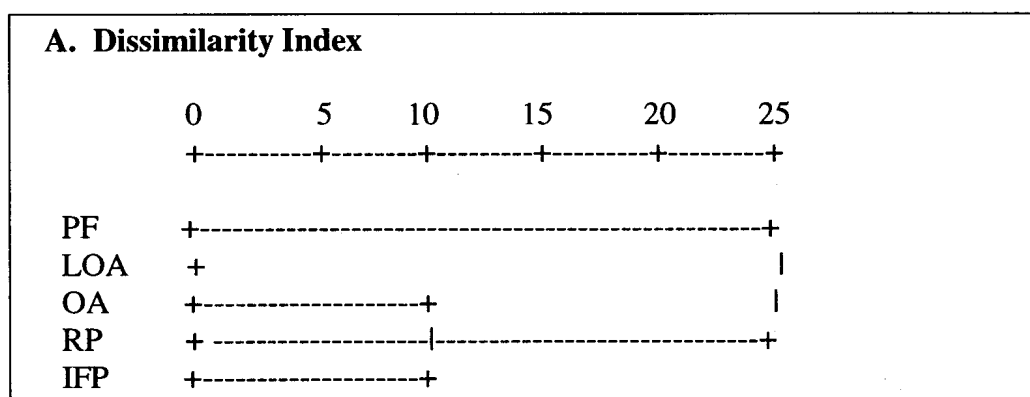
Reproduction:

We found 3 male rats in the field with imperfect testes (inguinal), only one showing perfect testes (scrotal). Another had just given birth and another 2 were pregnant.

Table 5.4
Records of rats for each land use type and each plot based on sexual status and reproduction.

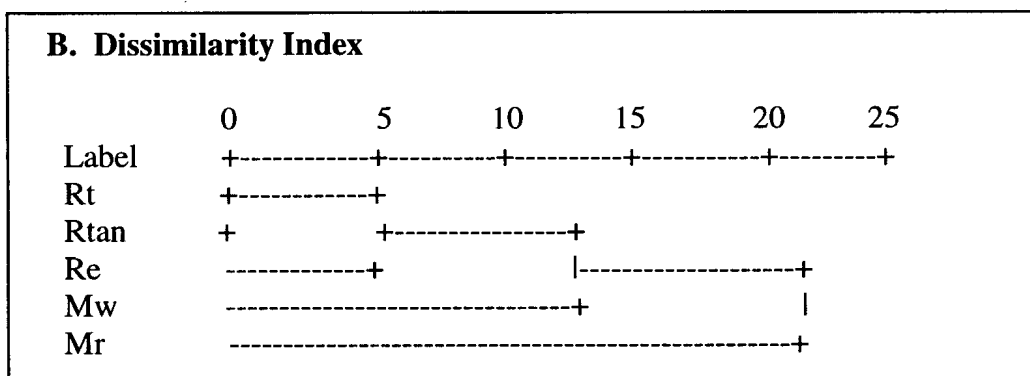
Habitat	Trap trial	Male mature	Male young	Female mature	Female young	Trapped	Trapping/ trial
Primary forest (BS1&2)	2	2		2		4	2
Logged-over (BS 3)	2	1		1		2	1
Logged-over 1983 (BS4 &5)	2	2	1	1		4	2
<i>Parasarianthes</i> (BS6)	2	4		2		6	3
<i>Parasarianthes</i> (BS7)	2	1		1		2	1
Rubber plantation (BS8&9)	2	2	-	1	-	3	1,5
<i>Imperata</i> (BS12&13)	1	6	3	2	2	13	13
<i>Cassava</i> (BS14&15)	1	-	-	-	-	-	-
Jungle Rubber (BS10&11)	1,3	-		1		1	0,76
Total		16	4	13	2	35	

Figure 5.1. Relationship between habitat type based on rats species



Note: PF = Primary forest, LOA = Logged-over area, OA = Open area *Imperata*, *Cassava*, RP = Rubber plantation, IFP = Industrial forest plantation

Figure 5.2. Relationship of rat species based on an ideal habitat



Note. Rt = *Rattus tiomanicus*, Rtan = *Rattus tanezumi*, Re = *Rattus exulans*, Mw = *Maxomys whiteheadii*, Mr = *Maxomys rajah*

5.4.3 Other Mammals (excluding rats and bats):

5.4.3.1 Species Richness:

From all land-use types sampled in this survey, the greatest richness of mammals, excluding rats and bat occurred in logged-over forest and jungle rubber. The total percentage of mammals in this area is 45%. If we compare to primary forest as baseline indicator (Alikodra 1990), the species richness in logged-over forest or rubber jungle is greater by 28.57%. This indicates that several mammals, excluding rats and bats, prefer an area with medium crown cover. Larger mammals such as pig (*Sus scrofa*; babi hutan) and deer (*Rusa sambar*) can be found at *Imperata* and *Cassava* plantation where the species richness has decreased to 71.43%. In the rubber plantation, the richness of big mammals is less than in industrial forest plantation or open area. This may be due to differences in food source and other habitat components (Table 5.5). Jungle rubber is a very good alternative habitat for large mammals because there is almost no treatment of plants and the vegetation is not homogeneous. This habitat will provide a wide variety of local habitats for different plant types. Hence, the component of the habitat is still complete. One mammal has been identified, *T. cristatus* (lutung budeng) with a black and white colour pattern that facilitates studying the social relationship between them. Using the Shannon Index of diversity (Ludwig and Reynold 1988), we see that the percentage of jungle rubber, 19.58% (Table 5.6), is higher than primary forest. The differences based on community

similarity index between two locations is about 23.53%. It seems that species diversity in jungle rubber is higher than primary forest. There would be changes of 60.45% if primary forest were to change to an open area such as alang-alang or *Cassava* (Figure 5.3).

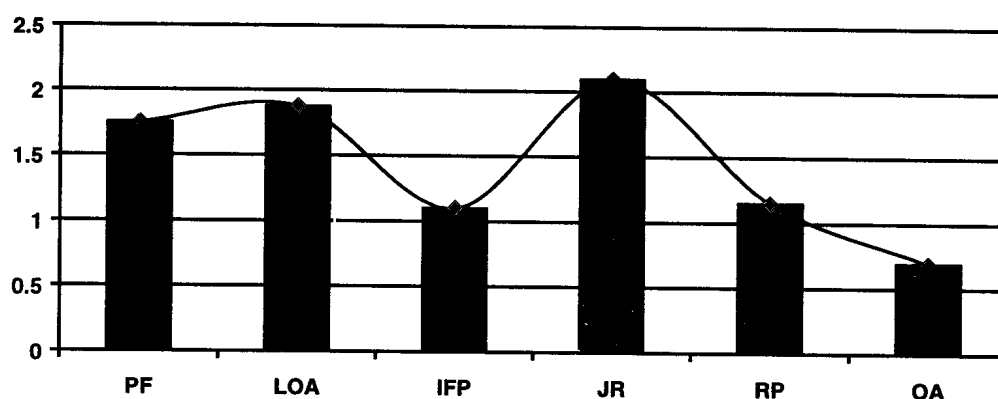


Figure 5.3 .Shannon similarity index changes base on habitat type

Community Similarity Index

The community similarity index tends to be high between primary forest and logged-over forest (about 55.56%). This index can show the effect of conversion from primary forest to logged-over forest and indicates an impact on dominant changes on mammals of about 44.44%.

Table 5.5
Mammals species excluding rats and bats in the study area

No.	English name	Species	PF	LOA	IFP	JR	RP	OA
1	Agile gibbon	<i>Hylobates lar agilis</i>	X	X				
2	Banded langur	<i>Presbytis melalophos</i>	X	X				
3	Banded palm civet	<i>Hemigalus derbyanus</i>	X					
4	Barking deer	<i>Muntiacus muntjak</i>		X				
5	Bearded pig	<i>Sus barbatus</i>	X	X	X	X	X	
6	Common treeshrew	<i>Tupaia glis</i>				X		
7	Domestic pig	<i>Sus scrofa</i>						X
8	Giant squirrel	<i>Ratufa affinis</i>			X			
9	Horse-tailed squirrel	<i>Sundasciurus hippurus</i>				X		
10	Large treeshrew	<i>Tupaia tana</i>				X		
11	Leopard cat	<i>Prionailurus bengalensis</i>					X	
12	Lesser mouse-deer	<i>Tragulus javanicus</i>		X				
13	Long-tailed macaques	<i>Macaca fascicularis</i>	X	X				
14	Low's squirrel	<i>Sundasciurus lowii</i>				X		
15	Plantain squirrel	<i>Callosciurus notatus</i>				X		
16	Prevost's squirrel	<i>Callosciurus prevostii</i>	X	X		X	X	
17	Sambar deer	<i>Cervus unicolor</i>				X		X
18	Silvered leaf monkey	<i>Trachypithecus cristatus</i>		X		X	X	
19	Sun bear	<i>Helarctos malayanus</i>	X		X			
20	Whiskered flying squirrel	<i>Petinomys genigarbis</i>		X				
Total Individual (n)			32	63	3	12	9	4
Total species (S)			7	9	3	9	4	2
Percentage of species distribution (%)			35.00	45.00	15.00	45.00	20.00	10.00
Conversion of primary forest (%)			-	28.57	-57.14	28.57	-42.86	-71.43

Microbiogeography:

A dissimilarity measure based on mammals species in six land-use types, suggests there are 3 groups of habitat from the identified 20 mammals that can be used as future indicators for mammals. The first group is *Paraserianthes*, along-alang, *Cassava* plantation, and rubber plantation. The second group is jungle rubber, and the last group is primary forest and logged-over forest (Figure 5.4). Classification of habitat type is almost similar with microbiogeographical classification on habitat type of rats (see Figure 5.1 and 5.2).

Table 5.6
Species Diversity index on different land use types

No.	Species	PF		LOA		IFP		JR		RP		OA	
		n	H'	n	H'	n	H'	n	H'	n	H'	n	H'
1	<i>Hylobates lar agilis</i>	7	0.333	15	0.342								
2	<i>Presbytis melalophos</i>	5	0.290	10	0.292								
3	<i>Hemigalus derbyanus</i>	1	0.108										
4	<i>Muntiacus muntjak</i>			1	0.066								
5	<i>Sus barbatus</i>	2	0.173	2	0.110	1	0.366	1	0.207	1	0.244		
6	<i>Tupaia glis</i>							1	0.207				
7	<i>Sus scrofa</i>											2	0.347
8	<i>Ratufa affinis</i>					1	0.366						
9	<i>Sundasciurus hippurus</i>							1	0.207				
10	<i>Tupaia tana</i>							1	0.207				
11	<i>Prionailurus bengalensis</i>									1	0.244		
12	<i>Tragulus javanicus</i>			1	0.066								
13	<i>Macaca fascicularis</i>	12	0.368	17	0.354								
14	<i>Sundasciurus lowii</i>							1	0.207				
15	<i>Callosciurus notatus</i>							1	0.207				
16	<i>Callosciurus prevostii</i>	3	0.222	3	0.145			3	0.347	2	0.334		
17	<i>Cervus unicolor</i>							1	0.207			2	0.347
18	<i>Trachypithecus cristatus</i>			13	0.326			2	0.299	5	0.326		
19	<i>Helarctos malayanus</i>	2	0.173			1	0.366						
20	<i>Petinomys genigarbis</i>			1	0.066								
Total individual (n)		32		63		3		12		9		4	
Total species (S)		7		9		3		9		4		2	
Shannon Index (H')			1.667		1.765		1.099		2.095		1.149		0.694

The habitat type indicates the importance of the density of tree and crown cover, but the most important influence is availability of food. The first location, which includes along-alang, *Cassava* plantation, *Paraserianthes*, and rubber plantation, tends to have more open habitat types. There are 4 group of animals which occupy 3 habitat types within and between which they interact. The 4 groups are as follows :

- Group 1 : *Tragulus javanicus*, *Petinomys genigarbis*, *Muntiacus muntjak*, *Presbytis melalophos*,
Macaca fascicularis, *Hylobates lar agilis*.
Group 2 : *Ratufa affinis*, *Helarctos malayanus*, *Hemigalus derbyanus*,

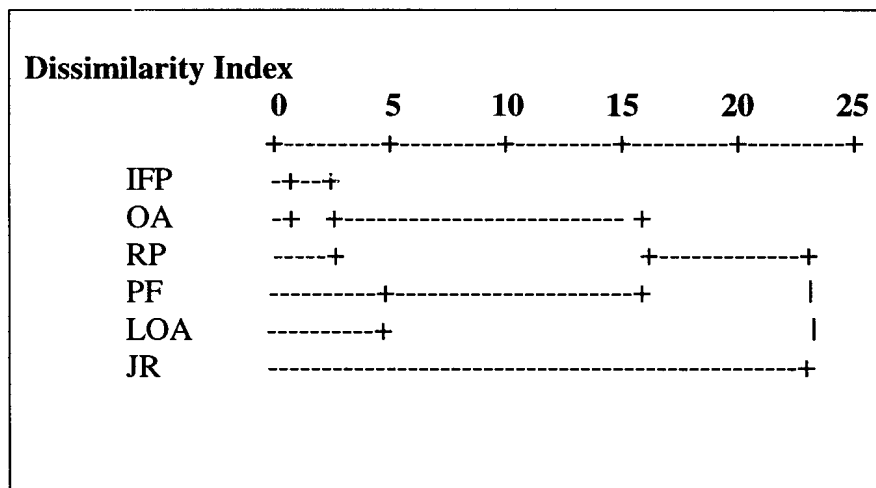
Group 3 : *Sundasciurus lowii*, *Callociurus notatus*, *Tupai glis*, *Sundasciurus hippurus*, *Tupaia tana*,
Cervus unicolor, *Sus scrova*, *Prionailurus bengalensis*,
Group 4 : *Callociurus prevostii*, *Trachypithecus cristatus*, *Sus barbatus* (Figure 5.5).

5.5 Function of food:

For the 4 groups of mammals above, each group can not necessarily live together on the same spatial distribution of food. Even if we find several mammal who live together at the same habitat, they do not necessarily compete for food because they have different spatial ranges. Mammals species identified in this survey were mostly from the group that eat fruits (38.10%), followed by seed-eaters (14.29%) and then grass or root tuber eaters (9.52%). The source of food consumption is outlined in Table 5.7. The food source can also be used to predict the *Hylobates lar* as an indicator of forest condition. There are 5 groups of animals, based on spatial distribution, that are dispersed across different elevations 0-1, 1-3, 3-15, 15-30, >30 meter (Table 5.8).

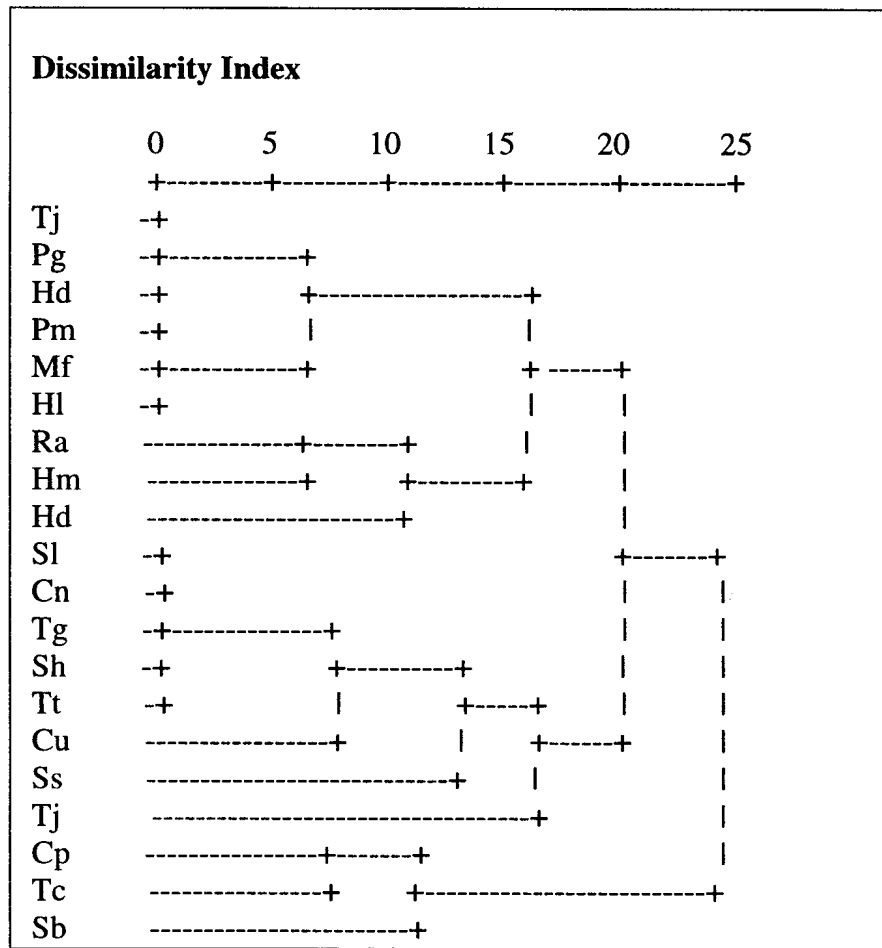
Figure 5.4

Relationship between type of habitat base on mammals species excluding rats and bats.



Note: IFP= *Paraserianthes* plantation, OA= Open Area / *Imperata*, *Cassava*,
RP= Rubber Plantation, PF= Primary Forest, LOA= Logged-Over Forest,
JR= Jungle Rubber

Figure 5.5
Relationship between species mammals based on an ideal habitat.



Note: Tj= *Tragulus javanicus*, Pg= *Petinomys genigarbis*, Mm= *Muntiacus muntjak*, Pm= *Presbytis melalophos*, Mf= *Macaca fascicularis*, Hl= *Hylobates lar agilis*, Ra= *Ratufa affinis*, Hm= *Helarctos malayanus*, Hd= *Hemigalus derbyanus*, Sl= *Sundasciurus lowii*, Cn= *Callociurus notatus*, Tg= *Tupaia glis*, Sh= *Sundasciurus hippurus*, Tt= *Tupaia tana*, Cu= *Cervus unicolor*, Ss= *Sus scrova*, Pb= *Prionailurus bengalensis*, Cp= *Callociurus prevostii*, Tc= *Trachypithecus cristatus*, Sb= *Sus barbatus*.

Table 5.7

Potential sources of food for mammals

No	Species	Food source														
		Insect	Arthropoda	Warm	Bee nest	Termites	Leave	Young leave	Fruit	Seed	Grass	Ground tree	Shrub	Mushroom	Small animals	Vegetables
1	<i>H. lar</i>	x					xx		xxx							
2	<i>P. melalophos</i>						xx		xx	xxx						
3	<i>H. derbyanus</i>	xx		xxx											x	
4	<i>M. muntjak</i>							xx	x	x	x	xxx				
5	<i>S. barbatus</i>			xx					xxx	xx		xx			x	
6	<i>T. glis</i>	xxx	xx						x							
7	<i>Sus scrofa</i>										xxx				xx	xx
8	<i>R. affinis</i>						x			xxx						
9	<i>S. hippurus</i>	x							xx	xxx						
10	<i>T. tana</i>		xxx	xx					x							
11	<i>P. bengalensis</i>	xx													xxx	
12	<i>T. javanicus</i>							xx	xxx					x		
13	<i>M. fascicularis</i>	x					xx	xx	xxx					x		
14	<i>S. lowii</i>	xx							xxx					x		
15	<i>C. notatus</i>	xx							xxx							
16	<i>C. prevostii</i>	xx				x			xxx							
17	<i>C. unicolor</i>						x		x		xxx	xx	xx			
18	<i>T. cristatus</i>						xxx	xx	x							
19	<i>H. malayanus</i>				xxx	xx			x						xx	
20	<i>P. genigarbis</i>	x														

Table 5.8**Spatial distribution of species according to food source**

Elevation meter	No.	English Name	Species
0 - 1	1	Banded langur (BW)	<i>Presbytis melalophos</i>
	2	Banded palm civet	<i>Hemigalus derbyanus</i>
	3	Barking deer	<i>Muntiacus muntjak</i>
	4	Bearded pig	<i>Sus barbatus</i>
	5	Domestic pig	<i>Sus scrofa</i>
	6	Lesser mouse-deer	<i>Tragulus javanicus</i>
	7	Large treeshrew	<i>Tupaia tana</i>
	8	Low's squirrel	<i>Sundasciurus lowii</i>
	9	Leopard cat	<i>Prionailurus bengalensis</i>
	10	Sambar deer	<i>Cervus unicolor</i>
	11	Sun bear	<i>Helarctos malayanus</i>
1 - 3	1	Common treeshrew	<i>Tupaia glis</i>
	2	Horse-tailed squirrel	<i>Sundasciurus hippurus</i>
	3	Long-tailed macaques	<i>Macaca fascicularis</i>
3 - 15	1	Plantain squirrel	<i>Callosciurus notatus</i>
	2	Prevost's squirrel	<i>Callosciurus prevostii</i>
	3	Silvered leaf monkey	<i>Trachypithecus cristatus</i>
	4	Whiskered flying squirrel	<i>Petinomys genigarbis</i>
15 - 30	1	Banded langur	<i>Presbytis melalophos</i>
	2	Giant squirrel	<i>Ratufa affinis</i>
>30	1	Agile gibbon	<i>Hylobates lar</i>

5.6 Recommendations:

- Conversion to monoculture areas such as alang-alang, *Cassava*, industrial forest plantation (*Paraserianthes*), and rubber plantation will cause a decrease in species richness. Hence, it is important to maintain an area that includes natural mixed forest.
- *T. cristatus* found in the field has a different colour pattern; we need further study of its ecological status.
- Bats are potentially useful pollinators and agents for pest control. The smoke hazard may have caused several animals to either die or to migrate to alternative habitats. We need further research about this.
- We found one bat taxon that may represent a new species. To confirm this will require comparison with collected specimens from Malaya in the Raffles Museum, Univ. of Singapore.

UCAPAN TERIMA KASIH

Penulis mengucapkan terima kasih pada CIFOR sebagai penyandang dana pada penelitian ini dibawah pimpinan proyek Dr. Andi Gillison, dan Ir. Nining Liswanti sebagai koordinator selama di lapangan. Tidak lupa pula kami ucapkan terima kasih pada Bapak Sidam sebagai pengemudi, Burhanudin dan Aswandi sebagai pembantu lapangan selama penelitian berlangsung.

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SECTION 6: CANOPY INSECTS

CANOPY ARTHROPODS AND BUTTERFLY SURVEY: PRELIMINARY REPORT

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6.1 Introduction:

Arthropod diversity in tropical forests represents a concentration of biodiversity locally, regionally and globally. Arthropods carry out many significant ecosystem processes, notably decomposition, herbivory and pollination, and they also represent a food source for many vertebrate species. A few Lepidoptera are even a direct source of income in parts of Indonesia and elsewhere. Forest clearance, whether partial or complete, represents a major threat to arthropod diversity. The size of this threat is, however, unknown, as are the consequences for ecosystem 'health'. Theoretical predictions of species extinctions as a result of forest clearance are no substitute for direct measurement of biodiversity. Among the many problems with theoretical predictions based on supposed species-area relationships is the assumption that areas, once cleared of forest, are no longer suitable for any species. This is clearly untrue - secondary forest, plantations of rubber and other tree species and other types of land use all have the potential to contain many arthropods and other species. We are clearly correct in assuming that some forms of land use have lower levels of biodiversity than intact forest, but few studies have actually measured the effect of land-use change on biodiversity. The main problem with actually measuring biodiversity (and the attraction of theoretical approaches) is that biodiversity is impossible to measure in its entirety. Rapid biodiversity assessment methods have therefore been developed to allow comparisons of biodiversity in different places, or the same place at different times, by sampling a subset of biodiversity in a statistically rigorous way in as short a time as possible. The lowland forests of Sumatra have been logged and cleared to such an extent that very little intact forest remains. Clearance has resulted in a range of land uses including secondary forest, rubber plantations and *Imperata* grassland. The effect on biodiversity of such dramatic changes in land use is not known, and there is an urgent need to develop a rational strategy for the conservation of biodiversity. This strategy might entail the protection of remaining fragments of intact forest or the promotion of alternative land uses which are both productive and rich in biodiversity. Such a strategy requires a much better understanding of the variation in biodiversity in the mosaic of land uses in lowland Sumatra.

As part of an overall programme to carry out a rapid biodiversity assessment in the Jambi Province of Sumatra, assessment of arthropod diversity was measured in several ways. This report describes canopy arthropod and butterfly surveys. Separate reports describe termite diversity assessment (Jones *et al.* 1988), light trapping and general insect survey. The aim of this part of the project was to assess the impact of logging and other land use changes on the diversity of arthropods in central Sumatra. Canopy arthropods were surveyed because previous studies indicate that arthropod diversity reaches a maximum in the canopies of tropical forest trees. However, few studies have compared the diversity of arthropods in the canopies of intact forest and plantation trees. Butterfly surveys were carried to provide a comparison of insect diversity in all sites -- several land-use types surveyed had no tree canopy.

The following land use types were surveyed:

- Intact forest
- Logged forest
- Secondary forest
- Jungle rubber
- Rubber plantation
- *Paraserianthes* plantation
- Cassava fields
- *Chromolaena* fallow
- *Imperata* grassland

Full site descriptions are given by Gillison *et al.* (this report).

6.2 Aims and objectives:

The aim of this project was to assess the impact of logging and other land use changes on the diversity of arthropods in central Sumatra and so provide baseline data for biodiversity assessment based on arthropod diversity.

The objectives of this project were:

- To assess the abundance and diversity of the *canopy arthropod* community of selected land-use types.
- To assess the abundance and diversity of the *butterfly* community of selected land-use types.

6.3 Personnel:

Allan D Watt - Institute of Terrestrial Ecology, Scotland, UK

Paul Zborowski - Kuranda, Australia

C Noor Rohmah - CIFOR, Indonesia

6.4 Methods:

6.4.1 Review of existing methods:

6.4.1.1 Introduction:

A wide range of methods is used to assess the diversity of insects in tropical forests and other habitats. These include canopy fogging and butterfly transects; the two methods used here and discussed below. Other methods include a) general collecting, b) ground quadrat or transect sampling (as used to estimate termite and ant diversity (Jones *et al.* 1988)), c) light trapping, and d) Malaise and flight interception trapping. These methods are discussed at length elsewhere and will not be described in detail here. It is worth pointing out that some methods are more suitable for collection of specimens for taxonomic work, and other methods are more suitable for biodiversity assessment. The key requirement for the latter is comparability. Many methods do not provide data that are comparable or are only comparable after analytical methods, which are not designed for biodiversity assessment (such as rarefaction). Broadly speaking, techniques which employ standardised sampling across transects or grids are the best methods and general collecting over non-standardised time periods are the worst. Trapping techniques should also be avoided where possible (at least in rapid surveys) because unless the

traps are used under the same environmental conditions (e.g. cloud cover and moonlight for light trapping), the results will not be comparable. Additional problems exist for 'passive' traps, such as Malaise traps, whose catches are affected by the degree to which they are located in open (e.g. grassland) or closed habitats (e.g. intact forest). This is a problem which may not be overcome, and results may be obtained which reflect the movement of insects within and through plots, rather than the diversity of insects within them.

6.4.1.2 Canopy arthropods:

The sampling of canopy arthropods has only been made possible through the development of canopy fogging methods. A full review of canopy sampling is given by Stork, Adis and Didham (1995). The techniques as applied in this project are outlined below.

6.4.1.3 Butterfly sampling:

A number of different approaches can be used to sample butterflies, including trapping and netting, but perhaps the most significant development in butterfly survey has been the use of 'butterfly walks' (Pollard and Yates 1993). This method was originally developed for European species and has proved useful in quantifying temporal and spatial trends in the abundance and diversity of species in the UK and elsewhere (e.g. Pollard, Moss and Yates 1995). It has now also been adapted for use in tropical forests (e.g. Hill *et al.* 1995, Watt *et al.* 1997, Lawton *et al.* 1998, Stork *et al.* in prep.).

6.4.2 Field methods used on this survey:

6.4.2.1 Plot locations:

Two plots were chosen in each land-use type, apart from *Chromolaena* fallow and secondary forest (where single plots were surveyed). The plots in intact forest, logged forest and *Paraserianthes* plantation were distinct enough spatially to be regarded as replicates for the arthropod survey, but the rubber plantation, jungle rubber, Cassava and *Imperata* plots were situated very close to each other and should be regarded as 'pseudo-replicates'. The data from these plots have not been combined for the purposes of this report, but this problem is discussed below.

6.4.2.2 Canopy fogging:

Canopy fogging was done at all 11 plots with tree canopies, *i.e.* the forest and plantation plots. A 'King' fogger [specifications available] was used to fog the canopy with a pyrethroid-based insecticide diluted with diesel. In each plot, apart from the jungle rubber plots, 25 1m² collecting trays were suspended on ropes strung between trees. In each of the jungle rubber plots, 20 trays were used. The collecting trays were placed within, or close to, the 4x50 m transects used for the plant surveys (Gillison *et al.* 1988). Approximately two trays were placed under each tree so that about twelve trees were fogged in each plot. A collecting bottle was attached to each tray with approximately 2 cm of 70% alcohol. A pre-printed label was placed in each collecting bottle identifying the location of each sample.

One hour after fogging, the trays were washed down with 70% alcohol and the collecting bottles (and trays) were removed. The arthropod samples were then cleaned, transferred to glass tubes and sorted as described below.

6.4.2.3 Butterfly transects:

Butterfly transects were done in all plots, i.e. those with and without tree canopies. Two butterfly transects were sampled in each plot, so that each of the two available recorders could work independently without disturbance. Each transect comprised about half the 'plant' transects plus another 25m. The observers walked up and down their transect for 30 minutes and then moved to the other transect. Thus each plot was surveyed for two person-hours. The observers attempted to catch any butterfly flying close to them. Captured butterflies were placed in paper envelopes on which were written the date, time, plot number and recorder. Butterfly abundance in each plot was measured by additionally recording the number of butterflies seen and not caught. All butterflies were identified to family level in the field. Captured butterflies were removed for sorting to morpho-species.

6.4.3 Analysis:

6.4.3.1 Canopy fogging:

Canopy fogging was used to assess the abundance of arthropods in different orders and the diversity of ants, spiders and beetles. Thus, during the field survey ants, beetles and spiders were removed from each sample, the samples were fully sorted to order, and the abundance of each group recorded.

The aim of post-field survey work is to:

1. Sort the ants, beetles and spiders to morpho-species.
2. Sort all samples to order.

For this report, preliminary analyses on the data were carried out as described in the results section. After sorting to morpho-species, further analyses were being carried out, including estimation of species richness (Colwell and Coddington and Coddington 1994) and comparison of the species composition of different sites (Krebs 1989).

6.4.3.2 Butterfly transects:

It was concluded that there were insufficient individual butterflies caught, as a result of the time available for surveying butterflies, to allow comparisons of species richness and composition. Analysis of butterfly abundance, including the abundance of different families of butterflies was carried out.

6.4.4 Data storage and access:

At present copies of all data are held by the consultants and CIFOR. Long-term arrangements for data storage and access will be made during early 1998. (Annex III, Table 8,9,10)

6.5 Preliminary results:

6.5.1 Canopy arthropod abundance:

Total arthropod abundance

The mean number of arthropods varied from about 20 to 290 arthropods m⁻² (Figure 6.1). Arthropods were most abundant in one of the jungle rubber plots (BS11) and least abundant in

one of the *Paraserianthes* plots (BS6). Note that Figure 6.1 and subsequent figures show mean abundances and standard errors.

Abundance of different arthropod groups

Table 6.1 shows the average number of arthropods in each of the groups sorted to order (or family). Note that all the data discussed below are from partial sorting, apart from the ants, beetles and spiders, and must be considered to be preliminary. The most abundant groups were the ants and the termites, on average 32 and 21 m⁻², respectively. Together these two groups made up 67% of the total number of arthropods sampled. The next most abundant groups were the Coleoptera, Diptera, Hemiptera, Thysanoptera, and spiders (Araneae). Together these group, plus the ants and termites, made up 85% of the total number of arthropods. Psocoptera, Hymenoptera (other than ants), Collembola and several other groups made up the remaining 15%. Each group is considered separately below.

Ants

Not surprisingly, the pattern of abundance of ants in different plots was very similar to the pattern of abundance of total arthropods (Figure 6.2). Ants were notably abundant in the jungle rubber plots (BS11 in particular), one of the intact forest plots (BS1), and the secondary forest plot. Ants were notably few in numbers in the rubber plantation plots.

Termites

Termites were the most patchily distributed group across the different plots (Figure 6.3). They were only recorded in four plots and abundant in only two of those: one of the intact forests plots (BS2), and one of the logged forest plots (BS5).

Table 6.1
The mean and percentage abundance of different arthropod groups recorded from canopy fogging at Pasir Mayang area, Jambi, Sumatra Nov. 1997.

Order	Mean	Percentage
Ants	31.7	32.7
Termites	20.7	21.3
Coleoptera	8.3	8.6
Diptera	6.4	6.6
Hemiptera	5.5	5.7
Thysanoptera	5.2	5.4
Spiders	4.6	4.7
Psocoptera	4.4	4.5
Hymenoptera	3.5	3.6
Collembola	2.7	2.8
Lepidoptera	1.5	1.6
Acari	0.9	0.9
Orthoptera	0.8	0.8
Blatodea	0.5	0.6
Neuroptera	0.1	0.1
Total	97.0	100.0

Coleoptera

Coleoptera were most abundant in the jungle rubber plots and one of the rubber plantation plots (Figure 6.4). Elsewhere, they were more-or-less equally abundant.

Diptera

Diptera were most abundant in the rubber plantation plots, the jungle rubber plots, one of the logged forest plots (BS5) and one of the *Paraserianthes* plots (BS7) (Figure 6.5).

Hemiptera

Hemiptera were more abundant in the logged and secondary forest plots, the jungle rubber plots and one of the *Paraserianthes* plots (BS7) than elsewhere (Figure 6.6).

Thysanoptera

Thysanoptera were particularly abundant in the jungle rubber plots and one of the logged forest plots (BS4) (Figure 6.7).

Spiders

Spiders were most abundant in one of the jungle rubber plots (BS11) and more or less evenly abundant elsewhere (Figure 6.8).

Psocoptera

Psocoptera were most abundant in one of the jungle rubber plots and least abundant in one of the *Paraserianthes* plots (BS7) (Figure 6.9).

Hymenoptera

Hymenoptera other than ants were notably abundant in one of the jungle rubber plots (BS11) and notably few in number in one of the *Paraserianthes* plots (BS6) and one of the intact forest plots (BS2) (Figure 6.10).

Collembola

Collembola were most abundant in the forest plots, recorded in low numbers in the jungle rubber and rubber plantation plots and absents from the *Paraserianthes* plots (Figure 6.11).

Lepidoptera

Lepidoptera were notably abundant in only one plot, the BS8 *Paraserianthes* plots (Figure 6.12).

Acari

Acari were more abundant in the secondary forest plot and one of the logged plots (BS4) than elsewhere (Figure 6.13).

Orthoptera

Orthoptera were uncommon in all plots, particularly the rubber plantation plots, and were not recorded in the *Paraserianthes* plots (Figure 6.14).

Blattodea

Small numbers of Blattodea were recorded but they were most abundant in the secondary forest plot and one of the jungle rubber plots (BS11) and not recorded in the *Paraserianthes* plots (Figure 6.15).

Neuroptera

Very few Neuroptera were recorded in the survey, none at all in the jungle rubber and *Paraserianthes* plots (Figure 6.16).

6.5.2 Butterfly transects:

6.5.2.1 Total butterflies:

The total number of butterflies caught or seen in an hour ranged from almost 50 in one of the rubber plantation plots to less than one in the *Imperata* grassland plots (Figure 6.17). Butterflies were particularly uncommon in the *Imperata* and Cassava plots and in one of intact forest plots (BS2), and most abundant in the jungle rubber, *Chromolaena*, one of the logged forest plots (BS4) and one of the rubber plantation plots (BS9). Figure 6.18 shows the numbers of butterflies seen; that is, it excludes the relatively small numbers of butterflies caught. It is included to show the variation between different sampling periods. The number of butterflies recorded in each family is described below.

Papilionidae

The greatest numbers of papilionids were recorded in the jungle rubber plots and one of the rubber plantation plots (BS9), and none were recorded in the Cassava and *Imperata* plots (Figure 6.19).

Pieridae

Large numbers of pierids were recorded in one of the rubber plantation plots (BS9), intermediate numbers were recorded in the jungle rubber plots and one of the logged forest plots (BS4), and few or none were recorded elsewhere (Figure 6.20).

Nymphalidae

Nymphalids were more abundant in the jungle rubber plots and the *Chromolaena* plot than elsewhere (Figure 6.21).

Lycaenidae

Lycaenids were more abundant in the jungle rubber, rubber plantation and one of the logged forest sites than elsewhere and notably absent from the Cassava, *Imperata* and one of the intact forest plots (BS2) (Figure 6.22).

6.6 Discussion:

6.6.1 Preliminary results:

6.6.1.1 Canopy fogging:

It must be emphasised that the above results are preliminary, subject to amendment after the final order sorting and include no species diversity information. The following tentative observations should, however be highlighted as a basis for subsequent discussion.

- Eleven plots were surveyed, producing a total of 22,700 arthropods, an average of 97m⁻².
- The most abundant groups were ants and termites.
- The abundance and composition of arthropod taxa was affected by land use as follows:
 - total arthropod abundance and the abundance of ants, Coleoptera, spiders, Hemiptera, Thysanoptera, Hymenoptera (other than ants) and Blattodea was greatest in the jungle

rubber plots; however, these plots contained relatively low numbers of Collembola, Acari and Neuroptera;

- the abundance of arthropods in the intact forest plots was surprisingly low but these plots, like all 'forest' plots, contained relatively high numbers of Collembola;
- arthropod numbers in the logged and secondary plots were greater than or similar to those found in the intact forest plots;
- total arthropod numbers were lowest in the plantation plots; the rubber plantation plots had particularly low numbers of ants, Collembola, Orthoptera and Blattodea and the *Paraserianthes* plots contained no Collembola, Orthoptera, Blattodea and Neuroptera.

In discussing these results, their unique nature must be borne in mind: no other study of the effects of land use on arthropod diversity has included such a range of land uses. Thus we can compare the results of this study with surveys of intact and disturbed forest elsewhere, but we cannot compare the jungle rubber and plantation plots with studies elsewhere, because this is the first time this has been attempted. Nevertheless:

- The mean total number of arthropods recorded in this survey is in line with that recorded elsewhere (e.g. Watt *et al.* (1997a) in Cameroon).
- The numbers of ants and other taxa accord with other studies, but the number of termites is markedly higher than found elsewhere.
- This study is similar to a few others (e.g. Eggleton *et al.* 1996, Watt *et al.* 1997ab, Lawton *et al.* 1998) in finding that the replacement of intact forest with other land uses tends to result in a decrease in the abundance of several groups of arthropods.
- This survey suggests that some land-use alternatives to intact forest, such as jungle rubber, may be rich in arthropods.

Differences in arthropod abundance do not necessarily lead to parallel differences in arthropod diversity so it must again be emphasised that these comments are tentative.

6.6.1.2 Butterfly survey:

The butterfly survey suffered from being too rapid. Because of the priority given to canopy sampling in as many plots as possible, we were only able to spend a maximum of two person hours in each plot. This meant that the numbers of butterflies caught were too small to permit analysis, and we have relied instead on the numbers seen during the transect walks. Even these data are not as useful as they would have been if we had been able to spend about twice as long in each plot. There is also the concern that the numbers of butterflies were particularly low because of the recent drought.

It would, therefore, be wrong to conclude too much from this survey. However the following tentative conclusions may be made:

- Butterfly abundance in most families was notably high in the jungle rubber plots.
- The total number of butterflies in one of the rubber plantation plots was higher than elsewhere, mainly due to the particularly high number of pierids recorded there.
- Numbers of butterflies in one the intact forest plots was particularly low (lower than in any of the other forest or plantation plots).

- The number of butterflies, particularly nymphalids, in the *Chromolaena* plot was surprisingly high. However, the proximity of this very small plot to the jungle rubber plots should be noted - these plots also had similar numbers of nymphalids.
- Very small numbers of butterflies were recorded in the Cassava and *Imperata* plots.

6.6.2 Review of methods:

6.6.2.1 Canopy fogging:

Eleven sites were fogged and the material collected partially sorted in ten days (excluding time spent travelling and organising). Excluding sorting time (travel *etc.*), each plot took six whole days (or approximately 30 person days, comprising twelve person days of the consultant's time, six person days from technical support staff and twelve person days from labourers). A total of about ten person days were spent partially sorting arthropods during and immediately after the survey. It is critically important that fogging surveys produce comparable data. This can only be guaranteed by the selection of representative plots and complete coverage of the canopy of each plot by the insecticide fog. We consider that all the plots chosen were representative of the land-use types in the survey area. We also consider that some plot types were more affected than others by the recent exceptional dry season. In particular, the intact forest plots and the *Paraserianthes* plots had much less canopy foliage than the rubber (jungle and plantation) plots.

Most of the plot 'pairs' within each land use provided adequate replicates. However, the jungle rubber plots and the rubber plantation plots may have been too close to be considered true replicates for arthropod survey. The finding that there was marked variability in the abundance of arthropods in these plots demonstrates how spatially variable arthropod communities are in forests and plantations.

6.6.2.2 Butterfly survey:

As mentioned above, insufficient time was given to the butterfly survey because of other priorities. Two (person) hours were spent collecting and recording the numbers of butterflies present in each plot. Surprisingly, this led to relatively little variation within the numbers of butterflies seen - note the errors in Figure 6.18. A relatively small increase in the amount of time spent recording butterfly abundance would have yielded much more useful data. Considerably more time would have been needed to collect useful data on species composition. The recent drought is likely to have reduced the number of butterflies in the area and this factor, plus the small amount of time spent surveying butterflies, means that we have probably considerably underestimated the abundance and diversity of butterflies in the study area.

The comments above regarding replication apply to the butterfly survey as well. For example, many individual butterflies were seen flying from one plot to another in the rubber plantation. Plot size is likely to have affected the results in at least one case: the surprisingly numbers of butterflies recorded in the relatively small *Chromolaena* plot may have been dispersing from the nearby jungle rubber plots.

6.6.3 Relevance of study at regional and global levels:

As mentioned above, no previous study has investigated the effects of such a range of land uses on arthropod diversity. It is therefore unique regionally and one of a very few similar studies globally (Eggleton *et al.*, 1996; Watt *et al.*, 1997; Lawton *et al.*, 1998).

6.6.4 Relevance to Rapid Biodiversity Assessment:

This survey is relevant to Rapid Biodiversity Assessment (RBA) first, because arthropods comprise the largest component of terrestrial biodiversity. Second, the techniques employed fulfilled the criterion of 'rapid' because of the short time spent collecting samples in the field. Third, both methods were designed to produce comparable results.

6.6.5 Need for further surveys in this and other regions:

Generally, many more surveys such as this are needed to assess the impact of land use change on biodiversity. These surveys should include as many land-use types as possible. For example, a similar survey in many other parts of Sumatra should include oil palm (not yet widely planted in the part of Jambi where this survey was conducted). Specifically, surveys such as this should be repeated where there is significant seasonal variation in the abundance of the taxa being considered or where particular conditions prevail. It is likely, for example, that this survey was affected by the severe drought which preceded it.

6.7 Conclusions:

Tentative conclusions are presented above at the start of the Discussion section. The main conclusions are summarised below:

- This study is similar to a few others in finding that the replacement of intact forest with other land uses tends to result in a decrease in the abundance of several groups of canopy arthropods.
- However, this survey suggests that some land use alternatives to intact forest, such as jungle rubber, may be rich in canopy arthropods.
- The butterfly survey was of limited value apart from demonstrating that arthropod abundance and diversity in Cassava and *Imperata* was considerably poorer than in all other land use types.

6.8 Recommendations:

It is recommended that:

- Further studies such as this are carried out to assess the impact of land use change on biodiversity.
- Such studies should use RBA techniques because it is more important to survey many land-use types adequately than a few sites in unnecessary detail.
- More research is therefore needed to establish suitable RBA techniques, particularly standard techniques for particular taxa.
- RBA projects should follow the multi-taxa approach adopted here (Gillison *et al.* 1998), so that as much biodiversity as possible is sampled without any assumptions being made about 'indicator' taxa, and so that relationships between the diversity of different taxa can be better understood and, perhaps, lead to the development of reliable biodiversity indicators.

6.9 References¹

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¹References to other reports in this series to be inserted.

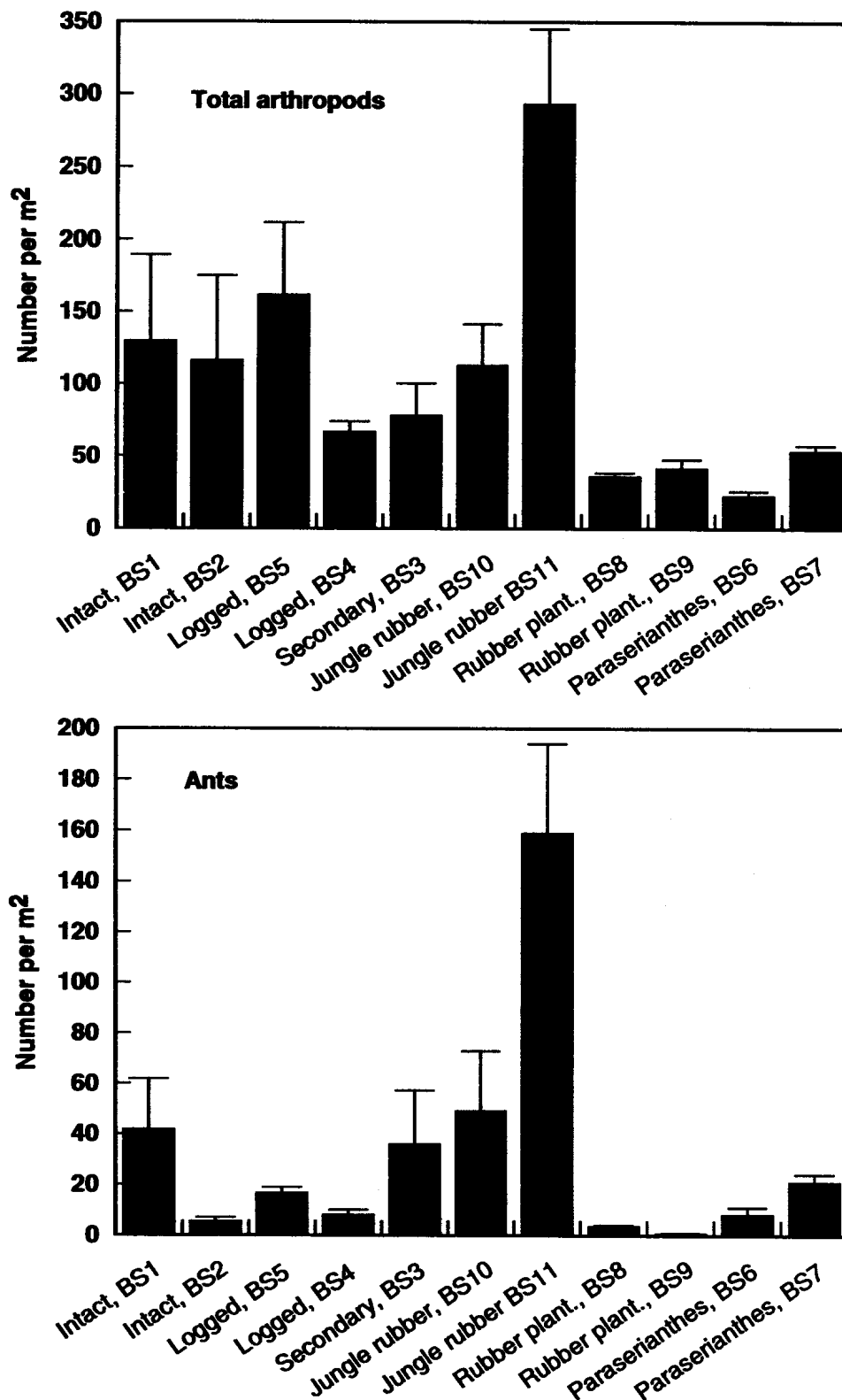


Figure 1 (above) and 2 (below): mean abundance of total arthropods and ants, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.1. & 6.2

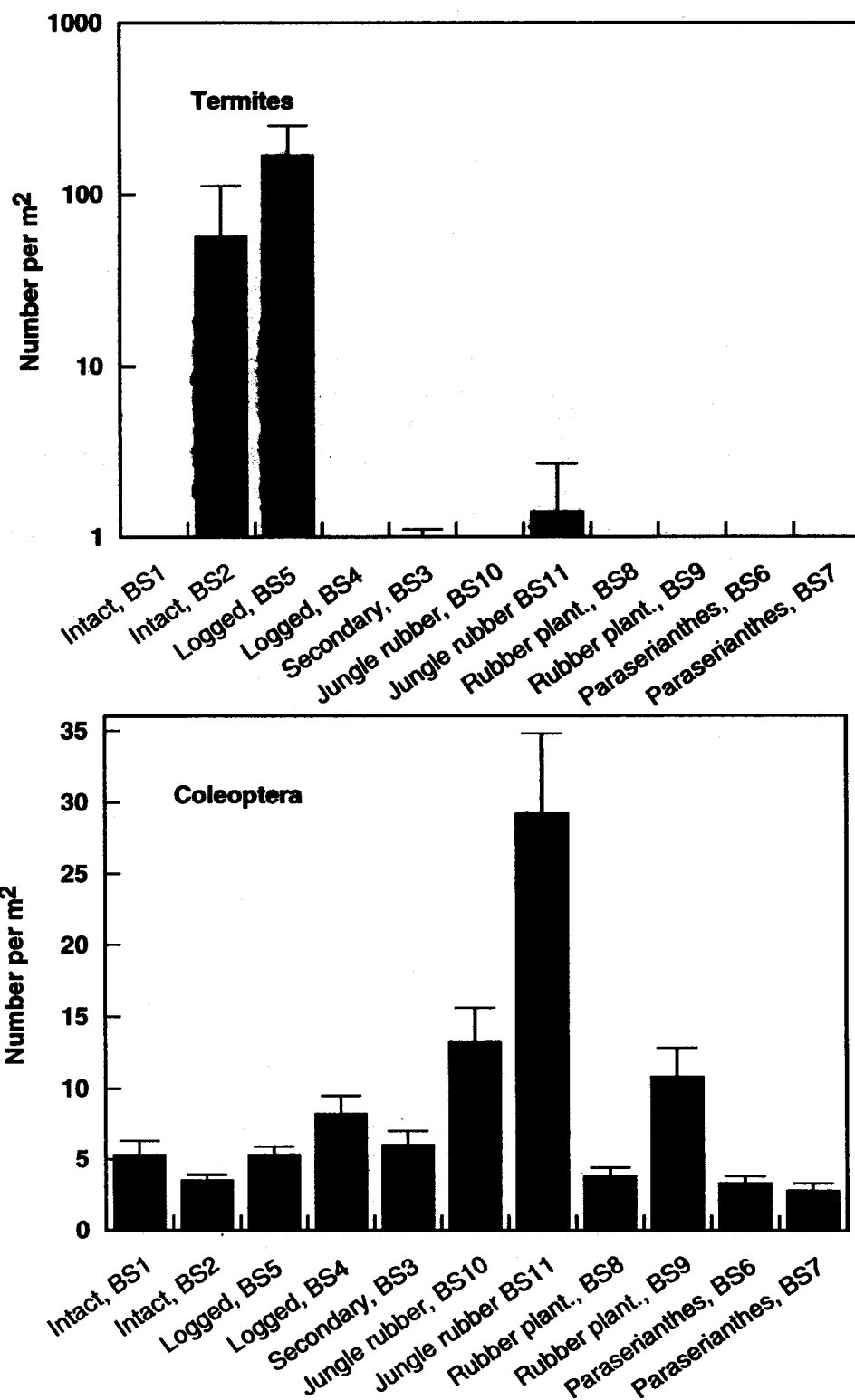


Figure 3 (above) and 4 (below): mean abundance of termites and Coleoptera, respectively, assessed by canopy fogging in the Pasir Mayang are Jambi, Sumatra, November 1997.

Figures 6.3 & 6.4

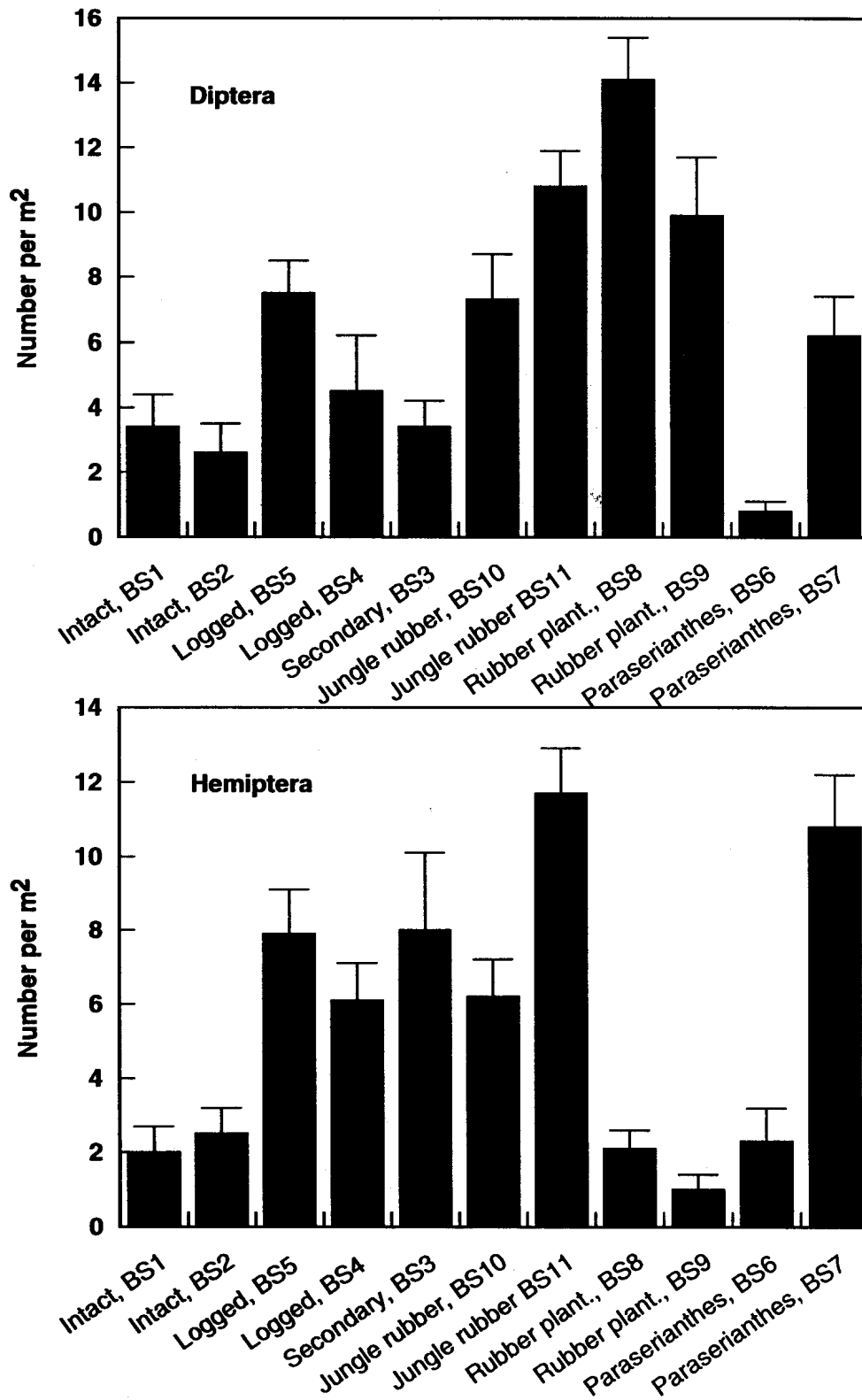


Figure 5 (above) and 6 (below): mean abundance of Diptera and Hemiptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.5 & 6.6

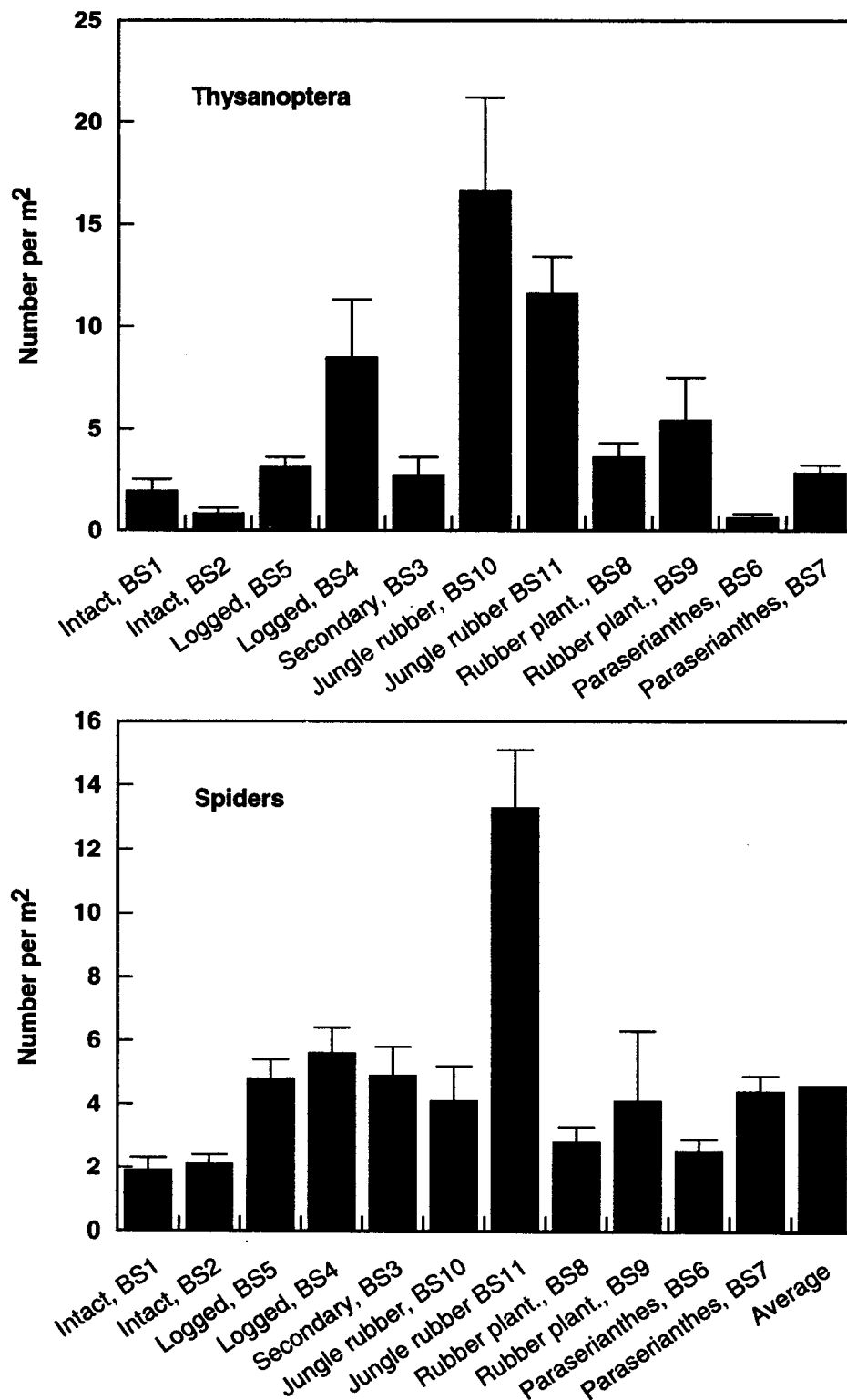


Figure 7 (above) and 8 (below): mean abundance of Thysanoptera and spiders, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.7 & 6.8

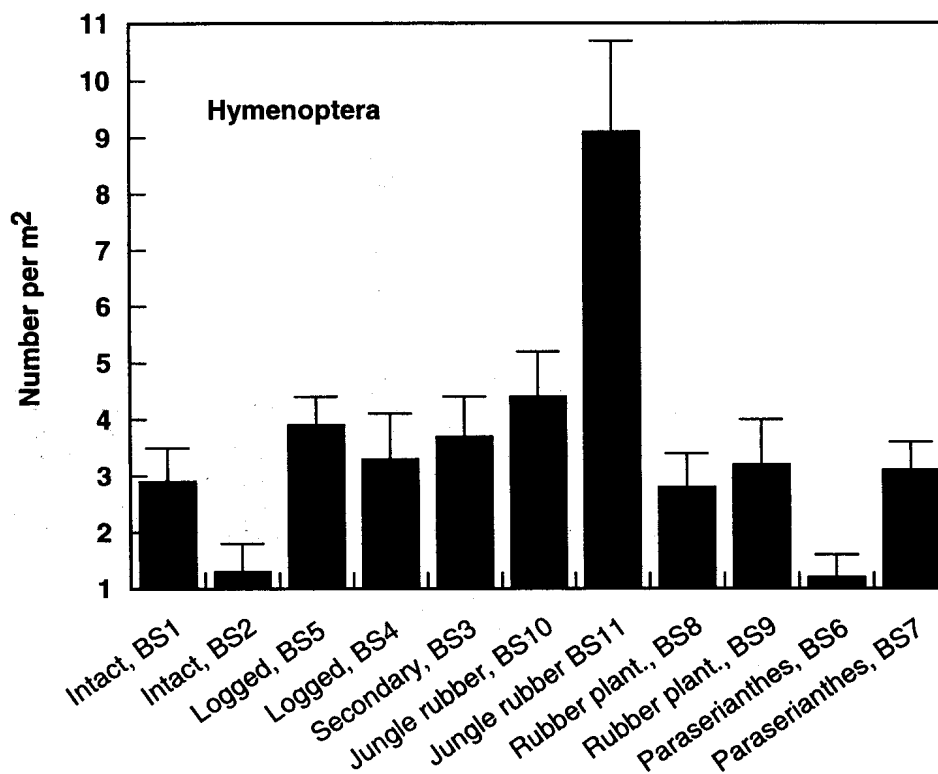
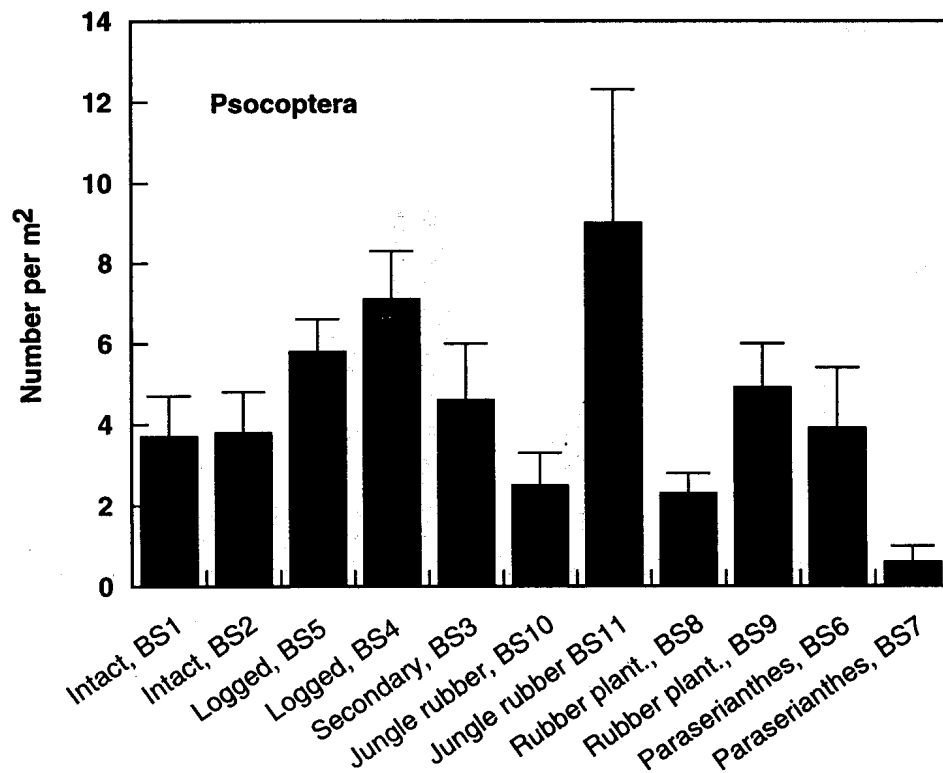


Figure 9 (above) and 10 (below): mean abundance of Psocoptera and Hymenoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.9 & 6.10

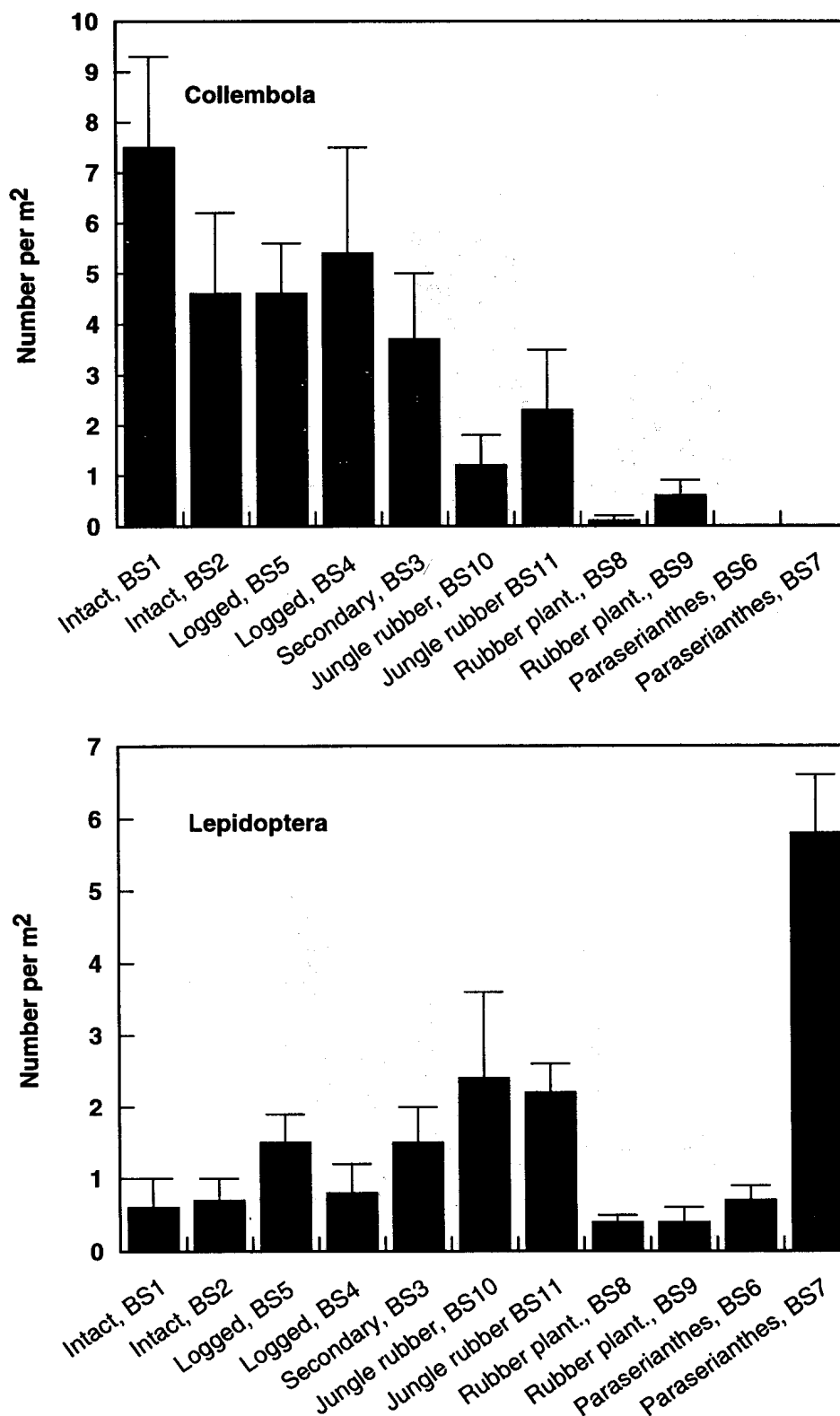


Figure 11 (above) and 12 (below): mean abundance of Collembola and Lepidoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.11 & 6.12

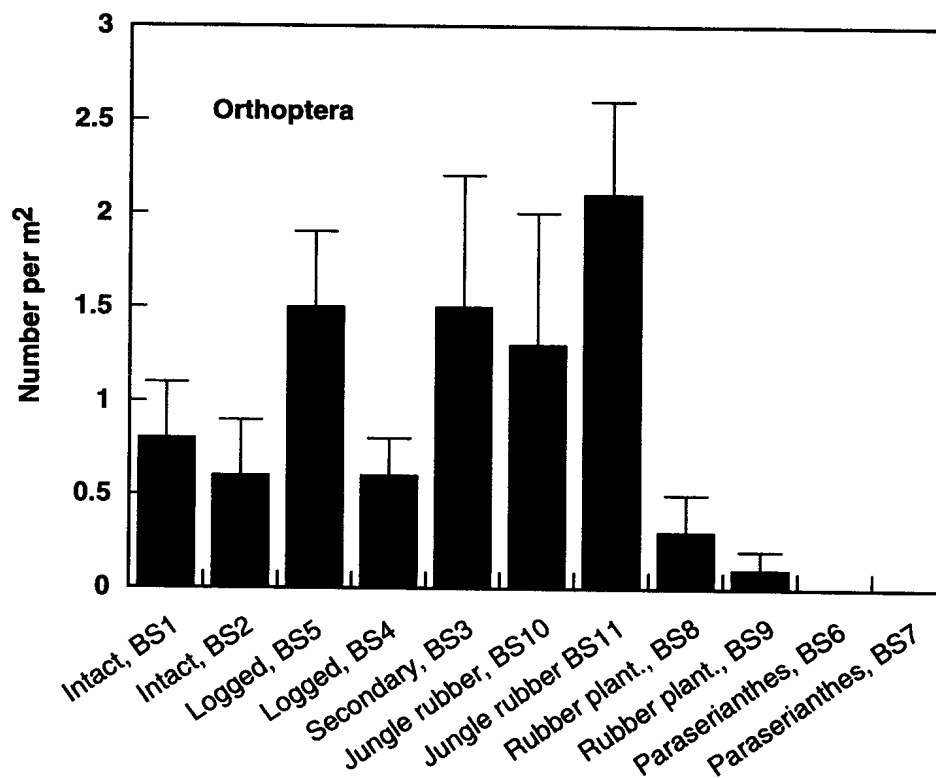
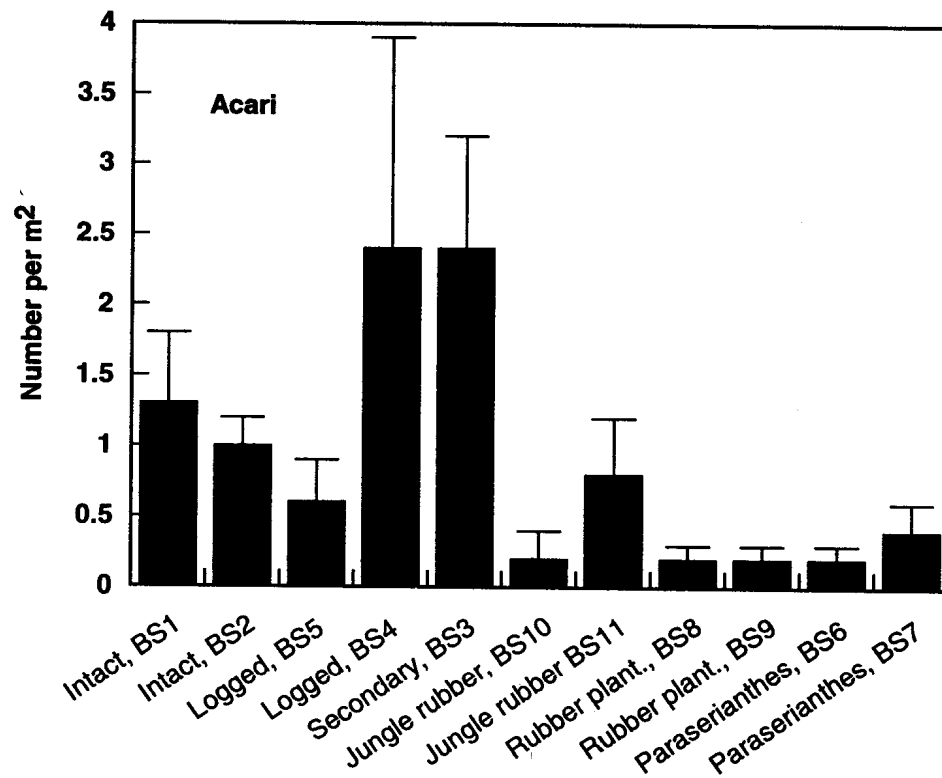


Figure 13 (above) and 14 (below): mean abundance of Acari and Orthoptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.13 & 6.14

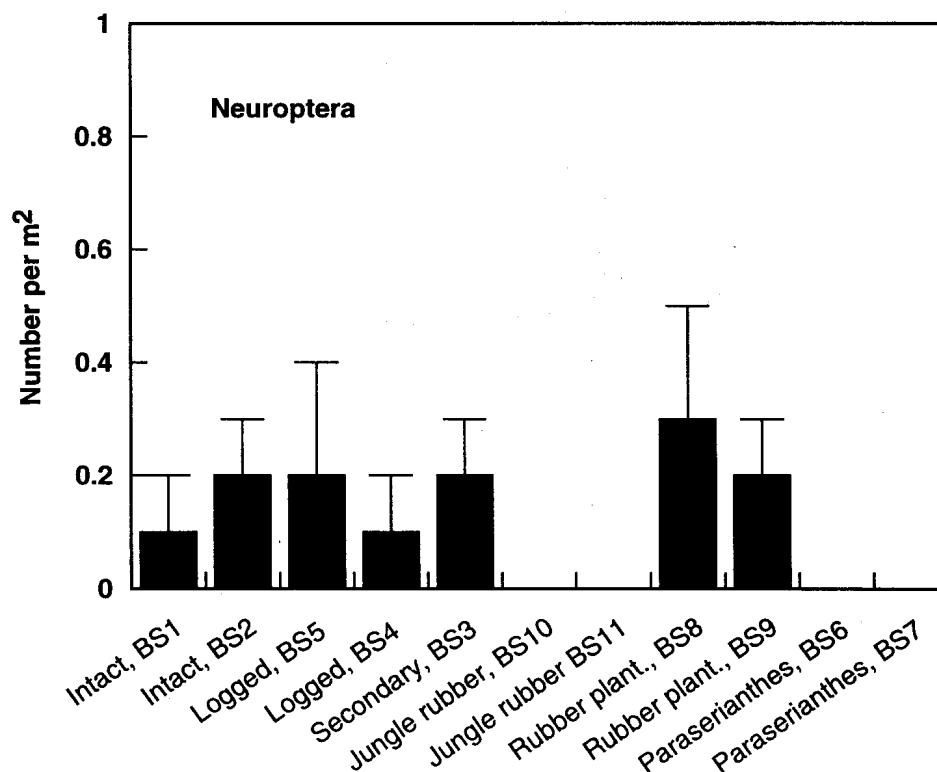
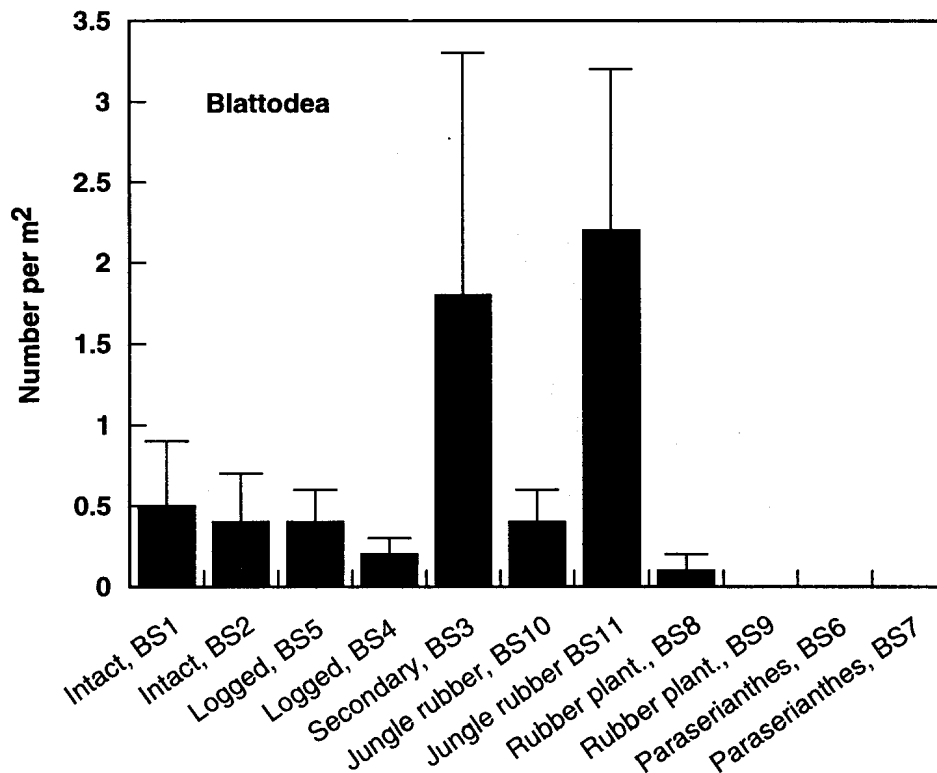


Figure 15 (above) and 16 (below): mean abundance of Blattodea and Neuroptera, respectively, assessed by canopy fogging in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.15 & 6.17

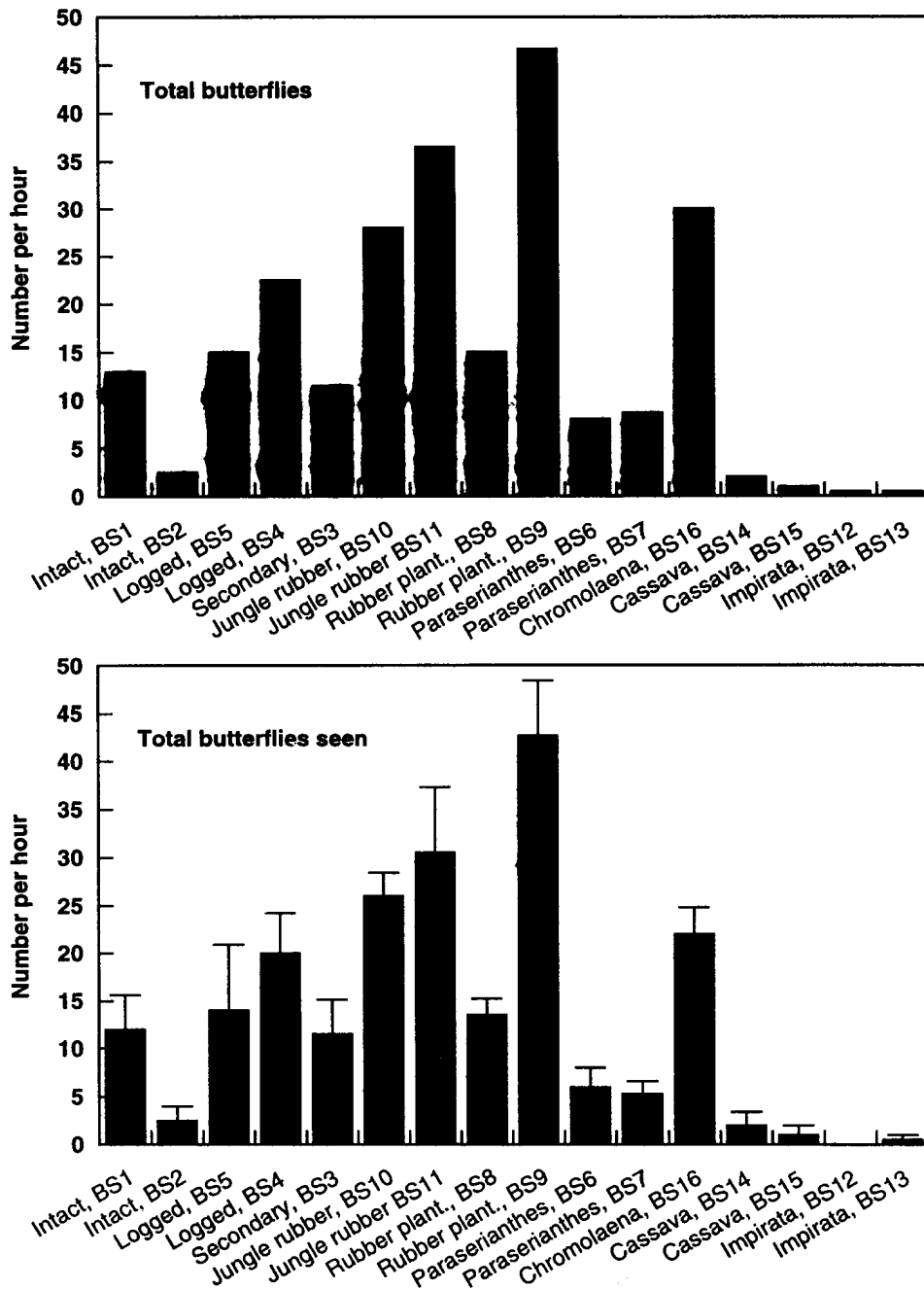


Figure 17 (above) and 18 (below): mean abundance of butterflies seen and caught and seen only, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.17 & 6.18

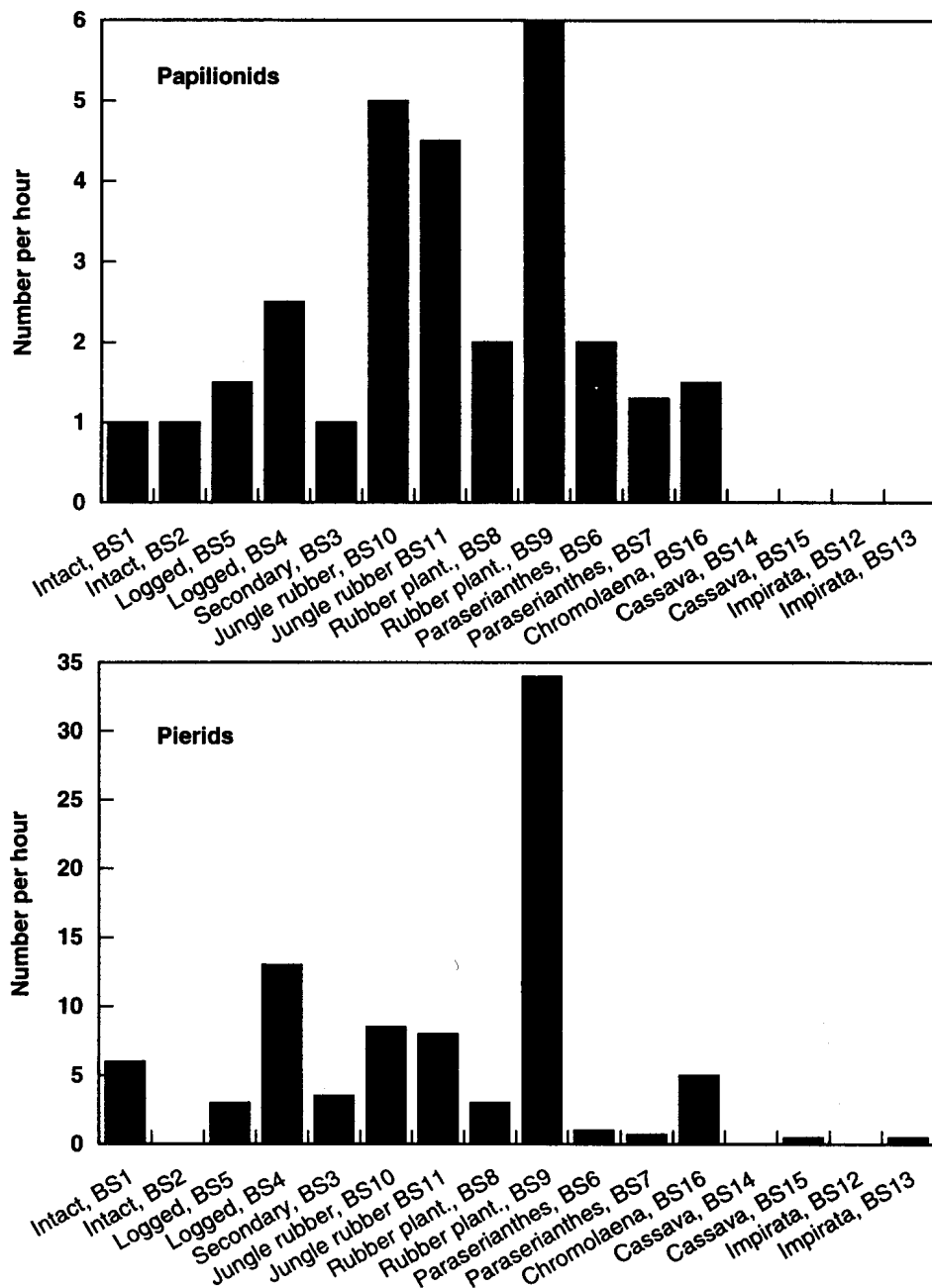


Figure 19 (above) and 20 (below): mean abundance of papilionids and pierids, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.19 & 6.20

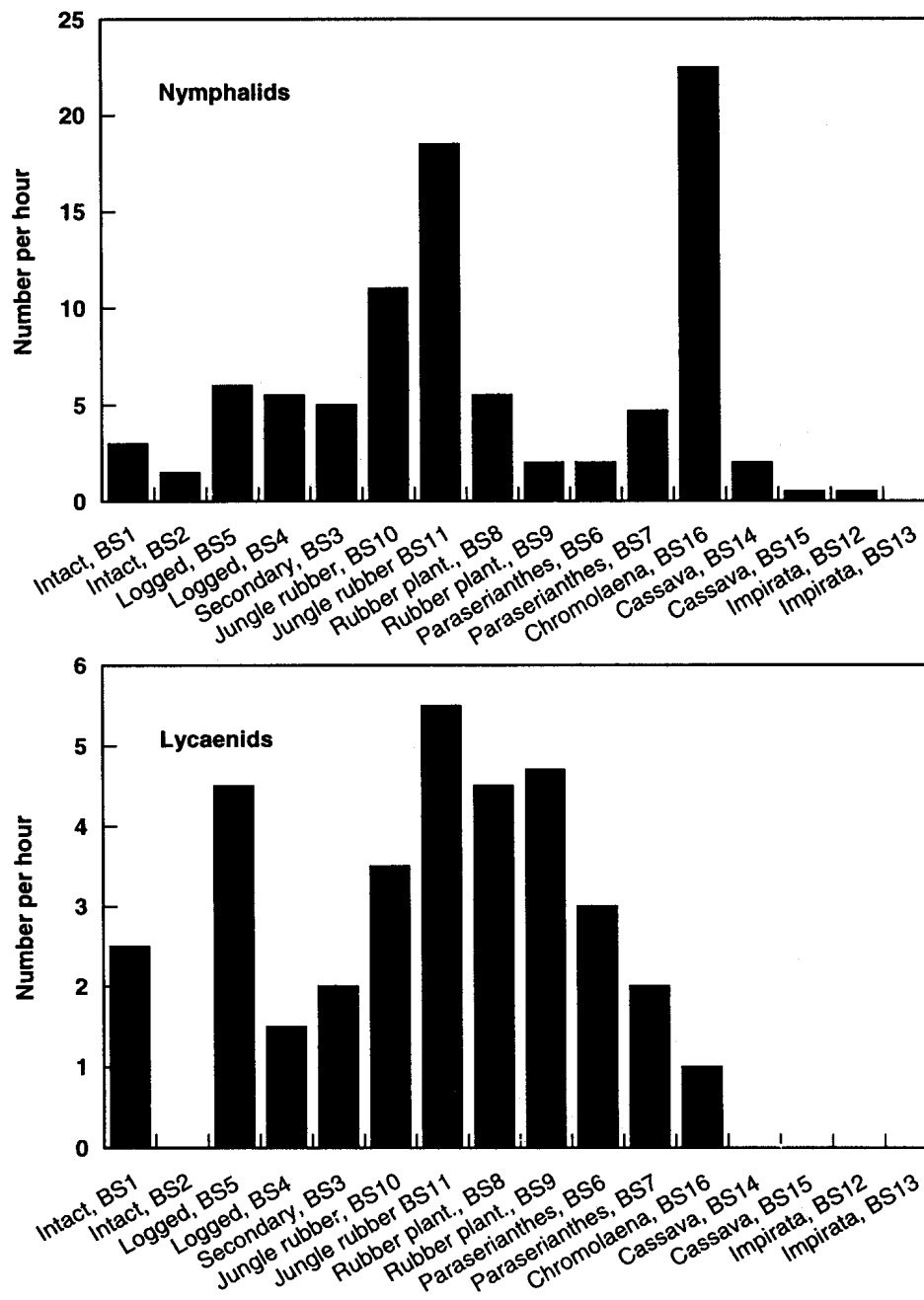


Figure 19 (above) and 20 (below): mean abundance of nymphalids and lycaenids, respectively, assessed by transect counts in the Pasir Mayang area, Jambi, Sumatra, November 1997.

Figures 6.21 & 6.22

SECTION 7: SOIL MACROFAUNA

GROUND-DWELLING ANTS, TERMITES, OTHER MACROARTHROPODS AND EARTHWORMS.

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7.1 Introduction:

The Humid Forest Zones (HFZ) of the tropics cover about 8% of the Earth's land surface, of which about 20% occurs in SE Asia. The present forest is a mosaic of different types of land use: patches of logged-over forest in varying states of regrowth, secondary forest and fallow vegetation, some tree plantations including forms of agroforestry and significant remnants of primary vegetation, as well as degraded grasslands exhausted of almost all arable potential (Swift & Mutsaers, 1992; van Noordwijk *et al.*, 1997). The dominant soils are acidic (oxisols and ultisols derived from low activity clays), commonly exhibiting Al toxicity, low cation-exchange capacity, low base saturation and low P availability. Consequently, they have low inherent fertility and, in many cases, low structural stability if soil organic matter is excessively depleted. The traditional food-production systems of the HFZ are those of shifting cultivation (slash and burn) and (increasingly) recurrent fallow rotation, with rice, plantain, cocoyam (Taro), maize, Cassava and groundnut as typical staples, the last two of these having relatively low fertility requirements. In recent years, socioeconomic factors (including changing world prices for cocoa, oil-palm, rubber latex and other cash crops), population growth, the restriction of urban employment opportunities and legal uncertainties over title to timber revenue, have led to an increase in the clearance of forest for food or cash-crop production and, concomitantly, an accelerated decline in the fertility of soils under cultivation as fallow periods have shortened (Woomer & Swift, 1994). Agricultural research for the HFZ has therefore been directed towards the improvement of sustainability, for example, by the conservation of soil organic matter and the provision of better mulching regimes. Added to this is the development of flexible mixed cropping systems, for example, the combination of marketable tree crops with field-planted staples, or mixtures of commercially valuable trees such as rubber and natural secondary regrowth (Scholes *et al.*, 1994; van Noordwijk, 1997). Multistrata systems provide an opportunity for the simultaneous production of timber (and/or other tree crops) and food, with a sustained supply of organic matter and nutrients to soil and the stabilization of structure.

The importance of macrofauna to the promotion of tropical soil fertility has been stressed in recent reviews (Fragoso *et al.*, 1993; Lavelle *et al.*, 1997; Garnier-Sillam & Harry, 1995; Nash and Whitford, 1995; Brussaard & Jumas, 1996; Wood, 1996). The distribution, protection and stabilization of organic matter, the genesis of soil structure (macroaggregates), humification, the release of immobilized N and P, the improvement of drainage and aeration, and the increase in exchangeable cations have all been demonstrated in soils modified by termites and earthworms (e.g. Mulongoy & Bedoret, 1989; Lavelle *et al.*, 1992; 1998). Soil ants and other macrofauna represent predators, herbivores (granivores) and bioturbators, bringing about important changes in the physical and chemical properties of soils, as well as dispersing plant propagules. Networks of galleries and chambers increase the porosity of the soil, increasing

drainage and aeration (Cherrett, 1989) and reducing bulk density (Baxter and Hole, 1967). Ant-plant communities are much more species-rich in the tropics than elsewhere; a pattern associated with habitat heterogeneity (Davidson and McKey, 1993; Folgarait, 1996).

Depletion of termite abundance and diversity is now a well-established effect of forest clearance (Wood *et al.*, 1982; Eggleton *et al.*, 1995; 1996). Effects on earthworms also include the loss of typical forest species, but also possible invasion by exotic species, with adverse consequences for soil structure (Reddy & Dutta, 1984; Barros *et al.*, 1996). Information on ants is limited, but Belshaw and Bolton (1994) found similar levels of leaf litter ant diversity in secondary forest, primary forest and cocoa plantations in Ghana. A more recent study in Cameroon by Watt *et al.* (1997), showed that moderate forest disturbance, for example, by enrichment planting after partial clearance, increased species numbers and overall ant abundance in both leaf-litter and canopy-dwelling ants. Complete clearance reduced abundance severely, although diversity was comparable to that in closed canopy forest. There is a general consensus that the conservation of indigenous invertebrate biodiversity should be an integral part of land-management strategies in the HFZ, if the goal of increased crop-yield sustainability (and concomitant forest conservation) is to be realized (e.g. Smith *et al.*, 1993; Lavelle, 1996; Lavelle *et al.*, 1998).

The soil biota (and hence soils as a whole) respond to human-induced disturbance such as agricultural practices, deforestation, pollution and global environmental change with many negative consequences including loss of primary productivity, loss of cleansing potential for wastes and pollutants, disruption of global elemental cycles, feedbacks on greenhouse gas fluxes and erosion. At the same time, global food supply depends on intensive agriculture. As intensification proceeds, above-ground biodiversity is reduced, one consequence of which is that the biological regulation of soil processes is altered and often substituted by the use of mechanical tillage, chemical fertilizers and pesticides. This is assumed to reduce below-ground diversity as well, which, if accompanied by the extinction of species, may cause losses of function and reduce the ability of agricultural systems to withstand unexpected periods of stress and bring about undesirable effects. Scientists have begun to quantify the causal relationship between i) the composition, diversity and abundance of soil organisms, ii) sustained soil fertility, and iii) environmental effects such as greenhouse gas emission and soil carbon sequestration.

Large numbers of farmers in the tropics have limited access to soil inputs (i.e. fertilizer and pesticides) but are nonetheless forced by circumstances to drastically reduce the complexity of their agroecosystems in an attempt to intensify production. An alternative solution is to intensify while at the same time retaining a greater degree of above-ground diversity. The maintenance of diversity of crops and other plants in cropping systems is widely accepted as a management practice which buffers farmers against short-term risk. Enhanced biodiversity and complexity above-ground contributes to the re-establishment or protection of the multiplicity of organisms below-ground able to carry out essential biological functions. This can be considered at both the field and the landscape level to enhance structural complexity and functional diversity, especially in degraded lands.

In this paper, we report quantitative and qualitative sampling in 7 representative land uses in or close to the Pasir-Mayang Forest Reserve, Jambi Province, central Sumatra, using rapid assessment methods which enabled most sites to be examined in 1-2 days. Ants and other macrofauna were sampled qualitatively by the use of pitfall traps and quantitatively from standard soil monoliths.

7.2 Sites:

The sites selected were chosen to have an approximately even spacing along a presumed disturbance gradient from pristine forest through to degraded grassland (Table 7.1). As a total of only 16 sites was available, not all land uses could be addressed, and no replication was attempted other than the within-site pseudo-replication inherent in transects and pitfall lines (see below). Sites were generally sampled last, in a planned sequence, after botanical, ornithological, soil and other site surveys had been completed and following the sampling of mammals, canopy arthropods and butterflies. Sampling was usually completed in 2 days, including dissection of monoliths. An intuitive grading of the sites, based on expected macrofaunal diversity, would be:

BS1 ---> BS3 ---> BS10 ---> BS8 ---> BS6 ---> BS14 ---> BS12

least disturbed most disturbed

most diverse least diverse

The notional gradient used, reflecting disturbance history, disturbance intensity and vegetation is:

BS1---→ BS3---→ BS6---→ BS8---→ BS10 ---→ BS12 ---→ BS14

Table 7.1.
Seven landuses selected for ant and other macrofaunal sampling in Pasir Mayang and adjacent areas of central Sumatra.

Site coding	Dominant vegetation form	General character	GPS reference
BS 1	Intact rainforest	A small area of pristine lowland forest on a moderately steep slope, well drained with closed stratified canopy and generally light understorey. Tree buttresses and stilts present.	01-04-47 S 102-06-02 E <u>Pasir Mayang</u>
BS 3	Secondary rainforest	A ridge-top site contiguous with BS1 but logged-over with secondary regrowth on old log collection points and skid trails. Transects and pitfalls placed to run through secondary areas. Generally patchy canopy but of limited stratification. High liana/creeper burden.	01-04-43 S 102-05-55 E <u>Pasir Mayang</u>

An expanded version of Table 1, incorporating botanical, soil physio-chemical data and additional site information is given as Annex III, Table 12.1.

7.3 Aims and objectives:

- To provide data on species richness, numerical density and biomass density for ground-dwelling ants, with estimates of population variance for numerical density and biomass density, in 7 LUTs.
- To provide data on numerical density and biomass density of earthworms and termites, with estimates of population variance, in 7 land uses.
- To provide an estimate of species richness of earthworms.
- To provide an estimate of taxonomic richness (to the best level of resolution possible) for other macrofauna (in addition to earthworms, ants and termites).
- To give pooled (i.e. overall) data for numerical density and biomass density for other macrofauna.
- To allocate basic functional attributes to macrofauna.

The objectives were developed to test the following hypotheses:

- Agricultural intensification results in a reduction of soil biodiversity, leading to a loss of ecosystem services detrimental to sustained productivity.
- Above-ground and below-ground biodiversity are interdependent across scales of resolution from individual plant communities to the landscape.
- Agricultural diversification (at several scales) promotes soil biodiversity and enhances sustained productivity.
- Sustainable agricultural production in tropical forest margins is significantly improved by enhancement of soil biodiversity.

7.4 Methods:

7.4.1 Review of existing methods:

General approaches to the sampling of invertebrate animals, and the advantages and disadvantages of particular methods, are described by Murphy (1962), Phillipson (1971) and Southwood (1978).

Soils differ greatly in composition, particle size, structure, depth and compaction, and whether they are under trees, grassland or cultivation. Since the soil fauna is incorporated closely into the soil structure, the assessment of populations of these organisms is extremely difficult and laborious, and generally necessitates a wide range of specialized techniques if animals in the three major size categories (macrofauna, mesofauna and microfauna) are to be assessed (Edwards, 1991).

The basic options are a) hand soil *sifting* and sorting (including litter layer dissection), b) *trapping* with or without baits, and c) *extraction* methods. In the last category are techniques based on *flotation*, which separates buoyant animals from the inert soil particles with water-based solutions (for example brine or sugar solutions) or organic solvents, or enables them to escape from the particle matrix by swimming (for example enchytraeids and nematodes in wet funnel methods), or *dry heat* extraction in which litter or soil samples suspended above funnels

are slowly dried, causing animals to migrate out of the litter into the funnels, from which they can be recovered, preserved and concentrated in alcohol (Bater, 1996). For ants, which are exceptionally mobile and respond rapidly to desiccation, a special modification of the extraction principle can be employed through the use of Winkler bags. These are narrow-mesh closed fabric bags forming a double-pyramid shape and enclosing suspended samples of soil or litter; the bags are hung up in a dry place for 6-8 days while the samples dry out naturally and any ants they contain are eventually captured in pots of alcohol fitted into the lower apex.

However, extraction methods like this are generally slow and usually require some kind of laboratory base, so for rapid assessment focussed on the larger soil animals, it is normally sufficient to use just *hand sorting*; i.e. a measured quantity of soil or litter (usually delimited by a quadrat) is gradually crumbled over a sheet of plastic or other material and the invertebrates collected with forceps or pooter as they are released and stored in a suitable preservative (5% formalin for earthworms and gastropods; 70% alcohol for other invertebrates). Samples tend to accumulate faster than they can be sorted, so it is permissible to store samples in plastic bags (but out of direct sunlight) for up to 12 hours for later sorting. The efficiency of hand-sorting is generally high for animals which can be seen with the naked eye, as long as field assistants are adequately trained, but some authors have reported making allowances of up to 12% for lost or undiscovered specimens (e.g. Wood *et al.*, 1982).

Trapping methods can be used to exploit accidental encounter by invertebrates, but baiting is not usually employed for ants, as attractants may introduce bias by selecting for some species more than others. Pitfall traps, containers sunk into the soil flush with the soil surface, containing either a preservative or some other immobilizing fluid and with raised covers to prevent flooding by rain, are probably the most commonly used method of catching invertebrates (Bater, 1996). The main variations are in the size of container and the use, or otherwise, of guiding fins or other corralling devices to increase interception. The limitations of pitfall traps are largely in the interpretation of data, since the numbers of animals trapped are related both to overall numbers present and their activity, and so may not sample each population entirely. There is a tendency for such traps to accumulate ants, beetles, crickets, isopods, myriapods and spiders (all of which are active on the surface of the ground, particularly at night). The optimum period for capture is about 24 hours, after which traps are often disturbed by vertebrates and birds. There are methods available to convert the numbers of invertebrates trapped to populations, usually based on physically delimiting sampling areas with some form of barrier or using mark-recapture techniques.

7.4.2 Functional classification of soil fauna:

(after Lavelle, 1988; Anderson and Ingram, 1993).

Soil invertebrates can be classified according to their feeding habits and distribution in the soil profile as follows:

Epigeic species which live and feed on the soil surface. These may act as litter transformers or the predators of litter transformers, but do not actively redistribute plant material.

Anecic species which remove litter from the soil surface through their feeding, redistributing it to other horizons or locations, accompanied by effects on soil structure and hydraulic properties.

Endogeic species which live entirely within the soil, feeding on organic matter and dead root materials, which are mixed with other components of the soil, creating mineral-humus complexes and influencing a large suite of soil properties. The quantification of these effects on soil processes requires detailed study, but a simple characterization of macrofauna can assist in assessing their role in different landuses and under various regimes of management (Table 7.2).

Table 7.2
Functional classification of common soil fauna

Taxon	Category
Ants	Epigeic and anecic
Arachnids (esp. spiders)	Epigeic
Beetle adults	Epigeic and endogeic
Beetle larvae	Epigeic
Cockroaches	Epigeic
Centipedes	Epigeic
Cicada larvae	Endogeic
Crickets	Epigeic
Earthworms (pigmented)	Epigeic and anecic
Earthworms (unpigmented)	Endogeic
Millipedes	Epigeic
Slugs and snails	Epigeic
Wood-feeding termites	Epigeic and anecic
Soil-feeding termites	Endogeic
Fungus-growing termites	Anecic
Woodlice	Epigeic

7.4.3 Sampling design:

Sampling in each land use is based on a single quadrat of 40x5 m, which is compatible with concurrent botanical and other pedological sampling exercises (Gillison and Liswanti, this volume). The recommendation is for a minimum of 5 soil monoliths, each 25x25x30cm spaced along the mid-line of the transect at approximately 8m intervals, accompanied by at least 10 pitfalls (using 14cm diameter glass or plastic containers) arranged in a flanking line parallel to the transect or along its long edge. The choice of the starting point for the transect should be random, but its direction is normally determined by the line of best visual habitat homogeneity.

7.4.4 Procedure:

Procedures follow Anderson and Ingram (1993) closely:

- a. 5 sampling points (for monoliths) are located and marked within the transect.
- b. 10 pitfall traps are fitted at roughly 4m intervals along one flank of the transect. The traps are put in during the afternoon or early evening and emptied 24 hours later. Each trap contains a little water, with a few drops of detergent added, to immobilize specimens by drowning.

- c. At each sampling point litter is removed from within a 25cm quadrat and hand-sorted at the site.
- d. Isolate the monolith by cutting down with a spade a few centimetres outside the quadrat and then digging a 20cm wide and 30cm deep trench around it. NB. In a variant of the method not adopted in Pasir Mayang, all invertebrates longer than 10cm excavated from the trench are collected; these will be mainly large millipedes and earthworms with very low population densities but representing an important biomass. Their abundance and biomass can be calculated on the basis of 0.42 m² samples, i.e. the width of the block plus two trench widths, squared.
- e. Divide the delimited monolith block into three layers, 0-10cm, 10-20cm and 20-30cm. This can be done conveniently using a parang or machete held horizontally and grasped at both ends. Hand-sort each layer separately. If time is short or the light poor (sorting in closed canopy forest is usually difficult after about 3.30pm), bag the soil and remove to a laboratory. Ants can be extracted by gently brushing small (handful) quantities of soil through a coarse (5mm) sieve into a tray: the sieve retains the ants.
- f. Record the number and fresh (preserved, after blotting) weight of all animals and identify to at least the taxonomic and functional levels indicated in Table 7.2 (but preferably further). The presence and weight of termite fungus combs (if any) should also be noted.

7.4.5 Analysis:

The following steps should be followed:

- i) Make a list of species, if possible grouped into subfamilies or families. Use generic names to generate alphabetical orders. Use the results from pitfall traps and monoliths to compile this list.

Fully identified species should be listed with the full binomial and descriptive authority:

e.g. *Dorylus laevigatus* Smith

Morphospecies should be listed by number:

e.g. *Crematogaster* sp. 1
Crematogaster sp. 2
 etc.

Species identified only to genus should be listed without numbers:

e.g. *Colobopsis* sp.

Incorporate the species list into a table showing the sites where each occurred.

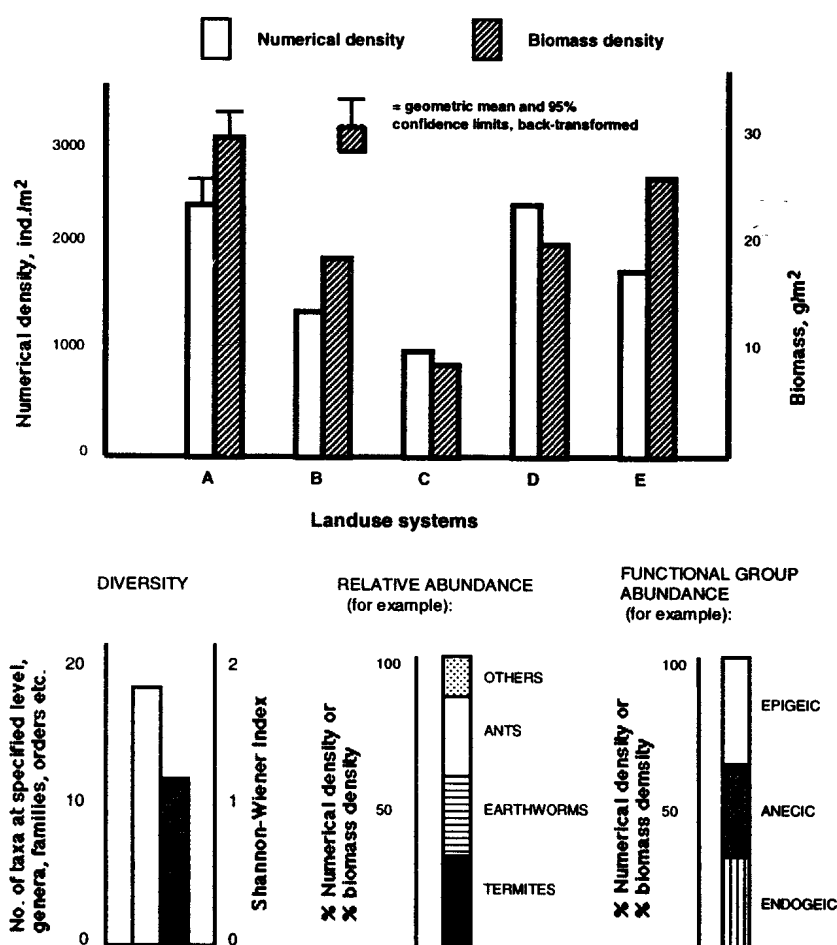
- ii) Estimate abundance as numbers m⁻² from each monolith (multiply the raw number per monolith by 16 (except earthworms and millipedes, see above), combining data for all species.

Calculate an arithmetical mean. To estimate the 95% confidence limits the primary data should be transformed as $\log_{10}(x+1)$. If there are not too many zeros, this should roughly normalize the data and produce homogeneous variances from group to group. In difficult cases, a log-log transformation can be tried. Apply descriptive statistics to the transformed dataset, including 95% confidence limits, and back transform to obtain a geometric mean. Quote means for untransformed data, together with the geometric mean and confidence limits for $\log(x+1)$ transformed data. The transformed data can be used for histograms and site-to-site comparisons.

Estimate biomass as g m^{-2} in a similar way. Use fresh weight or the mass of blotted preserved specimen, if possible. Avoid the use of dry weight because of the different oven temperatures used by different scientists and the variable water content of different types of organism. Where insect specimens in a range of sizes are available, an alternative method is to calibrate live biomass against head width in representative specimens covering the whole size range. The weight of unknowns can then be estimated from the curve. For log transformations of data, it is most convenient to work in $(\text{mg} + 1)$, then back-transform and express as g.

iii) Results should be presented as species/taxa lists, plus the standard histograms as illustrated below:

Figure 7.1. Graphical summaries of biodiversity data – some examples



iv) An overall quantitative synthesis of data for macrofauna can be attempted using the following matrix:

Table 7.3
Synthesis matrix for macrofauna

Region	Landuse System				
	A = natural control site	B	C	D	E
e.g. Pasir Mayang	x = 80	x = 67 p = 0.1 % = -16	x = 50 p = 0.04 % = -38	x = 95 p = 0.11 % = +19	x = 57 p = 0.05 % = -29

where, x = average of monoliths

p = level of significance for a comparison with the control site by an appropriate statistical test.

% = percentage difference between the mean of each landuse and the control site, with an indication (+/-) of the direction of change (increase or decrease).

The control site is selected as the least disturbed local land use; in most cases this would be a tropical forest, preferably primary, or else old growth secondary or disturbed primary forest. Arrangement of sites in rank order to form a disturbance gradient may be somewhat arbitrary, especially if site histories are incompletely known, but disturbance intensity, management intensity and time since the imposition of disturbance are the usual criteria employed.

Matrices can be prepared for the following data:

- total numerical density
- total biomass density
- earthworm numerical density
- earthworm biomass density
- earthworm species richness
- termite numerical density
- termite biomass density
- termite species richness
- ant numerical density
- ant biomass density
- ant species richness
- all macroarthropod numerical density
- all macroarthropod biomass density

v) A qualitative synthesis can be given by answering the following questions:

- what is the effect of each landuse system on biodiversity?
- which groups change the most with disturbance and along the land use gradient?
- what is the relationship between the functional group changes and the degree of sustainability of each land use?

7.4.6 Data analysis:

Carry out a non-parametric ANOVA (Kruskal-Wallis) on each dataset to see if there is a significant difference across the sites (or treatments). This can be followed by pairwise comparisons between sites using the Mann-Whitney U test. Parametric ANOVA can be performed on log transformed data.

7.5 Results:

7.5.1. Ants:

The total number of subfamilies sampled was 8:

- Dorylinae: BS10 only
- Formicinae: all sites
- Myrmecinae: all sites
- Ponerinae: all sites except BS14
- Leptanillidae: BS 8 only
- Pseudomyrmicinae: BS 6 and BS 10 only
- Cerapachyinae: BS 8 only
- Dolichoderinae: BS 6, BS 10, BS 12 and BS 14 only

The species lists for each site are available in Annex III, Table 12.11 . Details of ant numerical density and biomass density by site and by stratum are given in Annex III, Table 12.2 and 12.3 , respectively. The following figures summarize ant diversity and abundance:

Figure 7.2. Ant species richness

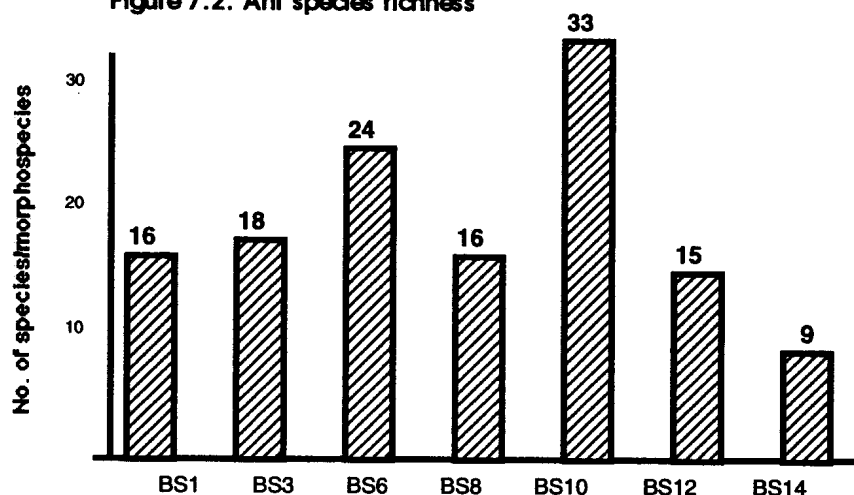
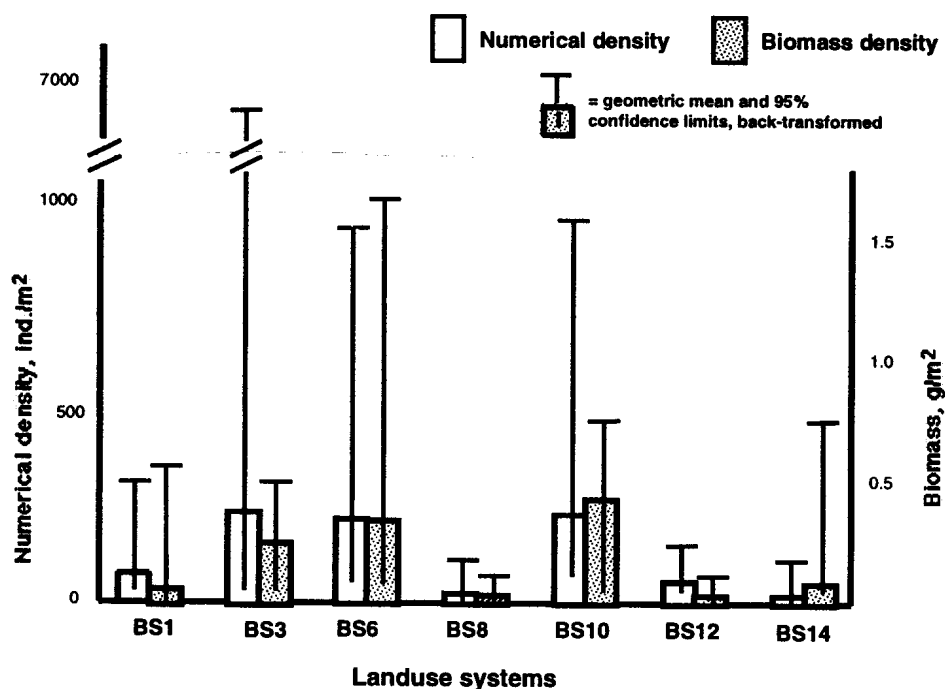


Figure 7.3. Ant abundance and biomass



Abundance and biomass were totalled for each monolith and assessed by the non-parametric one-way Kruskal-Wallis ANOVA, using arithmetic data. Abundance and biomass did not vary significantly across the sites ($p > 0.05$). One-tailed pairwise comparisons of ant abundance between sites were, however, carried out by the Mann-Whitney test (Table 7.10). These generally showed significant differences between some of the richer sites (BS3, BS6, BS10) and those that were highly disturbed (BS12, BS14).

BS3, BS6 and BS10 all had more ants than either BS12 or BS14 ($p < 0.025$ in all comparisons). BS10 had more ants than BS 8 ($p < 0.025$). All other site comparisons were non-significant (see Table 7.10 and Annex III, Table 12.10).

BS3 had a higher biomass of ants than BS8 ($p=0.05$) and BS12 ($p=0.025$). BS6 and BS10 also had a higher biomass than BS12 ($p<0.025$). All other site comparisons were non-significant (see Table 7.11 and Annex III, Table 12.10).

Untransformed abundance and biomass data from each soil stratum were summed across all sites. Transformed data were used to compute geometric means and 95% confidence limits, using the average of each monolith (numbered 1-5) across all 7 sites (Table 7.8). ANOVA tests on these data showed no significant differences between strata.

In a further analysis of abundance and biomass, all 140 data points (5 monoliths X 4 strata X 7 sites) were transformed and subjected to a parametric two-way ANOVA in which the variables were site and stratum (Table 7.9). This showed a significant variation across sites (abundance: $p<0.025$; biomass: $p<0.05$) and between strata (abundance: $p<0.001$; biomass: $p<0.025$). However the interactions between site and stratum were not significant for either abundance or biomass ($p>0.5$).

Functional group allocation (epigeic, anecic, see Figure 7.11) was made from information in Holldobler and Wilson (1990) and by anecdote (E. Widodo and M. Maryati, personal communications).

All three measures of ant activity (species richness, abundance and biomass) were consistent in showing BS3, BS6 and BS10 as sites of high ant activity. On abundance data BS10 was significantly different from two other sites and on biomass data different from one. In statistical analysis, biomass differences were more weakly supported by pairwise comparisons between sites. BS3, BS6 and BS10 had no zero samples from monoliths.

Table 7.4
Abundance and biomass totals (arithmetic data)

Site	Total no individuals sampled from monoliths.	Total biomass of ants sampled from monoliths, mg
BS1, primary forest	110	109
BS3, logged over	163	83
BS6, <i>Paraserianthes</i>	172	1583
BS8, rubber	39	32
BS10, jungle rubber	169	268
BS12, alang-alang	25	12
Bs14, Cassava	15	105

Table 7.4 gives some indication of the real quality of the data; a small amount of material from which to extrapolate to the landscape level. Nevertheless, it is instructive in illustrating the way in which this group of insects does not have its highest species richness, abundance or biomass in the primary forest, but in two disturbed sites of somewhat different character.

Trends across the sites relative to the control site (BS1, primary forest) are given in Table 7.5, in standard format. The literature contains few data for comparison. Belshaw and Bolton (1994)

give average litter-ant abundance across several woodland sites in Ghana as 117 m⁻². Watt *et al.* (1997) examined a range of forest sites in Cameroon representing a disturbance gradient similar to that observed in Pasir Mayang, but give figures in the range 20-80 m⁻². However, the lightly and heavily disturbed sites were towards the lower end of this range, while sites with intermediate disturbance yielded the higher abundances. Stork and Brendell (1993) give 3 g m⁻² as the biomass of all non-social insects in the forest system of Seram, Indonesia.

Table 7.5
Trends across the sites relatives to the control sites (BS1)

Parameter	Landuse System						
	Natural control site = BS1	BS1	BS6	BS8	BS10	BS12	BS14
<u>Numerical density</u>							
Arithmetical average of monoliths, nos m ⁻²	352	522	550	134	541	80	48
p value for comparison with control site (transformed data)	0	ns.	ns.	ns.	ns.	ns.	ns.
% difference of means from control site	0	+48%	+56%	-62%	+54%	-77%	-86%
<u>Biomass density</u>							
Arithmetical average of monoliths, nos m ⁻²	0.346	0.285	4.889	0.102	0.857	0.03	0.336
p value for comparison with control site (transformed data)	0	ns.	ns.	ns.	ns.	ns.	ns.
% difference of means from control site	0	-18%	+1400%	-71%	+248%	-92%	-1%

ns. = not significant (p > 0.05)

7.5.2. Termites:

The species lists for each site are available in Section 8 of this report. Details of termite numerical density and biomass density by site and by stratum are given in Annex III, Table 12.4 and 12.5, respectively. Figures 7.4 and 7.5 summarize termite diversity and abundance.

Abundance and biomass were totalled for each monolith and assessed by the non-parametric one-way Kruskal-Wallis ANOVA, using arithmetic data. Abundance and biomass were found to vary significantly across the sites (Tables 7.9; p<0.025). One-tailed pairwise comparisons of ant abundance between sites were carried out by the Mann-Whitney test (Tables 7.10 and 7.11).

These generally showed significant differences between the richest site (intact rainforest, BS1) and others. In addition, sites BS3 and BS6 were significantly greater in abundance and biomass than site BS12 (the *Imperata* grassland; p varies between <0.05 and <0.005). There were no other significant differences between sites. Untransformed abundance and biomass data from each soil stratum were summed across all sites. Transformed data were used to compute geometric means and 95% confidence limits, using the average of each monolith (numbered 1-5) across all 7 sites (Table 7.8). ANOVA tests on these data showed that vertical biomass distribution varied significantly across the sites (Table 7.9; $p<0.05$). For both abundance and biomass, all 140 data points (5 monoliths X 4 strata X 7 sites) were transformed and subjected to a parametric two-way ANOVA in which the variables were site and stratum. This showed a significant variation across sites ($p<0.001$) and between strata ($p<0.001$). The interactions between site and stratum were significant for abundance ($p<0.05$) and biomass ($p<0.01$). Termites generally showed highest numerical and biomass densities in the top 10 cm of the soil.

Functional group allocation (anecic, endogeic, see Figure 7.11) was made from knowledge of termite natural history (see Jones, 1999 in preparation). Generally, species nesting arboreally and feeding on the surface were designated anecic, those building epigeal nests and subterranean nests but feeding on the surface anecic, and those feeding within the soil endogeic, wherever the nesting site. The epigeic category was not recognized for termites.

Overall, termite abundance and biomass were heavily reduced by forest disturbance. This confirms their status as sensitive indicators of forest quality (Eggerton *et al.*, 1995; 1996; Watt *et al.* 1997). Diversity remained relatively high in two disturbed sites (BS3, logged over forest; BS10, jungle rubber), but this was not matched by a corresponding retention of abundance and biomass.

Figure 7.4. Termite species richness

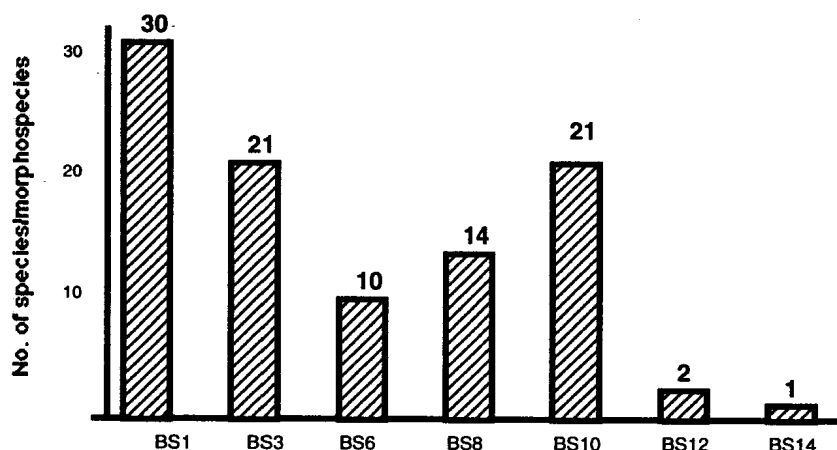
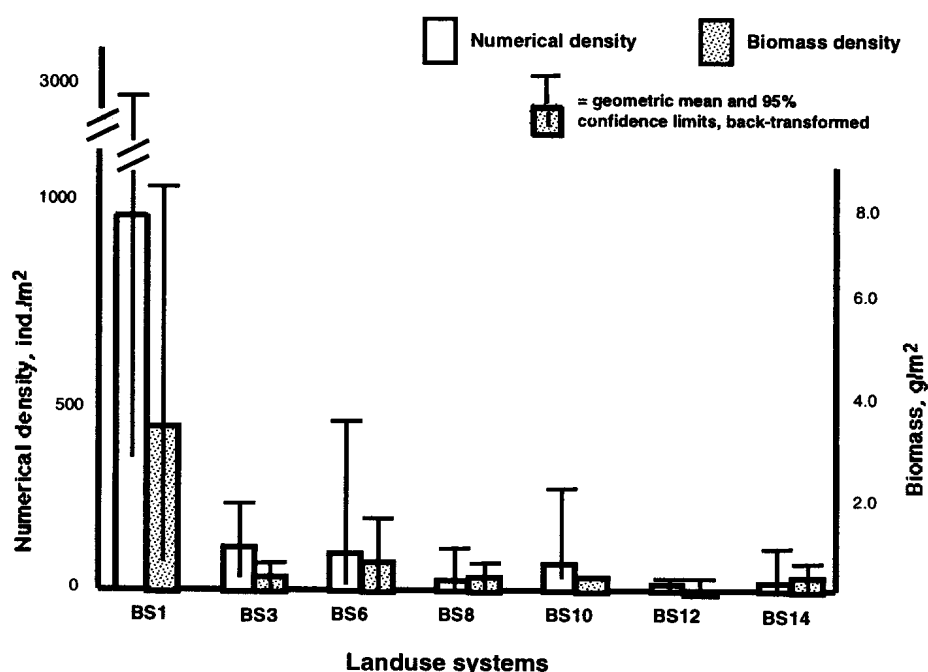


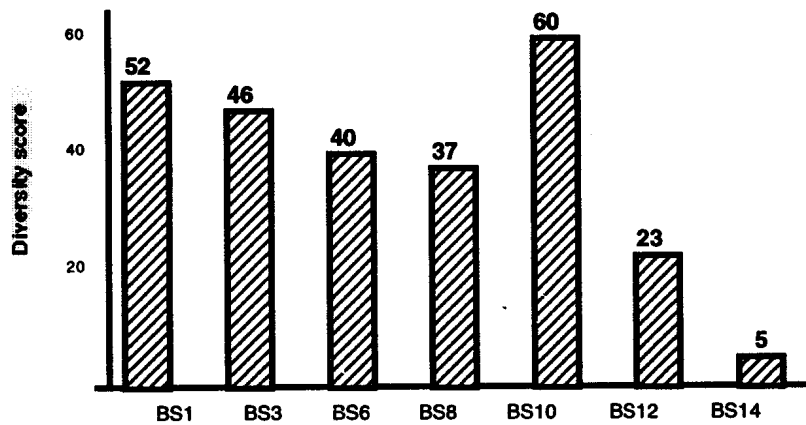
Figure 7.5. Termite abundance and biomass



7.5.3. All macroarthropods:

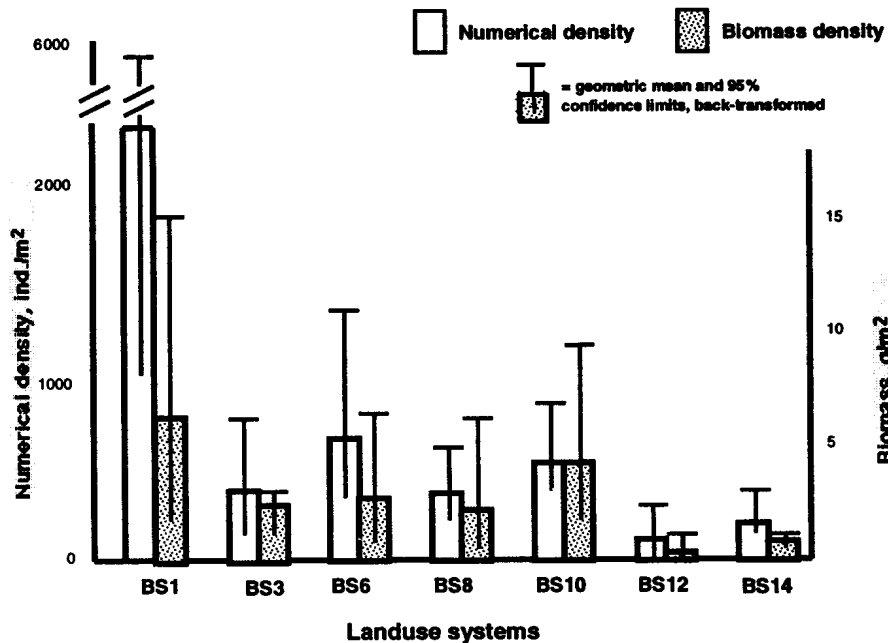
Macroarthropods other than ants and termites were recovered from monolith dissections and pitfall traps. These were predominantly Coleoptera, Diptera, Hemiptera, Dictyoptera Orthoptera, Isopoda, Myriapoda and Arachnida, including many juvenile forms. In most, cases identification was made at class and ordinal level only, more rarely to family, but abundance and biomass were determined as for ants and termites. To make use of the resulting data, they were added to those of ants and termites to make a composite dataset representing all macroarthropods. This is summarized in Figs. 7.6 and 7.7 below, with detailed information in Annex III, Table 12.6 and 12.7.

Figure 7.6. All macroarthropods taxonomic richness



Diversity score = ant species + termite species + other groups at ordinal level or above (earthworms not included)

Figure 7.7. All macroarthropods abundance and biomass



A crude diversity index for macroarthropods was obtained by summing ant and termite species richness, then adding other groups at the level of taxonomic resolution obtained. This shows a more even decline across the gradient, with the exception of BS10 (jungle rubber), which scored a higher diversity than any other site. However, it must be borne in mind that groups with inherent very high diversity, e.g. Coleoptera, Diptera, Arachnida, are almost certainly inaccurately represented (i.e. underestimated) by this method.

Abundance and biomass were totalled for each monolith and assessed by the non-parametric one-way Kruskal-Wallis ANOVA, using arithmetic data. Abundance and biomass were found to vary significantly across the sites (Tables 7.9; abundance, $p < 0.005$; biomass, $p < 0.025$). One-tailed pairwise comparisons of ant abundance between sites were carried out by the Mann-Whitney test (Tables 7.10 and 7.11). For abundance, these generally showed significant differences between the richest site (intact rainforest, BS1) and others. In addition, sites BS6, BS8 and BS10 were significantly greater in abundance and biomass than heavily degraded sites

(BS12 and BS14; p varies <0.025 to <0.005 , except BS6 vs BS14, which is not significant). For biomass, BS1 was significantly greater than BS3, BS12 and BS14. Biomass in BS12 and BS14 was also exceeded by that in BS10 and that in BS12 by BS6 and BS8. Untransformed abundance and biomass data from each soil stratum were summed across all sites. Transformed data were used to compute geometric means and 95% confidence limits using the average of each monolith (numbered 1-5) across all 7 sites (Table 7.8). ANOVA tests on these data showed that vertical abundance and biomass distribution varied significantly across the sites (Table 7.9; abundance, $p<0.01$; biomass, $p<0.005$). For both abundance and biomass, all 140 data points (5 monoliths X 4 strata X 7 sites) were transformed and subjected to a parametric two-way ANOVA in which the variables were site and stratum. This showed a significant variation across sites ($p<0.001$) and between strata ($p<0.001$). The interactions between site and stratum were not significant. The data are, of course, heavily influenced by ant and termite distributions, but for macroarthropods as a whole, the highest numerical and biomass densities were found in the top 10 cm of the soil.

Functional group allocations for macroarthropods other than ants and termites (engineers, litter transformers, macropredators, see Figure 7.10 and epigeic, anecic, endogeic, see Figure 7.11) were made from knowledge of natural history and by reference to Anderson and Ingram (1993; Table 7.2). Animals which did not fit any of these categories, for example sap-feeders, were excluded from the subsequent analysis of functional group distribution across sites.

Few, if any, published studies of soil macroarthropod communities are available for comparison with these data. The inclusion of data for arthropods other than ants and termites appears useful in providing some additional resolution between sites, not obtained from scrutiny of the ants and termites alone. This may be a consequence of the well-known patchiness of soil animal distributions, since individual groups may show very large variance between replicate samples in a single site, but a composite category of macroarthropods may show less overall variation. The category "macroarthropods", however, disguises group to group turnovers which may characterize disturbance gradients.

7.5.4. Earthworms:

Earthworms were recovered from monolith dissections, but were only rarely present in pitfall traps. Summary data on diversity, abundance and biomass are given in Figs. 7.8 and 7.9, with further details in Appendices 7.8 and 7.9. Overall earthworm diversity was low, with only a single morphospecies recognized from the forested BS1 and BS3 sites. However, very high abundance and biomass were associated with sites BS6 and BS10.

Abundance and biomass were totalled for each monolith and assessed by the non-parametric one-way Kruskal-Wallis ANOVA, using arithmetic data. Abundance and biomass were found to vary significantly across the sites (Tables 7.9; $p<0.005$). One-tailed pairwise comparisons of ant abundance between sites were carried out by the Mann-Whitney test (Tables 7.10 and 7.11). For abundance, these showed significant differences between the richest site (jungle rubber, BS10; $p<0.005$) and all others. In addition, site BS6 was significantly greater than BS1, BS3, BS8 and BS12. BS14 (Cassava garden) was relatively abundant, exceeding BS1 and BS3 ($p<0.025$). For biomass, BS10 exceeded BS8 and BS12 (p variable <0.05 to <0.005), while BS6 exceeded BS1, BS3, BS8, BS12 and BS14. (p variable <0.05 to <0.005). This somewhat anomalous result reflects the large confidence interval associated with site BS10.

Untransformed abundance and biomass data from each soil stratum were summed across all sites. Transformed data were used to compute geometric means and 95% confidence limits, using the average of each monolith (numbered 1-5) across all 7 sites (Table 7.8). ANOVA tests on these data showed that vertical abundance and biomass distribution varied significantly across the sites (Table 7.9; $p < 0.001$). For both abundance and biomass, all 140 data points (5 monoliths X 4 strata X 7 sites) were transformed and subjected to a parametric two-way ANOVA in which the variables were site and stratum. This showed a significant variation across sites ($p < 0.001$.) and between strata ($p < 0.001$). The interactions between site and stratum were significant for both abundance ($p < 0.001$) and biomass ($p < 0.001$). Earthworms generally showed highest numerical and biomass densities in the top 10 cm of the soil, with only a few specimens recovered below this level and none in the litter.

Functional group allocation (epigeic, anecic, endogeic, see Figure 7.11) was made from pigmentation (see Lavelle, 1988 and Lavelle et al., 1997). Anecic and endogeic earthworms were considered engineers.

Figure 7.8. Earthworms taxonomic richness

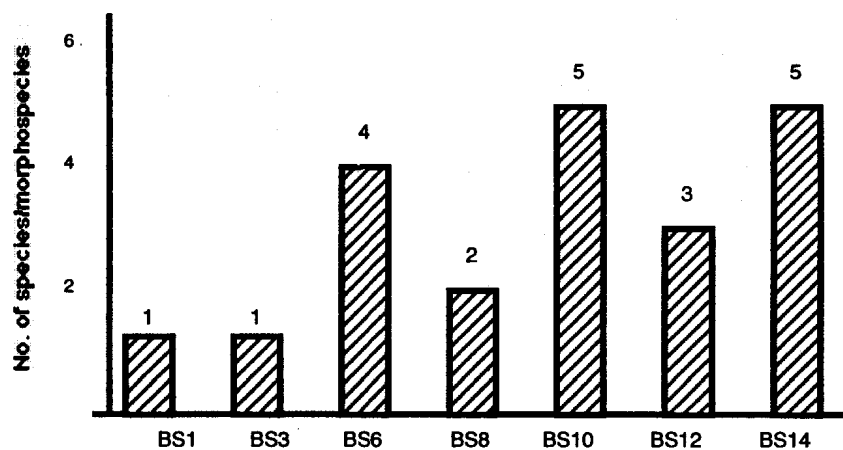
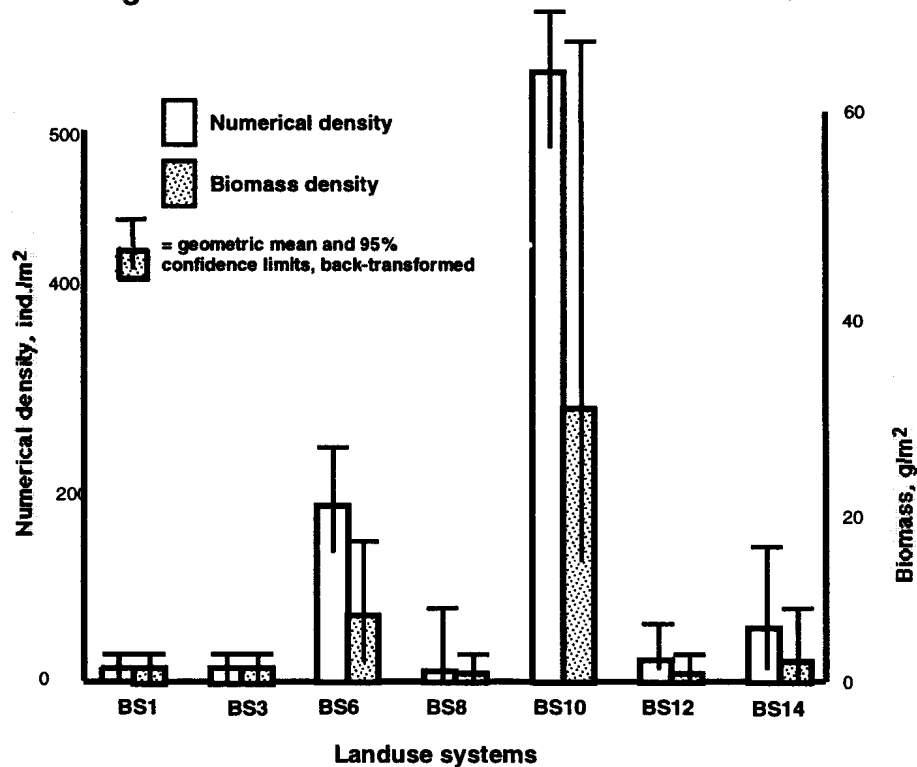


Figure 7.9. Earthworms abundance and biomass



Few data exist documenting the responses of tropical forest earthworms to disturbance gradients, but increases in population size and biomass following conversion of natural forest to plantation have been observed (Lavelle *et al.*, 1997). The alternative explanation that disturbed sites have abundant dead wood and litter, thereby supporting increased earthworm populations, is not supported by measurements of the actual resources available at BS6 and BS10 (Annex III, Table 12.1).

7.6. Synthesis:

Tables 7.6 and 7.7 summarize soil faunal abundance and biomass (respectively) across the 7 sites. Arithmetic totals (the sum of means of each group) are included for illustrative purposes, although it is not suggested that these totals are useful population parameters. It can be seen that the relative contributions of the groups to overall abundance and biomass is not the same in

all sites. Ants were the most abundant group in 5 sites (BS3, BS6, BS8, BS10 and BS12), but not at the extremes of the disturbance gradient, where termites (BS1) and earthworms (BS14) predominated. The rank order of macrofaunal abundance was BS1>BS6>BS10>BS3>BS8>BS14>BS12, broadly indicating that the more severe and the more recent disturbances reduced numbers. Earthworms had the highest biomass in 4 sites (in rank order BS10, BS6, BS14 and BS12), whereas termites made the greatest contribution in BS, and macroarthropods other than ants and termites in BS3 and BS8. The rank order of total biomass was BS10>BS6>BS1>BS14>BS8>BS3>BS12. Two disturbed sites, jungle rubber and *Paraserianthes* plantation, therefore, exceeded the intact rainforest in macrofaunal biomass, in both cases due to the development of large earthworm populations. The overall picture that emerges from these data is of the dominance of termites in intact primary rainforest, and their progressive replacement by other groups, especially ants and earthworms, in disturbed sites. BS12, the alang-alang grassland is clearly the most impoverished site by all measures.

Table 7.8 summarizes the vertical distribution of the soil macrofauna across the 7 Jambi sites. Abundance and biomass are notably concentrated in the top 10 cm of the mineral soil, so that the particular effects of disturbance at this level, whether positive or negative, may be the primary factor determining the responses of soil animals. Sample sizes were considered too small to permit site by site comparisons of the vertical distribution of each group; however, the data are available for such an analysis (not shown). Two ways ANOVA after log transformation indicates a significant interaction between sites and strata for termites and earthworms (Table 7.9).

Table 7.9 shows the results of all ANOVA tests carried out on the soil macrofaunal data. *Post hoc* pairwise comparisons of abundance and biomass between sites are shown in Tables 7.10 and 7.11, respectively. No widely accepted method of statistical testing exists for soil macrofaunal data, indeed such data are relatively rarely presented even with confidence limits or other indications of variance. Table 7.9 demonstrates a reasonable correspondence between the results of non-parametric and parametric analyses; however, ant abundance and biomass were not significantly different between sites or strata in one-way ANOVAs. Other groups differed overall between sites and strata in both abundance and biomass.

Pairwise comparisons of macrofaunal abundance in sites by Mann-Whitney showed significant differences in 19 out of the 21 possible pairings. Termites were significantly different in 7 comparisons, ants in 7 (of which 1 was unique, i.e. not reflected by other groups), all macrofauna in 10 (of which 2 were unique) and earthworms in 13 (of which 4 were unique). This suggests that earthworm abundance and total macroarthropod abundance were more sensitive in discriminating between sites than ant or termite abundances alone. Pairwise comparisons of macrofaunal biomass showed significant differences in 18 of the possible 21 pairings. Termite biomass was significantly different in 7 comparisons (of which 2 were unique), ant biomass in 4 comparisons (of which 1 was unique), all macrofauna in 8 comparisons (of which 2 were unique) and earthworm biomass in 5 comparisons (of which 5 were unique). Total macroarthropod and earthworm biomass, therefore, were also more sensitive site discriminators than ant or termite biomass alone.

Table 7.6

Summary of abundance data for soil macrofauna across a forest disturbance gradient in Jambi Province, Central Sumatra. Numerical densities are given as nos. m⁻², based on 5 monoliths per site, spaced along a 40 m transect. For geometric means, data are transformed as log₁₀(x+1), then back-transformed. 95% confidence limits (C.Ls.) are given for the geometric means. Arithmetic total is the sum of means.

Abundance parameters	BS 1 Primary forest	BS 3 Logged-over forest	BS 6 <i>Paraserianthes</i> tree plantation	BS 8 <i>Hevea</i> (rubber) plantation	BS 10 Jungle rubber	BS 12 Degraded <i>Imperata</i> grassland	BS 14 Cassava garden
Ants							
Arithmetic mean	352	522	550	134	541	80	48
Geometric mean	23	239	223	17	226	15	6
95% C.Ls.	1-1348	28-2004	24-2065	1-529	24-2123	1-833	1-131
Termites							
Arithmetic mean	2892	163	512	128	211	3	26
Geometric mean	971	65	47	11	25	2	10
95% C.Ls.	190-4966	12-364	1-1923	2-201	2-1107	0-8	0-124
All macroarthropods							
Arithmetic mean	3668	713	1312	397	833	86	160
Geometric mean	2455	331	630	346	512	30	148
95% C.Ls.	630-9120	86-788	184-2152	177-679	219-1202	2-429	86-253
Earthworms							
Arithmetic mean	3	6	195	35	576	263	102
Geometric mean	2	2	186	6	565	14	53
95% C.Ls.	1-8	1-14	116-297	1-123	428-743	2-103	12-228
Arithmetic total	3671	619	1507	432	1406	112	262

Table 7.7

Summary of biomass data for soil macrofauna across a forest disturbance gradient in Jambi Province, Central Sumatra. Biomass densities are given as g m^{-2} , based on 5 monoliths per site, spaced along a 40 m transect. For geometric means, data are transformed as $\log_{10}(\text{mg}+1)$, then back-transformed. 95% confidence limits (C.Ls.) are given for the geometric means. Arithmetic total is the sum of means.

Biomass parameters	BS 1 Primary forest	BS 3 Logged-over forest	BS 6 <i>Paraserianthes</i> tree plantation	BS 8 <i>Hevea</i> (rubber) plantation	BS 10 Jungle rubber	BS 12 Degraded <i>Imperata</i> grassland	BS 14 Cassava garden
Ants							
Arithmetic mean	0.35	0.29	4.89	0.10	0.86	0.03	0.34
Geometric mean	0.02	0.19	0.35	0.02	0.24	0.01	0.022
95% C.Ls.	<0.01-1.43	0.05-0.72	0.01-9.86	<0.01-0.43	0.02-3.09	<0.01-0.16	<0.01-1.22
Termites							
Arithmetic mean	5.59	0.09	0.59	0.07	0.49	<0.01	0.02
Geometric mean	2.77	0.10	0.47	0.06	0.35	<0.01	0.02
95% C.Ls.	0.09-14.67	0.01-0.25	0.01-1.50	0-0.22	0-1.38	0-0.012	0-0.06
All macroarthropods							
Arithmetic mean	8.99	1.89	5.79	2.27	6.08	0.64	0.67
Geometric mean	5.08	1.82	2.13	1.55	3.99	0.44	0.66
95% C.Ls.	1.23-20.68	1.09-2.80	0.12-7.79	0.01-5.61	0.67-13.89	0.01-1.76	0.38-1.00
Earthworms							
Arithmetic mean	0.03	0.06	11.42	0.77	60.16	0.83	4.67
Geometric mean	0.01	0.06	8.40	0.53	33.59	0.12	2.79
95% C.Ls.	<0.01-0.05	<0.01-0.09	2.21-26.49	<0.01-2.18	11.92-91.81	0.04-1.22	1.11-11.03
Arithmetic total	9.02	1.95	17.21	3.04	66.24	1.47	5.34

Table 7.8

Summary of vertical distribution of invertebrate soil macrofauna in a forest disturbance gradient in Jambi province, Central Sumatra, with statistical analysis of transformed data by parametric analysis of variance (ANOVA). For geometric means data are transformed as $\log_{10}(x+1)$ for abundance and $\log_{10}(mg+1)$ for biomass, then back-transformed. 95% confidence limits (C.Ls.) are given for the geometric means. ns, not significant.

Population parameter	Litter layer	0-10 cm	10-20 cm	20-30 cm	ANOVA between strata	
					F _(3,16)	P
ABUNDANCE, nos m⁻²						
Ants						
Geometric mean	52	136	24	4	2.39	ns
95% C.Ls.	20-134	81-230	8-68	2-75		
Termites						
Geometric mean	15	80	44	4	2.30	ns
95% C.Ls.	3-64	43-148	24-78	1-50		
All macroarthropods						
Geometric mean	184	343	77	38	5.60	<0.01
95% C.Ls.	143-237	153-767	52-119	14-111		
Earthworms						
Geometric mean	0	82	1	0	36.47	<0.001
95% C.Ls.	-	47-138	1-7	-		
BIOMASS, g m⁻²						
Ants						
Geometric mean	0.04	0.21	0.03	0.04	1.28	ns
95% C.Ls.	0.01-0.12	0.05-0.92	0.01-0.12	0.01-0.12		
Termites						
Geometric mean	0.06	0.43	0.06	0.03	3.94	<0.05
95% C.Ls.	0-0.14	0.11-1.45	0.03-0.11	0-0.08		
All macroarthropods						
Geometric mean	1.12	1.17	0.23	0.18	8.45	<0.005
95% C.Ls.	0.62-1.97	0.57-2.28	0.12-0.34	0.09-0.32		
Earthworms						
Geometric mean	0	9.67	0.04	0	489.9	<0.001
95% C.Ls.	-	7.82-11.88	0-0.10	-		

Table 7.9
Summary of parametric and non-parametric ANOVA on invertebrate soil macrofaunal abundance and biomass
from 4 horizon levels and 7 sites in a forest disturbance gradient. ns, not significant.

Population parameter	One-way parametric ANOVA between sites ^a	One-way parametric ANOVA between strata ^b	Two-way parametric ANOVA ^c		Kruskal-Wallis non- parametric ANOVA ^d between sites
			Between sites	Between strata sites and strata	
Ant abundance	ns	ns	p<0.025	p<0.001	ns
Ant biomass	ns	ns	p<0.05	p<0.025	ns
Termite abundance	p<0.005	ns	p<0.001	p<0.001	p<0.025
Termite biomass	p<0.025	p<0.05	p<0.001	p<0.001	p<0.025
All macroarthropods abundance	p<0.005	p<0.01	p<0.001	p<0.001	p<0.005
All macroarthropods biomass	p<0.05	p<0.005	p>0.001	p<0.001	p<0.025
Earthworm abundance	p<0.001	p<0.001	p<0.001	p<0.001	P<0.005
Earthworm biomass	p<0.001	p<0.001	p<0.001	p<0.001	P<0.005

^aall strata combined for each monolith and data log transformed.

^beach stratum averaged across 7 sites and data log transformed.

^cstrata treated as replicate samples in each site and data log transformed.

^duntransformed data.

Table 7.10

Matrix summary of differences between treatments (sites) for invertebrate soil macrofaunal abundance across a forest disturbance gradient in Jambi Province, Central Sumatra. Groups are shown which are significantly different in pairwise comparisons of sites by one-tailed Mann-Whitney. * $p < 0.05$; ** $p < 0.025$; *** $p < 0.005$. Numbers in brackets indicate the site with the greater abundance.

BS1					
BS3	Termites ^{**} (1) Macroarthropods ^{**} (3)				
BS6	Earthworms ^{***} (6)	Earthworms ^{***} (6)			
BS8	Termites ^{**} (1) Macroarthropods ^{**} (1)	-	Earthworms ^{**} (6)		
BS10	Termites ^{**} (1) Macroarthropods ^{**} (1) Earthworms ^{***} (10)	Earthworms ^{***} (10)	Earthworms ^{***} (10)	Ants [*] (10) Earthworms ^{***} (10)	
BS12	Termites ^{***} (1) Macroarthropods ^{***} (1) Earthworms [*] (12)	Ants [*] (3) Termites ^{**} (3)	Ants [*] (6) Termites [*] (6) Macroarthropods ^{**} (6) Earthworms ^{***} (6)	Macroarthropods ^{**} (8) Ants [*] (10) Macroarthropods ^{**} (10) Earthworms ^{***} (10)	
BS14	Termites ^{***} (1) Macroarthropods ^{***} (1) Earthworms ^{**} (14)	Ants [*] (3) Earthworms ^{**} (14)	Ants [*] (6)	Macroarthropods ^{**} (8) Ants [*] (10) Macroarthropods ^{***} (10) Earthworms ^{***} (10)	-
	BS1	BS3	BS6	BS8	BS10
					BS12

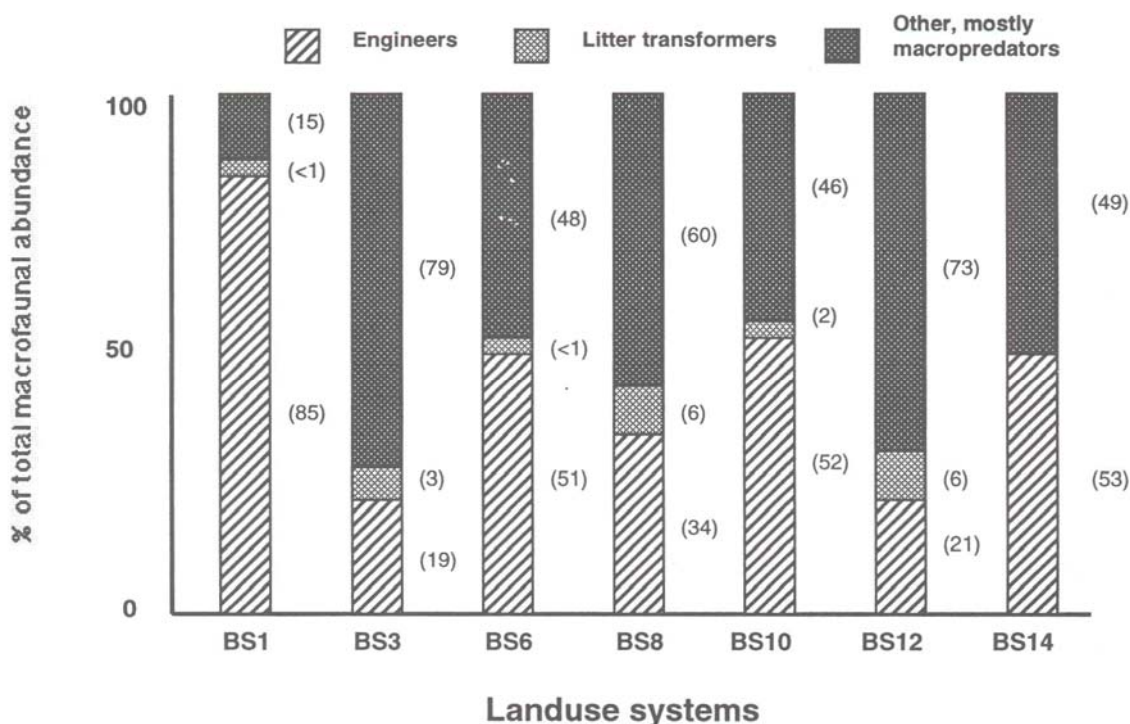
Table 7.11

Matrix summary of differences between treatments (sites) for invertebrate soil macrofaunal biomass across a forest disturbance gradient in Jambi Province, Central Sumatra. Groups are shown which are significantly different in pairwise comparisons of sites by one-tailed Mann-Whitney. * $p < 0.05$; ** $p < 0.025$; *** $p < 0.005$. Numbers in brackets indicate the site with the greater biomass.

BS1						
BS3	Termites ^{**} (1) Macroarthropods [*] (1)					
BS6	Earthworms ^{***} (6)	Earthworms ^{***} (6)				
BS8	Termites ^{***} (1)	Ants [*] (3)	Earthworms ^{***} (6)			
BS10	Termites [*] (1)	-	-	Earthworms ^{***} (10)		
BS12	Termites ^{***} (1) Macroarthropods ^{**} (1)	Ants ^{**} (3) Termites ^{***} (3)	Ants [*] (6) Termites [*] (6) Macroarthropods [*] (6) Earthworms ^{***} (6)	Macroarthropods [*] (8) Ants [*] (10) Macroarthropods [*] (10) Earthworms ^{***} (10)		
BS14	Termites ^{***} (1) Macroarthropods ^{***} (1)	Macroarthropods ^{**} (3)	Earthworms [*] (6)	-	Macroarthropods ^{***} (10) Earthworms ^{**} (10)	Earthworms [*] (14)
	BS1	BS3	BS6	BS8	BS10	BS12

Figs. 7.10 and 7.11 represent attempts to examine the functional composition of the soil macrofauna across the seven sites, made on the basis of abundance data means. Unfortunately, we do not have biomass totals for macroarthropods other than ants and termites itemized by taxon, so it is not possible to make the same classifications based on biomass. In Figure 7.10 (Scheme 1) animals are allocated to one of three functional groups reflecting feeding and ingestion habits: engineers, litter transformers and macropredators. Unpigmented worms and termites were designated as engineers; pigmented earthworms, diplopods, crickets, woodlice and cockroaches as litter transformers; and the rest (including all ants) as macropredators. This is a fairly easy classification to make from the available data, but it does involve some over-simplification for certain groups (for example not all ants are predatory). Generic names were available for some earthworms recovered from monoliths, which assisted the allocation of specimens between the engineer and litter transformer category.

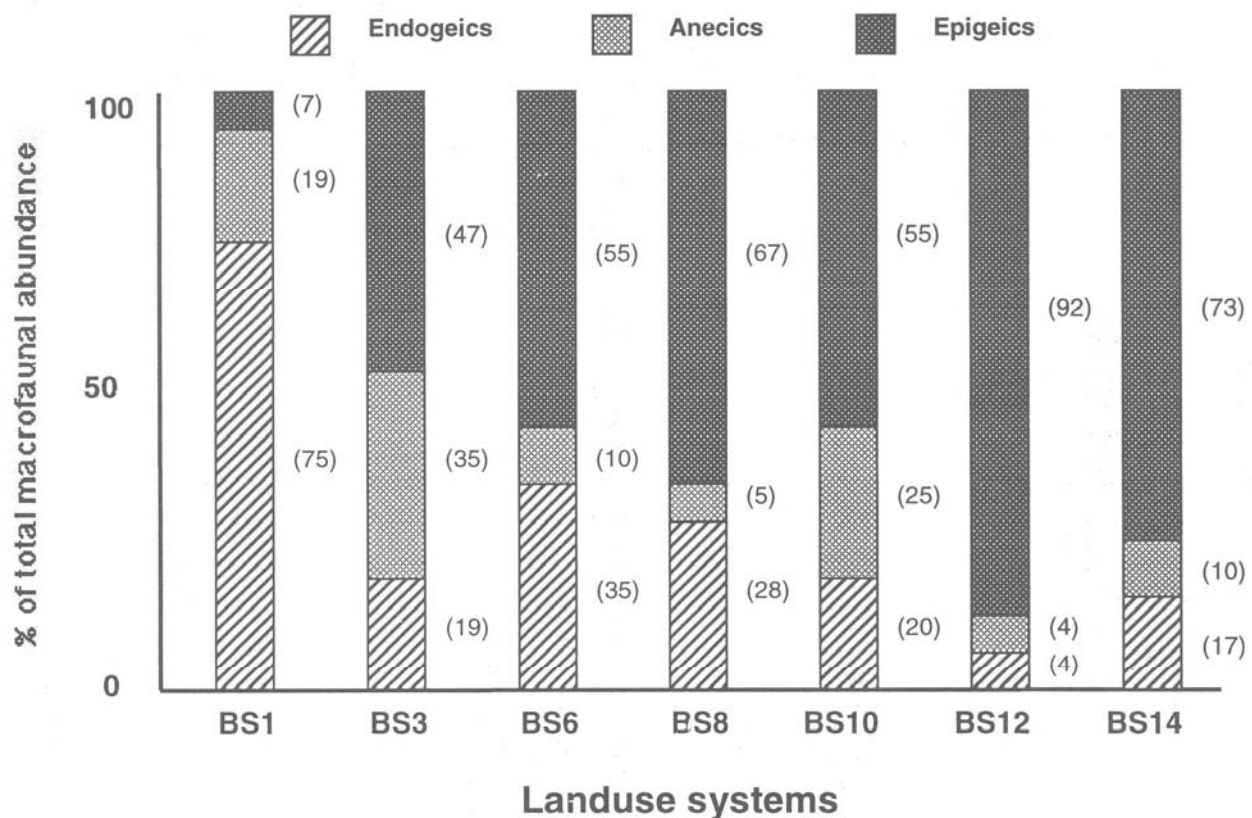
Figure 7.10. Proportion (by abundance) of macrofaunal functional groups 1



In this scheme there is no clear trend across the gradient, except that disturbed sites are relatively richer in macropredators and impoverished in engineers. In Figure 7.11 (Scheme 2), animals are allocated to one of three functional groups reflecting feeding habits and nesting/burrowing sites: epigeic (non-burrowing, living on the surface), anecic (burrowing but feeding on the surface) and endogeic (burrowing and feeding underground). Allocation is more difficult, as it requires making distinctions between different types of termites and ants, the two groups generally with the greatest abundance. Termites from the monoliths were not identified to species, so it is assumed that those found feeding in the litter are anecic and those feeding in the soil itself are endogeic. The epigeic category is not recognized for termites. For ants, all specimens were identified at least to genus level, and allocation of each to nesting type (above-ground or below-ground) was done anecdotally (by consulting experts) or from a literature search. Above-ground nesters are considered epigeic and below-ground nesters anecic. The endogeic category is not recognized in ants. For this scheme, Figure 7.11 clearly shows an

increase in the relative abundance of epigeic forms across the gradient, with the concomitant reduction of endogeics. Overall, disturbance diminishes the proportion of engineers and increases the proportion of epigeic invertebrates. Some amelioration of these trends is evident in the recovering forested sites BS6, BS8 and BS10.

Figure 7.11. Proportion (by abundance) of macrofaunal functional groups 2.



7.7. Synopsis

Figure 7.12 shows means for taxonomic diversity score (defined as in Figure 7.6, with the addition of the number of earthworm species and morphospecies), total abundance and total biomass of soil macrofauna across the seven sites (abundance and biomass presented as geometric means). The trend of diminishing diversity, ameliorated only for BS10, jungle rubber, is the most obvious feature. Surges of abundance and biomass are associated with sites BS6, *Paraserianthes* plantation and BS10, jungle rubber, reflecting large earthworm populations and/or an abundance of ants. A biomass mean of almost 40 g m⁻² (geometric mean) is a feature of the jungle rubber site, and easily exceeds the biomass of any other site. Abundance is greatest in intact rainforest, reflecting the high numerical density of termites, and their reduction in other sites.

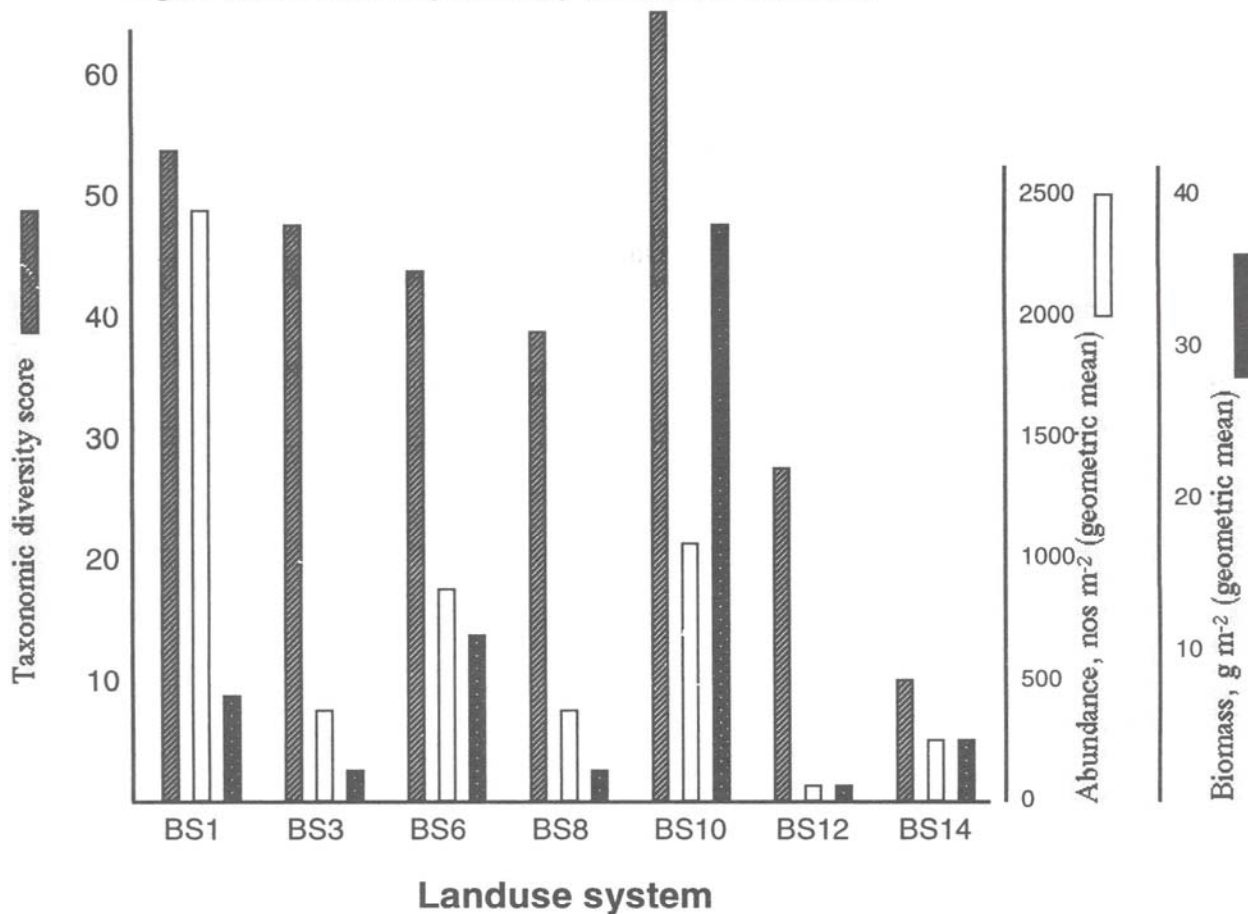
7.8 Discussion:

7.8.1 Methods and relevance to Rapid Biodiversity Assessment:

The sampling methods represent the consensus of best practice agreed in 1997 by the Below-Ground Working Group of the Alternatives to Slash-and-Burn Project (ASB). As far as

possible, the sampling addresses groups which are known ecosystem engineers (termites, ants and earthworms) and litter transformers (millipedes, woodlice, some coleopterous larvae), rather than surrogate groups or so-called "indicators" with dubious predictive value (see Lawton *et al.*, 1998). In the case of termites, ants and earthworms, the objective is to obtain resolution at species level, and thus contribute elements of true biodiversity to the dataset. The addition of pitfalls is a recent revision of ASB methodology and should assist the achievement of a more representative sampling of ants. Termite species richness is addressed through 100 x 2m qualitative transects (see report by Jones *et al.*, section 8), which take account of the known spatial heterogeneity of termites in forest or forest-derived systems and help to mitigate the variability of data from shorter transects on groups with typically patchy distributions.

Figure 7.12. Biodiversity summary (earthworms included)



Monolith dissection is still the only approach to the sampling of earthworms, and the disturbance involved is known to result in the escape of deep-burrowing species (James, 1996). The various other techniques of earthworm sampling available, for example chemical extraction, vibrational displacement and electrical shocking are considered too cumbersome or environmentally unacceptable for Rapid Biodiversity Assessment, but estimates based on cast frequency and density may have some potential (Hauser *et al.*, 1997; Norgrove *et al.* 1998; Hauser and Asawalam, 1998). Dry heat extractions, for example, using Berlese, Tullgren or Kempson funnel systems, are suitable for a wide variety of macrofauna (including earthworms) and mesofauna, but are limited by the time required for drying (24-48 hours) and the relative bulkiness and lack of portability of the equipment required, and, thus are not suited for concurrent or sequential rapid assessments over a large geographical range. There is a notable learning-curve effect in the digging of soil monoliths, so that 5 pits can normally be completed

comfortably in one day, though sorting extends the time required for each landuse to two days. Similarly, the qualitative termite transect requires 20 man-hours of effort, which usually translates into two days of sampling per land use, including sorting and cleaning of specimens. Neither monoliths nor termite transects can be completed in heavy rain, so a two-day sampling period is really the minimum that can be allocated per land use. The wisdom of starting work early in the day, when light is generally good and downpours less frequent is self-evident. ASB recommends 10 monoliths per transect, but there must be some doubt whether this is a realistic target, since the sorting of the resulting soil samples is a rate-limiting step. It is normally satisfactory to have 2-4 people working on the monolith digging and sorting; a larger number adds to the disturbance of the site and may interfere with other sampling activities taking place concurrently. ASB has now standardized the size of monoliths at 25x25x30cm. 30cm is considered a satisfactory depth, as only a relatively small component of the macrofauna is assumed active below this level in tropical forest zones. However, it should be noted that the assumption will not necessarily be valid in savanna systems.

Macrofauna are only one of five groups of soil organisms which ASB now recommends should be sampled for an adequate assessment of ecosystem function; the others are nematodes, nitrogen-fixing bacteria, mycorrhizal fungi and "decomposers" (i.e. microorganisms having a significant role in the nutrient cycling). Field sampling for these other groups is normally straightforward and rapid, consisting of coring and digging operations of various kinds, but subsequent extraction, cultivation, bioassay and strain-typing procedures impose severe constraints on technical and financial resources (Swift and Bignell, 1999). ASB recognizes that there will be variation in the degree of resolution of taxonomic identity and functional group allocation between the five major target groups of soil biota. This is not considered a problem as long as comparisons are made at the same level of resolution. Standard units have been agreed for expressing data at various levels and this report reflects those agreed for macrofaunas (basically by taxonomic group, functional group, abundance, biomass and biodiversity indices). In the latest (1997) revision of below-ground methods, ASB recommends new functional group classifications for the soil biota as a whole and for termites in particular:

Table 7.12
Functional Group Classifications for the Soil Biota and Termites

<u>Soil biota</u>	<u>Termites</u>
ecosystem engineers	soil-feeders
litter transformers	wood-feeders
macropredators	wood/soil interface feeders
micropredators	grass-feeders
microsymbionts	lichen-feeders
decomposers	fungus-growers

Additional new functional group classifications are to be considered for taxa where the current classifications are considered unsatisfactory, especially earthworms and beetles.

7.8.2 Significance of results at regional and global level:

The literature contains a few reports of tropical ant abundance and biomass (see above). The data obtained from Pasir Mayang are broadly in agreement with expectations. The study of soil

fauna on Mount Mulu (Sarawak) by Collins (1980) gave ant abundance in the lowland forest control site at 130 m elevation as 509 m⁻² (cf. 352 in the present study) and ant biomass as 0.445 g m⁻² (cf. 0.346 in the present study).

Globally, estimates of termite abundance for savannas (>50 to <4000 m²) overlap with those for agricultural systems (>1500 to <6000 m²), secondary forests/plantations (>100 to <10,000 m²), and primary forests (>1000 to <7000 m²). The reliability of individual estimates depends on the rigour of the sampling protocols, but the highest numerical densities are clearly associated with tropical forests. Regional/habitat biomass estimates follow abundance estimates closely, and vary from less than 1 g fresh weight m⁻² to a maximum value of 130 g in a near-primary site of the Mbal Mayo Forest Reserve (Eggleton *et al.*, 1996). Most site values, however, are less or much less than 10 g m⁻², with the highest values in forest systems. Broadly, the numerical and biomass densities of termites are matched with species diversity. Relatively few studies have compared termite abundance and biomass with that of other soil invertebrates in the same systems, but the conclusions of Collins *et al.* (1984) are probably typical of tropical forests: ants and termites have greater abundance than all other macrofauna put together, and also greater biomass than other macrofauna, excepting earthworms in particularly favourable conditions such as base-rich or neutral soils with high organic content (see also Fogden, 1977; Collins, 1980; 1989; Marsh and Wilson, 1981; Lavelle *et al.*, 1997). Given these data, termites may constitute as much as 10% of all animal biomass in the tropics (Wilson, 1993), and as much as 95% of soil insect biomass (Watt *et al.*, 1997). Estimated termite biomass in different biomes is given by Bignell *et al.* (1997). The relative biomass contribution of termites depends on where they are sampled, as the absolute biomass in African forests is considerably higher than in Asian forests (Table 7.1), declining on a rough longitudinal gradient to <1 g m⁻² in rainforests in Australia and Papua New Guinea.

Termite abundance, biomass and species richness are generally reduced when forest is cleared (Collins, 1980; Wood *et al.*, 1982; Eggleton *et al.*, 1995; 1996). However, in some cases temporary nutrient enrichment from cut and abandoned vegetation (Eggleton *et al.*, 1995; 1996; 1997), as well as the availability of termite species from adjacent savannas to colonize disturbed areas (Wood *et al.*, 1982; cf. Eggleton *et al.*, 1996) may obscure overall diversity reductions, as true forest species are replaced with others (i.e. the so-called "trash species"). Less extreme disturbances, such as foraging and hunting by local people, selective logging, conversion to tree plantation, or small-scale subsistence agriculture or agroforestry produce smaller effects on abundance and biomass (and in some cases no effects), but there may be a turnover of species with a tendency for wood-feeding forms to replace soil-feeders. In addition, there may be a lag between the onset of moderate disturbance and noticeable changes in assemblage composition, as colonies can survive for a number of years after disturbance (Eggleton *et al.*, 1996; 1997). Feeding group shifts are probably mostly due to changes in canopy cover, with concomitant effects on soil humidity, but both organic C and total N in soils may be reduced along disturbance gradients (Eggleton *et al.*, 1996). Lawton *et al.*, (1998) calculated a modified form of Whittaker's β index of species turnover (the β -2 index, see Harrison *et al.*, 1992) for termites in five sites along a disturbance gradient in the Mbal Mayo Forest Reserve ranging from near primary forest to an area completely cleared by bulldozer. This index varies from 0 (no turnover) to 100 (every site has a unique set of species). The value for termites was 28.8, lower than for beetles and canopy ants, but above butterflies, birds, litter ants and soil nematodes.

7.8.3 Needs for further work:

Further sampling in sites at both the light and heavy end of the disturbance gradients would be helpful to confirm the apparent benefit to ants and earthworms conferred by intermediate levels of disturbance. Transects with 6, 8 and 10 monolith dissections should also be attempted to see whether slightly or substantially larger sample sizes assist the descriptive and hypothesis-testing statistics, and therefore provide better site-to-site resolution.

7.9 Summary:

7.9.1 Assessments of species richness, abundance and biomass:

These were compared across of range of forest and forest-derived sites representing a disturbance gradient in or adjacent to the Pasir Mayang Forest Reserve, Jambi Province, Sumatra in November 1997. A combination of pitfall traps, dissected soil monoliths (to 30 cm depth) and transects of 100x2 m was used (variously) to assess species richness of ants, termites, other macroarthropods and earthworms; abundance and biomass of these groups were estimated from 5 monoliths (only) arranged along a 40 m transect.

7.9.2 Species richness, abundance and biomass according to land-use type:

Ants

57 species (Including some morphospecies) from 8 subfamilies were sampled overall, with the highest species richness (33) and taxonomic richness (6 subfamilies) associated with the jungle rubber site (BS10). Highest abundance (arithmetical mean 550 ants m⁻²) and highest biomass (arithmetical mean 4.889 g m⁻²) were recorded in the *Paraserianthes* tree plantation (BS6). Rubber plantation (BS8), alang-alang grassland (BS12) and Cassava garden (BS14) were generally poor sites for ants. Primary forest (BS1) and logged-over forest (BS3) were sites of intermediate species richness, abundance and biomass.

Termites

48 species (including some morphospecies) from 5 subfamilies were sampled overall, with the highest species richness (30) associated with the intact rainforest (BS1), which also had the highest abundance (2892 m⁻²) and biomass (5.59 g m⁻²), Rubber plantation (BS8), alang-alang grassland (BS12) and Cassava garden (BS14) were generally poor sites for termites, with jungle rubber (BS10), logged-over forest (BS3) and *Paraserianthes* tree plantation intermediate for species richness, abundance and biomass. See section 8 of this report.

Other macroarthropods

Arthropods other than ants and termites were of some significance in abundance and biomass totals in several sites, notably intact forest (BS1), logged-over forest (BS3), rubber plantation (BS8) and Cassava garden (BS14).

Earthworms

Earthworms had low diversity in Jambi sites, but were numerous and had high biomass in *Paraserianthes* tree plantation (BS6) and jungle rubber (BS10). In the latter site, numerical density was 576 m⁻² and biomass density 60.16 g m⁻² (both arithmetic means).

7.9.3 Variability in data collection:

This was high. Transformation of data as log₁₀ (x+1) and the use of non-parametric statistical analysis were considered essential. Many statistically significant differences were found between sites, with earthworms and all macroarthropods being better discriminators at intermediate levels of disturbance. Termites were significantly different between the richest and poorest sites. Abundance and biomass of ants did not differ significantly across the site gradient as a whole; however, it may still be concluded that ant activity and biodiversity are high in sites that are botanically diverse.

7.9.4 Surface concentration:

Ants, termites and earthworms were concentrated in the top 10 cm of the soil profile, more or less in all sites, to such an extent that sampling of litter and of the soil profile below 10 cm is probably unnecessary. The top 10 cm may, consequently, be a crucial zone for ecosystem processes mediated by the soil fauna, and the effects of disturbance on this layer probably determine the responses of the soil macrofauna as a whole.

7.9.5 Future studies.

These should employ 6-10 monoliths per transect; however the logistical and manpower requirements of such intensive sampling are very demanding.

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SECTION 8: TERRESTRIAL INSECTS: TERMITES

SPECIES RICHNESS, FUNCTIONAL DIVERSITY AND RELATIVE ABUNDANCE OF TERMITES UNDER DIFFERENT LAND USE REGIMES

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8.1 Introduction:

Indonesia contains more rain forest than any other country in the Asia-Pacific region, and is currently experiencing rapid changes in land use, although exact figures are difficult to obtain. It has been estimated that Indonesia lost between 0.5% to 0.8% of its total closed forest cover per year during the first half of the 1980s (Groombridge, 1992). The equatorial island of Sumatra is the third largest island in the Indonesian archipelago. The island's lowland forests have been heavily logged and large areas are seriously degraded (Riswan & Hartanti, 1995). Sumatra has a relatively high and rising population density and, under growing socioeconomic pressure, large areas of forest have been lost to commercial logging, permanent or shifting subsistence agriculture, or cleared for plantations and transmigration schemes (Whitten *et al.*, 1984). By 1991, Collins *et al.* estimated about 49% of Sumatra's original forest cover remained, although very little was pristine. In Jambi Province, Central Sumatra, during a six-year period up to 1992, about 8% of primary forest was converted to secondary forest, another 5% was converted to agricultural land, while about 0.3% became grassland (Murdiyarso & Wasrin, 1995).

Much of Sumatra is now a mosaic of different land-use types. Fragments of primary forest remain within large areas of impoverished logged-over and secondary forest, while various silvicultural systems, including vast industrial plantations of oil palm, rubber and fast-growing soft wood tree species, dominate the landscape. Indigenous agroforestry systems vary from cash-crop monocultures to complex multispecies and multi-storey gardens (Aumeeruddy & Sansonnens, 1994). The 'jungle rubber' system is a man-made diverse agroforestry system with a high concentration of rubber trees, which has a forest-like structure when in its mature phase and provides fruits, fuelwood and timber, as well as an income from latex (Gouyon *et al.*, 1993). Intensively farmed and burnt land can be exhausted of nutrients and often reduced to alang-alang (*Imperata cylindrica*) grassland. Some transmigration farming systems set up on former forested lands have been shown to be unsustainable with the current level of resourcing (Holden *et al.*, 1995).

Within the context of sustainable agricultural production under conditions of rapid land-use change, declining forest cover, loss of biodiversity and an increasing human population, research should be focused on those groups of organisms that contribute directly to plant productivity and their response to changes in land use. The importance of invertebrate macrofauna to the promotion of tropical soil fertility has been stressed in recent reviews

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(Fragoso *et al.*, 1993; Lavelle *et al.*, 1994; Garnier-Sillam & Harry, 1995; Nash & Whitford, 1995; Brussaard & Jumas, 1996; Wood, 1996). The distribution, protection and stabilization of organic matter, the genesis of soil structure, humification, the release of immobilized N and P, the improvement of drainage and aeration, and the increase in exchangeable cations have all been demonstrated in soils modified by termites and earthworms (Lavelle *et al.*, 1997). In African systems, forest clearance depletes termite abundance and diversity (Wood *et al.* 1982; Eggleton *et al.*, 1995; 1996) but similar studies are not yet available from Asia.

Termites are a key functional group of animals in the tropics and can achieve very high populations. For example, in the forests of southern Cameroon, termites are the most numerous of all insect groups (Watt *et al.*, 1997) with abundances of up to 10,000 m⁻², and live biomasses of 100 g m⁻² (Eggleton *et al.*, 1996). As the dominant arthropod detritivores, termites are important in decomposition processes (Wood & Sands, 1978; Collins, 1983) and thereby play a central role as mediators of nutrient and carbon fluxes (Jones, 1990; Abbadie *et al.*, 1992; Lawton *et al.*, 1996; Bignell *et al.*, 1997). However, being social insects, termites tend to concentrate around colony centres. These centres are often scattered unevenly through the habitat (for example, see Baroni-Urbani *et al.*, 1978; Gontijo & Domingos, 1991), leading to extreme heterogeneity of individuals and populations.

Given the ecological importance of termites, there is a need to characterize termite assemblage structure within and between sites. As a consequence of their highly patchy spatial distribution, combined with the many and varied field sampling regimes adopted by previous researchers, it has not been possible to use the existing data to make reliable direct comparisons of termite diversity and abundance between sites (see Eggleton & Bignell, 1995). As Sutton & Collins (1991) emphasised, it is necessary to develop and test standardised sampling methods that can be applied easily throughout the tropics. To this end, a standardised transect sampling method designed to measure termite species richness and functional diversity in tropical forests has been developed. The protocol has been used in Cameroon (Eggleton *et al.*, 1995), Thailand (Davies, 1997), Peninsular Malaysia (Jones & Brendell, in press) and two sites in Sabah; Maliau Basin (Jones *et al.*, in press) and Danum Valley (Eggleton *et al.*, in press).

8.2 Aims:

- To assess the termite assemblage under different land uses. The first aim is to measure species richness, functional diversity and the relative abundance of termites under seven different land-use regimes in Jambi Province, central Sumatra. The seven land uses are listed in Section 8.4. By using a standardised sampling protocol, the results from each site can be directly compared, both within this study and with other locations where the transect method has been employed.
- The responses of termites to land-use changes. If the history of exploitation at each of the Jambi study sites is known, it may be possible to arrange the sites along a 'land-use intensification gradient' or into one or more 'land-use sequences'. By assuming that all the Jambi sites were originally forested and had similar termite assemblages, it will be possible to hypothesise about the response of termites to changes in land use. This assumes the primary assumption is correct.
- The search for correlates between termites and other organisms. The multidisciplinary approach adopted in this project is rare in ecological field studies. In all, seven groups of organisms have been studied in the same sites in Jambi Province. These groups are:

vascular plants, mammals, birds, termites, butterflies, soil macrofauna (including ants and earthworms), and selected canopy arthropod groups. The third aim is, therefore, to investigate and identify possible correlates between termites and the other target taxa studied in this project.

8.3 Personnel:

Principal Investigator:

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Assisted by:

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Dr Suryo Hardiwibowo (biologist) - Gadjah Mada Universitas, Yogyakarta, Indonesia

8.4 Methods:

Seven sites in Jambi Province were studied during November 1997, each site representing a distinct land-use type. The seven land-use types and the dates sampled are listed below. One transect was run in each land-use type as follows:

Land use type	Site code	Date sampled
1. <i>Paraserianthes</i> plantation	BS 6	19 + 20 Nov. 1997
2. Primary forest	BS 1	21 + 22 Nov. 1997
3. Logged-over forest	BS 3	22 + 23 Nov. 1997
4. <i>Imperata</i> grassland	BS 12	24 Nov. 1997
5. Cassava garden	BS 14	24 + 25 Nov. 1997
6. Jungle rubber	BS 10	26 + 27 Nov. 1997
7. Rubber plantation	BS 8	27 + 28 Nov. 1997

8.4.1 The standardized transect sampling method:

All transects were co-located with a 40x5m strip transect used to sample vegetation and for other multidisciplinary studies. Each termite transect was 100 m long and 2 m wide, divided into 20 contiguous sections (each 5 m x 2 m), and numbered sequentially. Each section was sampled by two people for 30 minutes (a total of one hour of collecting per section). In order to standardise sampling effort, the trained collectors worked steadily and continuously during the 30 minute collecting period. In each section the collectors searched the following microhabitats which are common sites for termites: surface soil to 5 cm depth; accumulations of litter and humus at the base of trees; the inside of dead logs, tree stumps, branches and twigs;

the soil within and beneath very rotten logs; all subterranean nests, mounds, carton sheeting and runways on vegetation, and arboreal nests up to a height of 2 m above-ground level.

The protocol was designed to offer a flexible approach to the sampling, whereby the collectors used their experience and judgement to search for, locate and sample as many species of termite in each section as time allowed. Specimens from each termite population encountered were sampled. All castes were collected if present, but priority was given to finding soldiers and workers. Termites were placed in vials labelled with the section number and filled with 80% ethanol.

In structurally complex habitats, i.e. with a relatively large above-ground biomass (such as forests and plantation systems), the collectors spend approximately half their collecting time searching the above-ground microhabitats described above. The remaining 15 minutes were used searching for termites in the soil. However, in the case of the *Imperata* grassland (BS 12) and the Cassava garden (BS 14) there was relatively little above-ground biomass. Within the transects in both systems there were no trees and virtually no dead wood or leaf litter. Therefore, in these land-use types (*Imperata* grassland and the Cassava garden) the collectors sampled only for 15 minutes (total collecting effort = 30 minutes) in each section. This procedure ensured that equal effort was given to searching for termites in the soil in each transect.

The transect sampling method provides a semi-quantitative measure of the relative abundance of termites based on the number of encounters or 'hits' with each species in a transect. A hit is defined as the recorded presence of a species in one section. Therefore, if a species is present in every section of a transect it will have a relative abundance score of 20. The number of hits per transect can then be used as an indicator of the relative abundance of termites occurring within a transect, as well as between transects. It gives no measure of the absolute abundance per unit area.

8.4.2 Identification of material:

During the field trip, great effort was taken to examine as much of the material as time allowed. This was made possible due to the microscope and light source provided by David Bignell. In the evenings, many hours were spent making provisional identifications. All samples with soldiers were identified to genus, and then morphospecies numbers were allocated. A working reference collection was maintained so that material from all transects could be cross-referenced and the morphospecies designations applied consistently. Many vials contained two or more species, and some of these were separated where time and accuracy allowed. Two groups of samples were not identified. The first were samples with workers (i.e. no soldier specimens collected). Workers are difficult and time consuming to identify as the mandibles must be dissected, and the structure of the gut must be examined, sometimes necessitating the removal and mounting of the enteric valve. The second group were genera in the *Subulitermes* complex. These are small termites whose taxonomy is ill-defined and that are difficult to identify.

It must be stressed that the results given in this report are based solely on the provisional identifications made during the field trip. At the Natural History Museum every sample will be examined again, and accurate species-level identifications will be made. By comparison with the museum's extensive reference collection (which contains approximately 16000 vials of identified material, plus about 1000 vials of type material), it will be possible to put specific

names on a large proportion of the Jambi collection. It is estimated that the identification work at the museum should take about 4 to 5 weeks [*note*: completed July 1998. eds. See Annex III, Table 11)

Functional groups:

Genera were assigned to one of five functional groups based on known feeding habits (see Collins, 1984; Eggleton *et al.*, 1996; Jones *et al.*, in press; Eggleton *et al.*, submitted), the shape of the molar plates of the worker mandibles (Deligne, 1966), and worker gut content analyses (Sleaforth *et al.*, 1996). The functional groups are;

- Soil-feeding: termites that feed on humus and mineral soil.
- Wood-feeding: termites that feed on dead wood.
- Soil/wood interface-feeding: termites that feed on extremely decayed wood that has lost its structure and become soil-like.
- Litter-feeding: termites that feed exclusively on leaf-litter and small items of woody trash.
- Epiphyte-feeding: *Hospitalitermes* is known to feed on lichens and other free living non-vascular plants which they graze from the surface of tree trunks (Collins, 1979; Jones & Gathorne-Hardy, 1995).

8.5 Preliminary results:

8.5.1 *Species richness:*

The preliminary sorting carried out during the Jambi field work produced a conservative total of 23 genera and 48 morphospecies for all seven land-use types (Annex III, Table 11). However, in addition to these taxa, the *Subulitermes* complex and many vials of workers await examination. The senior author speculates that these vials will possibly contain several genera plus between 3 to 10 species which can be added to the checklist. Members of the Apicotermatinae subfamily are rare in Southeast Asia but have been collected in transects run in Sabah (Eggleton *et al.*, in press) and Peninsular Malaysia (Jones & Brendell, in press). Within this subfamily the soldiers are absent or rare, however, specimens may be present in the vials of workers from Jambi.

Table 8.1 gives the list of morphospecies currently recorded from each transect. The preliminary identifications clearly show that the primary forest site is the most species rich, while the *Imperata* grassland and the Cassava garden sites are the most depauperate. The logged-over forest site and the agroforestry systems all have intermediate levels of species richness. Figure 8.1 displays the taxonomic composition of each transect sample. The Termitinae are the dominant subfamily in sites except the *Paraserianthes* plantation site and the Cassava garden system.

8.5.2 *Relative abundance:*

The number of hits (the presence of a species in a section) is recorded in Table 8.1. Termites are most abundant in the primary forest site and least abundant in the Cassava garden. The termites collected in this study fall into four feeding groups. Wood-feeding and soil-feeding species are relatively abundant in most transects, while epiphyte-feeders are rare and interface-feeders (those species that feed on extremely decayed soil-like wood) vary considerably in abundance among transects. Figure 8.2 displays the relative abundance of termites in each

functional group. Of notable interest is the high relative abundance of soil-feeders in the jungle rubber system, and their absence from the *Paraserianthes* plantation. Grass-harvesting species and taxa that feed exclusively on leaf-litter appear to be absent from the study sites.

8.6 Discussion:

It must be stressed that the results given in the table and figures are based on provisional identifications. Table 8.1 also lists the number of vials containing specimens of the *Subulitermes* complex and workers which still await examination, and suggest the possible extent of extra species and hits that may be added to each transect. While we are certain that the final results for most of the transects will vary in species richness and relative abundance from those presented here, the senior author is confident that the overall patterns are likely to be similar to those already evident in the preliminary results.

Our knowledge of the termite fauna of Sumatra is very limited and based on casual sampling (Holmgren, 1913-14; Oshima, 1923, John, 1925; Amir, 1975). Tho (1992) lists a total of 89 species from Sumatra, but this is certainly an underestimate. The development of comprehensive and rigorous sampling techniques produces much higher local species richness estimates than those given by casual collecting methods. For example, after extensive and widespread collecting, Thapa (1981) lists 103 species from Sabah. However, recent research in one area (Danum Valley, South-east Sabah) using transects and labour-intensive sampling regimes produced a checklist of 93 species (Eggleton *et al.*, in press; Homathevi *et al.*, in prep.). Therefore, it is highly likely our studies at Jambi will increase the Sumatran species list.

The transect method has been tested against known local termite faunas and shown to produce representative samples that are not significantly different in taxonomic or functional composition from their local assemblage (Jones & Eggleton, in prep.). The highest species richness found in Southeast Asian forests using the transect method is 33 species at Danum Valley (Eggleton *et al.*, in press). There is a reasonable possibility that the Jambi primary forest transect will exceed the Danum Valley species richness. Changes in the taxonomic and functional composition of the termite assemblages across the seven land-use types will be discussed in detail when the final data set is produced.

The preliminary results show a decline in termites species richness (Fig. 8.1) and relative abundance (Fig. 8.2) across the seven land-use types. Casual observations of the botanical features at each site by the authors suggested a positive relationship between termite species richness and physical complexity. It has been speculated that the degree of canopy closure appears to have a strong influence on termite diversity (Eggleton *et al.*, 1995, 1996). Preliminary results from Jambi show a very high correlation between termite relative abundance and the recorded basal area of woody plants ($r^2 = 0.95$; Gillison, pers. comm.; see also Annex II, Figure 1c). We await the dissemination of the vascular plant data to investigate whether there are significant correlates between the termite assemblages and the plant communities.

The efficiency of the transect method, based on the number of species collected per unit effort (number of days for one trained person to collect and identify samples) has already been calculated (Jones & Eggleton, in prep.). One transect takes one trained collector four days to complete. The material from one primary forest transect at Danum Valley takes one taxonomist about 10 days to sort and identify to species. Given the known levels of species richness and taxonomic difficulty associated with the termite fauna of primary forest in

Southeast Asia, we can estimate that 14 days' effort is required for one trained person to run one transect and identify the material. If we make the assumption that the Jambi primary forest transect will have a final richness of 33 species, this equates to an approximate cost of 2.4 identified species per person per day.

8.7 Conclusions:

With the completion of seven termite transects and the preliminary sorting, the field-based phase of the Jambi project can be considered a great success. When all the museum-based identification work is complete, the top set of material will be deposited at the Bogor Museum. A smaller reference collection will be retained by the Natural History Museum. The results of the termite transect study in Jambi will be written-up for publication in an international peer-reviewed journal. This paper will address the first two aims stated in this report, and it will also address partially the third aim (correlates between the termite assemblage and the vascular plant community). This latter line of research is perhaps the most exciting and important theme to be investigated in the Jambi termite project. For the first time it will be possible to relate termite diversity to measured plant parameters. The full set of final results will be sent to Dr Andy Gillison and CIFOR, and it is hoped that at least one joint paper will be produced which investigates correlates between all the groups of organisms studied at Jambi, and the potential usefulness of these groups as target taxa in rapid biodiversity assessment.

Acknowledgements

The authors would like to thank Dr Andy Gillison and Ir Nining Liswanti for organising the field work in Jambi and all the travel arrangements. In addition, we are grateful to the logistical support provided by CIFOR and ICRAF while in Indonesia.

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Table 8.1 Species checklist of termites collected from the seven land-use types in Jambi Province, central Sumatra, in November 1997.

Termites were collected using the standardised transect sampling protocol. One transect was run in each land-use type. Figures are the relative abundance of each species, based on the number of 'hits' of each species in a transect (the presence of a species in one section represents one hit). Functional group are: W = wood-feeders, I = soil/wood interface-feeders, S = soil-feeders, E = epiphyte-feeders

Species	Functional group	Primary forest (BS 1)	Logged forest (BS 3)	Jungle rubber (BS 10)	Rubber pltn. (BS 8)	Parase-ianthes (BS 6)	Imperata grassland (BS 12)	Cassava garden (BS 14)
KALOTERMITIDAE								
<i>Glyptotermes</i> sp.	W	-	-	-	1	-	-	-
RHINOTERMITIDAE								
<i>Coptotermes curvignathus</i>	W	1	1	1	3	1	-	-
<i>Coptotermes sepangensis</i>	W	-	-	-	-	4	-	-
<i>Coptotermes borneensis</i>	W	-	-	-	-	1	-	-
<i>Heterotermes tenuior</i>	W	1	-	-	-	-	-	-
<i>Parrhinotermes near minor</i>	W	-	-	1	-	-	-	-
<i>Parrhinotermes near sp. C</i>	W	-	1	-	-	-	-	-
<i>Schedorhinotermes javanicus</i>	W	1	-	7	-	7	-	-
<i>Schedorhinotermes sarawakensis</i>	W	1	-	-	-	9	-	-
<i>Schedorhinotermes tarakanensis</i>	W	6	7	4	1	-	-	-
<i>Schedorhinotermes</i> sp.	W	-	-	-	2	-	-	-
Species	Functional group	Primary forest (BS 1)	Logged forest (BS 3)	Jungle rubber (BS 10)	Rubber pltn. (BS 8)	Parase-ianthes (BS 6)	Imperata grassland (BS 12)	Cassava garden (BS 14)
TERMITIDAE								
Macrotermatinae								
<i>Macrotermes gilvus</i>	W	-	-	-	-	-	-	1
<i>Macrotermes</i> sp. 1	W	1	-	-	-	-	-	-
<i>Odontotermes denticulatus</i>	W	-	-	5	-	-	-	-
<i>Odontotermes sarawakensis</i>	W	10	9	-	-	-	-	-
<i>Ancistrotermes pakistanicus</i>	W	-	-	3	-	-	-	-
Termitinae								
<i>Prohamitermes mirabilis</i>	I	3	7	-	6	4	-	-
<i>Labritermes buttelreeperi</i>	S	-	-	1	2	-	-	-
<i>Globitermes globosus</i>	W	8	4	1	-	-	4	-
<i>Microcerotermes serrula</i>	W	3	7	-	1	-	-	-
<i>Microcerotermes near havilandi</i>	W	-	1	-	-	-	-	-
<i>Termes comis</i>	I	4	1	-	-	1	-	-
<i>Termes propinquus</i>	I	3	-	-	12	1	-	-
<i>Homalotermes eleanorae</i>	I	1	-	-	3	-	-	-
<i>Homalotermes foraminifer</i>	I	1	4	-	-	-	-	-
<i>Mirocapritermes connectens</i>	S	-	2	10	-	-	-	-
<i>Malaysiocapritermes prosetiger</i>	S	3	2	10	-	-	-	-
<i>Procapritermes neosetiger</i>	S	-	-	-	6	-	-	-

Table 8.1 Species checklist of termites collected from the seven land-use types in Jambi Province, central Sumatra, in November 1997.

Species	Functional group	Primary forest (BS 1)	Logged forest (BS 3)	Jungle rubber (BS 10)	Rubber pltn. (BS 8)	Parasitantes (BS 6)	Imperata grassland (BS 12)	Cassava garden (BS 14)
<i>Procapritermes sandakanensis</i>	S	-	-	3	-	-	-	-
<i>Procapritermes setiger</i>	S	8	6	2	-	-	-	-
<i>Procapritermes near minutus</i>	S	4	-	1	-	-	-	-
<i>Procapritermes</i> sp. A	S	-	-	5	-	-	-	-
<i>Coxocapritermes</i> sp. A	S	6	1	-	-	-	-	-
<i>Coxocapritermes</i> sp. C	S	2	3	-	-	-	-	-
<i>Coxocapritermes</i> sp. D	S	1	3	2	-	-	-	-
<i>Kenneritermes</i> sp. A	S	4	1	-	-	-	-	-
<i>Pericapritermes dolichocephalus</i>	S	-	-	6	-	-	-	-
<i>Pericapritermes nitobei</i>	S	1	-	2	-	-	-	-
<i>Pericapritermes semarangi</i>	S	2	-	-	-	-	5	-
<i>Dicuspidiitermes nemorosus</i>	S	11	18	12	12	-	-	-
<i>Dicuspidiitermes santschii</i>	S	6	5	1	2	2	-	-
Nasutitermitinae								
<i>Havilanditermes proairipennis</i>	W	-	-	-	6	-	-	-
<i>Nasutitermes havilandi</i>	W	1	-	2	-	3	-	-
<i>Nasutitermes matangensisiformis</i>	W	-	-	2	-	-	-	-
<i>Nasutitermes neoparvus</i>	W	-	-	-	1	-	-	-
<i>Nasutitermes</i> sp. C	W	-	-	-	2	-	-	-
<i>Nasutitermes</i> sp. D	W	1	-	-	-	2	-	-
<i>Bulbitermes germanus</i>	W	2	-	-	-	-	-	-
<i>Bulbitermes prabhae</i>	W	1	-	-	-	-	-	-
<i>Bulbitermes</i> sp. A	W	3	1	-	-	-	-	-
<i>Hospitalitermes hospitalis</i>	E	4	-	-	2	-	-	-
<i>Hospitalitermes</i> sp. G	E	-	-	-	-	-	-	-
<i>Proaciculitermes ?malayanus</i>	S	1	3	-	-	-	-	-
<i>Proaciculitermes</i> sp. B	S	2	3	-	-	-	-	-
<i>Aciculoiditermes</i> sp. C	S	1	-	-	-	-	-	-
<i>Oriensubulitermes inanis</i>	S	2	4	2	-	-	-	-
Number of species	35	23	22	16	11	2	1	
Relative abundance (total hits)	110	94	83	62	35	9	1	

Figure 8.1. Species richness of termites collected from transects in seven land-use types in Jambi Province, Central Sumatra

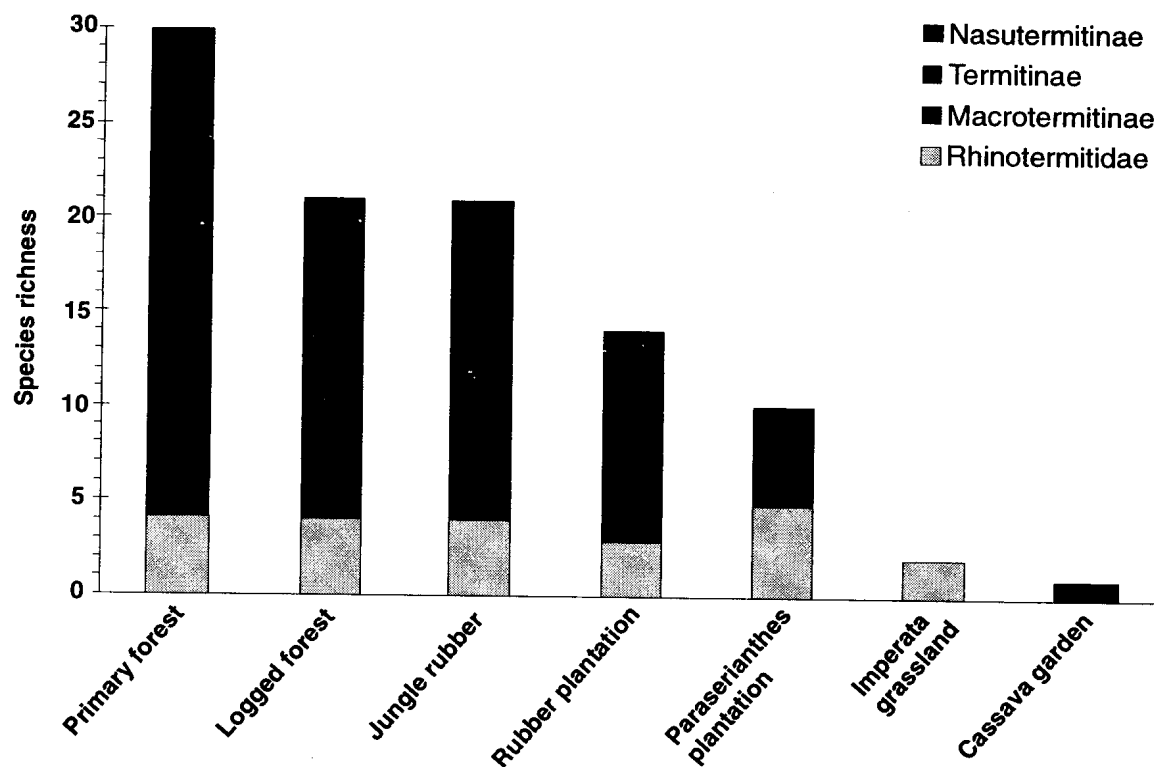
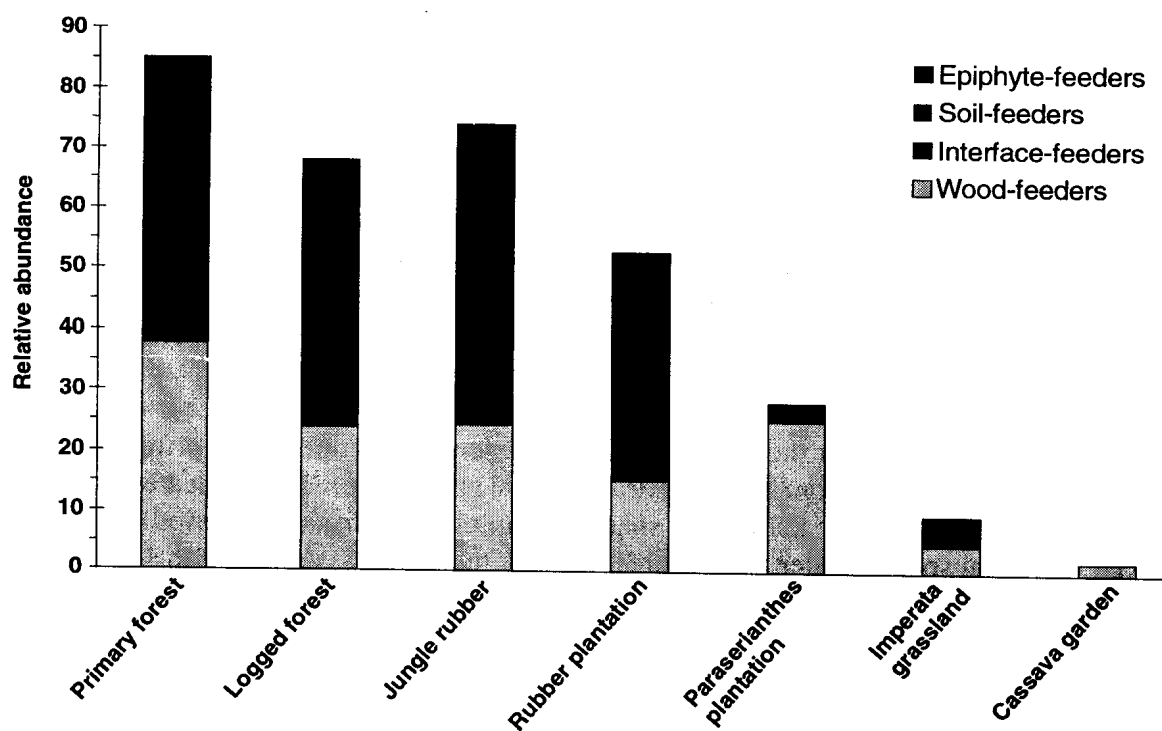


Figure 8.2. Relative abundance of termites collected from transects in seven land-use types in Jambi Province, Central Sumatra



SECTION 9: LAND SNAILS

SNAIL FAUNA UNDER VARYING LAND USE TYPES

By J.J. Vermeulen²

As part of a program on lowland forests of the Center for International Forestry Research (CIFOR, Bogor), a number of plots in various land use types in the Jambi lowland region in Central Sumatra were studied. The plots are situated in the Pasir Mayang - Muarabungo area, on low-nutrient ultisoils, at an altitude of 3-80 m asl.

In order to obtain some idea of the snail fauna present, soil samples were collected on 28/29 November 1997 by A. Gillison and E. Pumono (BIOTROP). In each 40x5 m transect, 3 x 1m² quadrats were sampled (one each at 0, 20 and 40 m points along the transect) and bulked. Loose leaf litter was removed by hand and the soil-litter interface was scraped by hand to a depth of about 3 cm. The samples were stored in plastic bags with holes punched in for aeration. All samples were collected during the start of the wet season, and were moist at the time of collection.

Upon arrival at the laboratory of the author, the samples were first generally assessed. Because all of them appeared either void or extremely poor in snails, it was decided to scan only a standardized portion of each sample (rather than the entire sample) in order to save time. The samples were then sieved to remove the fraction larger than 5 mm. Two samples were floated in water, a technique applied to remove rock pebbles and inorganic silt. Because this hardly reduced the size of the samples, this method was abandoned, and all samples were spread out to dry. After this, the samples were sieved through a 3 mm mesh sieve. The fraction of 3-5 mm was checked entirely for the presence of snails by systematically scanning small amounts spread thinly over a black surface. The fraction smaller than 3 mm was sieved again to remove all dust smaller than 0.8 mm. Then 0.3 liter of this fraction was selected by the method of piling-and-quarterming. This 0.3 l sample was checked for snails as described above. A small portion of the fraction smaller than 0.8 mm was also checked.

The results are listed in Table 9.1, below.

Most samples proved indeed void of snails, and even the few containing some shells can be considered extremely poor. Usually, the absence of snails is related to a low pH of the soil, which makes the environment extremely unsuitable for shell-bearing, soil-dwelling snails. The shell of any arboreal snail dying and falling to the forest floor also dissolves rapidly. As a consequence, soil samples without shells do not necessarily indicate the absence of a snail fauna.

However, at least some of the studied soil samples contained one or a few fresh-looking shells of soil-dwelling species (one with the dried animal still inside). This indicates that at least these samples formed a suitable habitat for snails, or can preserve for some period of time the shells of any arboreal species fallen to the forest floor. I, therefore, assume that the samples have been

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collected on localities that harbor at most an extremely poor snail fauna, both in species as well as in individuals.

In spite of this, the snail fauna collected are not without significance. The genus *Eremopeas*, known from northern and central Australia, is well characterized by the sculpture of the top of the shell. It is highly surprising to find a species apparently belonging to this genus on Sumatra. A first assumption would be its unintentional introduction by mankind. However, the Sumatran shells appear different from the two known Australian species. Therefore, the occurrence of a native, yet undescribed species of this genus in Sumatra seems more likely. The material now available (2 juvenile shells) is insufficient for a scientific description of the species. I therefore advise to search plot BS06 for more material; adults are probably slender shells of 5-15 mm high, of whitish or greenish colour. Both empty shells as well as living material preserved in alcohol of this remarkable species are very welcome.

Paropeas achatinaceum is probably native to Sumatra, but occurs widespread throughout SE Asia. *Lamellaxis clavulinus* are introduced species, originating from Africa. Both species add nothing to the biodiversity value of the plots.

Slugs (snails without a shell) may have been present on the plots. Mainly living on vegetation, they do not leave any trace when dying, and their presence cannot be ascertained by soil samples. Primary forests otherwise void of any snail species are known to harbor species of slugs on Borneo.

The samples consisted mainly of little decayed leaf litter, twigs, fruits, seeds and other organic matter. Rather remarkable was the abundant presence in most samples of small grains of perfectly transparent quartz, often attached to organic matter; some with a rounded but smooth surface, others displaying the typical trigonal crystal faces of this mineral. It is suggested that these quartz grains are possibly autigenous, that they are precipitated in situ in water saturated with SiO₂ after percolating through sandy soil.

Table 9.1
List of samples and the snail species found per sample.

Code	Environment	Date of collecting	Vol. in litres*	Snail species found, and number of specimens
BS10	Jungle Rubber	27/11/97	1.7	void
BS11	Jungle Rubber	27/11/97	1.0	void
BS 01	Primary forest	29/11/97	2.4	void
BS 02	Primary forest	29/11/97	2.4	void
BS 03	Heavily logged rain forest	29/11/97	3.4	void
BS 04	Logged over in 1983	28/11/97	1.3	void
BS 05	Logged over in 1983	28/11/97	1.4	void
BS 06	<i>Paraserianthes</i> plantation	29/11/97	4.4	<i>Erelopeas</i> sp. (2, juv.)
BS 07	<i>Paraserianthes</i> plantation	28/11/97	5.6	<i>Paropeas achatinaceum</i> (1, juv.)
BS 08	Rubber plantation	28/11/97	1.2	<i>Lamellaxis gracilis</i> (1, fragm.)
BS 09	Rubber plantation	28/11/97	1.7	void
BS 16	<i>Chromolaena</i> fallow	27/11/97	1.5	<i>Lamellaxis gracilis</i> (1, adult) <i>Paropeas achatinaceum</i> (1, juv.)

* Volume in litres, after removing the fraction >5 mm.

SECTION 10: SOIL PROPERTIES AND CARBON STOCKS

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10.1. Introduction:

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

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

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

10.2. Methods:

Methods for quantifying carbon stocks were used as specified in the ASB protocol (Palm *et al.*, 1994). For the vegetation and soil macrofauna, the sampling area was based on the 40 x 5 m² transect, as before. All tree diameters above 5 cm in the forest plots were measured by the BIOTROP team and data were converted into aboveground biomass with an allometric equation modified from Brown (1997) on the basis of additional data collected in the Jambi area (Ketterings *et al.*, *in prep.*):

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

where tree diameter (Diam) is measured in cm.

Understorey and herbaceous layer vegetation was measured in eight 0.25 m² quadrat samples (or four 1-m² samples for non-forest plots); total fresh weight was measured, and subsamples were collected for determining dry matter content. Diameter and length of dead wood (> 5 cm diameter) were measured within the 40 x 5 m² transect and converted to volume on the basis of a cylindrical form; three apparent density classes were used and ring samples were taken to assess the dry weight bulk density (g cm⁻³) of the partly decayed wood. Surface litter (including wood < 5 cm diameter) was collected down to the surface of the mineral soil in eight 0.25 m² samples. To remove mineral soil particles, the litter samples were washed and sundried; subsamples were taken for dry matter content.

Soil bulk density was measured for the 0-5 cm top soil layer (8 replicates per sampling point) by carefully inserting a 165 cm³ ring from the mineral soil surface, just below the litter layer.

Soil samples were collected (composited from 8 sample points per 200 m² sampling area) for the 0-5, 5-10, 10-20, 20-30 cm depth zone below the litter layer, passed through a 2 mm sieve and air-dried for analysis of texture (sand, silt, clay), pH (1N KCl), pH(H₂O), P Bray_{II}, C_{org} (Walkey and Black), N_{tot} (Kjeldahl), exchangeable K, Ca, Mg, Na, Al and H, and effective cation exchange capacity (ECEC) by summation. All these routine soil measurements were done on air-dried, sieved soil in the soils laboratory of Brawijaya University (Malang, Indonesia) with methods consistent with those described in Anderson and Ingram (1993). In addition, a size-density fractionation of macro-organic matter based on Ludox solutions of various densities was used, as described by Hairiah *et al.* (1995, 1996a) and Meijboom *et al.* (1995), for the 0-5 and 5-10 cm depth zone. The reference value for C_{org} ('Cref') was calculated on the basis of soil texture on the basis of a large data set of Sumatran soils (Van Noordwijk *et al.* 1997a, 1998, 1999).

10.3. Field notes on sampling points:

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

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

10.4. Results and Discussion:

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

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

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

All sites were acid, with the highest pH (H₂O) values found in the *Imperata* and Cassava sites around the transmigration village, possibly indicative of past lime applications (note that pH(KCl) values show less variation) and the *Chromolaena* fallow plot.

Soil organic carbon (C_{org}) and total N (N_{tot}) showed a strong decrease with depth, justifying the separation of the 0-5 and 5-10 cm depth layer. Available soil phosphorus levels were very low in sample 8, and relatively high in 10 and 11. The effective cation exchange capacity was low (< 12 cmol_e kg⁻¹) in all soils. Al saturation

was high in all soils, but lowest in sites 12 and 13. Overall, a weak but statistically significant relationship was found between Al-saturation and pH(H₂O):

$$\text{Al-sat} = 104.0 - 12.5 * \text{pH}(\text{H}_2\text{O}) \quad [n = 63, r^2 = 0.23, P < 0.001]$$

$$\text{Al-sat} = 99.2 - 14.8 * \text{pH}(\text{KCl}) \quad [n = 63, r^2 = 0.05, P = 0.045]$$

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

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

Table 10.1. Measured soil parameters

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

Table 10.1. Measured soil parameters

No.	LUT	Depth cm	Texture			pH _{H₂O}	pH _{KCl}	C _{org} %	N _{tot} %	C/N ratio	P _{brayn} mg kg ⁻¹	Exchangeable cations cmol. kg ⁻¹						Al sat	
			Sand	Silt	Clay							K	Na	Ca	Mg	Al	H	ECEC	%
7	HTI	0_5	46	28	26	5.2	3.8	4.21	0.28	15.0	8.78	0.41	0.62	4.68	1.56	1.33	0.87	9.47	14.0
7	HTI	5_10	45	19	36	5.2	3.9	2.11	0.16	13.2	1.20	0.21	0.45	4.16	1.14	1.89	0.21	8.06	23.4
7	HTI	10_20	43	22	35	4.8	3.6	1.78	0.14	12.7	0.69	0.19	0.43	3.12	1.04	4.23	0.80	9.81	43.1
7	HTI	20_30	43	22	35	4.8	3.6	1.62	0.11	14.7	0.19	0.12	0.38	1.87	1.25	5.14	0.90	9.66	53.2
8	RUB_P	0_5	14	27	59	4.6	3.5	5.97	0.38	15.7	1.20	0.19	0.36	2.41	0.95	3.96	2.07	9.94	39.8
8	RUB_P	5_10	14	11	75	4.5	3.7	2.95	0.18	16.4	0.19	0.12	0.29	2.10	0.31	2.81	1.25	6.88	40.8
8	RUB_P	10_20	12	16	72	4.9	3.7	1.96	0.13	15.1	0.19	0.12	0.33	1.68	0.41	2.81	0.86	6.21	45.2
8	RUB_P	20_30	11	13	76	4.9	3.8	1.86	0.12	15.5	0.19	0.1	0.32	1.52	0.94	1.63	0.71	5.22	31.2
9	RUB_P	0_5	15	41	44	4.4	3.6	3.27	0.53	6.2	10.0	0.27	0.38	1.78	0.59	5.67	1.89	9.40	60.3
9	RUB_P	5_10	13	15	72	4.8	3.7	2.41	0.31	7.8	7.50	0.13	0.36	1.62	0.42	3.23	1.21	7.65	42.2
9	RUB_P	10_20	13	18	69	4.7	3.9	2.19	0.16	13.7	1.25	0.09	0.18	1.80	1.08	3.14	1.04	7.50	41.9
9	RUB_P	20_30	12	23	65	4.5	3.9	2.13	0.14	15.2	0.18	0.05	0.17	1.57	0.63	3.36	1.08	6.82	49.3
10	J_RUB	0_5	6	70	24	5.2	3.8	6.23	0.46	13.5	41.5	0.51	0.69	2.37	0.76	5.31	2.63	10.7	49.5
10	J_RUB	5_10	7	58	35	5.1	3.8	3.97	0.28	14.2	17.2	0.23	0.63	2.12	0.42	5.05	1.49	11.1	45.6
10	J_RUB	10_20	5	54	41	5.1	3.8	2.81	0.22	12.8	10.5	0.22	0.37	1.59	0.21	4.93	1.48	8.81	56.0
10	J_RUB	20_30	5	46	49	5.1	3.8	2.13	0.19	11.2	4.78	0.13	0.31	1.26	0.31	4.88	1.15	8.37	58.3
11	J_RUB	0_5	9	52	39	5.4	3.9	5.76	0.37	15.6	32.8	0.46	0.68	2.46	0.33	3.39	1.76	8.47	40.0
11	J_RUB	5_10	9	50	41	5.3	3.9	3.20	0.27	11.9	10.2	0.25	0.45	1.71	0.23	3.98	1.53	8.38	47.5
11	J_RUB	10_20	9	42	49	5.2	3.8	2.44	0.23	10.6	5.44	0.25	0.42	1.84	0.32	3.77	1.26	8.13	46.4
11	J_RUB	20_30	7	33	60	5.1	3.8	2.11	0.20	10.6	1.30	0.27	0.52	1.72	0.34	3.10	1.02	7.21	43.0
12	IMP	0_5	66	14	20	5.8	4.1	2.19	0.13	16.8	8.27	0.20	0.36	1.56	1.04	1.21	0.05	5.39	22.4
12	IMP	5_10	67	11	22	5.5	4.2	2.03	0.12	16.9	6.25	0.12	0.37	1.35	0.41	1.03	0.61	3.33	30.9
12	IMP	10_20	69	9	22	5.3	3.8	1.78	0.10	17.8	1.20	0.11	0.31	1.35	0.73	1.51	0.31	4.62	32.7
12	IMP	20_30	61	13	26	5.2	3.9	1.22	0.09	13.6	1.20	0.05	0.22	1.56	0.52	2.00	0.39	4.66	42.9
13	IMP	0_5	66	13	21	5.7	4.0	2.23	0.13	17.2	4.15	0.09	0.42	1.12	0.51	1.18	0.67	3.71	31.8
13	IMP	5_10	67	5	28	5.6	4.0	2.10	0.12	17.5	3.16	0.20	0.45	1.12	0.71	1.48	0.68	4.63	32.0

Table 10.1. Measured soil parameters

No.	LUT	Depth cm	Texture		pH_ H ₂ O	pH_ KCl	C_org %	N_tot %	C/N ratio	P_brayn mg kg ⁻¹	Exchangeable cations							Al sat	
			Sand	Silt							Clay	K	Na	Ca	Mg	Al	H	ECEC	%
					cmol _c kg ⁻¹														
13	IMP	10_20	65	8	27	5.4	4.0	2.07	0.12	17.3	2.66	0.18	0.44	1.72	0.41	1.78	0.19	5.21	34.2
13	IMP	20_30	65	8	27	5.4	4.0	1.51	0.09	16.8	1.67	0.14	0.41	1.34	1.02	1.78	0.38	4.88	36.5
14	CAS	0_5	61	16	23	5.0	3.8	1.51	0.11	13.7	18.0	0.11	0.25	1.02	0.81	2.19	0.09	4.76	46.0
14	CAS	5_10	57	16	27	5.0	3.8	1.27	0.10	12.7	6.13	0.10	0.24	1.63	0.94	2.07	0.82	5.07	40.8
14	CAS	10_20	54	19	27	5.0	3.8	0.97	0.09	10.8	2.21	0.06	0.23	2.29	0.63	2.12	0.71	6.15	34.5
14	CAS	20_30	51	16	33	4.8	3.8	0.49	0.05	9.8	0.19	0.05	0.22	1.56	1.04	2.48	0.41	6.06	40.9
15	CAS	0_5	68	13	19	5.1	3.9	1.78	0.12	14.8	17.4	0.11	0.36	2.08	0.45	1.51	0.50	4.92	30.7
15	CAS	5_10	61	18	21	5.1	3.8	1.70	0.11	15.5	7.77	0.11	0.34	1.56	0.52	1.51	0.69	4.54	33.3
15	CAS	10_20	60	16	24	5.2	3.9	1.62	0.10	16.2	6.76	0.11	0.31	1.56	1.04	1.81	0.70	5.52	32.8
15	CAS	20_30	60	16	24	5.2	3.9	1.38	0.10	13.8	4.23	0.08	0.29	1.56	0.41	1.81	0.70	4.85	37.3
16	CHRO	0_5	9	66	25	5.7	4.2	4.66	0.32	14.6	35.1	0.48	0.88	2.64	2.41	1.20	0.88	8.31	14.4
16	CHRO	5_10	9	59	32	5.3	3.9	3.64	0.28	13.0	17.9	0.28	0.71	2.28	0.57	2.65	1.49	7.37	36.0
16	CHRO	10_20	6	57	37	4.9	3.8	2.72	0.20	13.6	6.49	0.27	0.61	2.96	0.22	2.85	1.43	8.40	33.9
16	CHRO	20_30	10	52	38	4.8	3.7	2.27	0.16	14.2	3.37	0.12	0.54	1.62	0.54	3.45	1.12	7.70	44.8

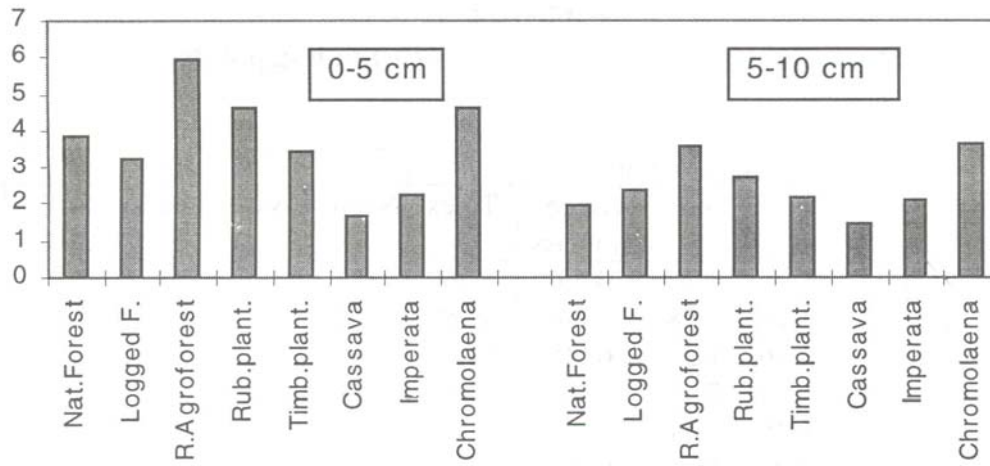
Table 10.2.
Bulk density (g cm⁻³) of the top 5 cm based on 8 replicates per sampling point

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

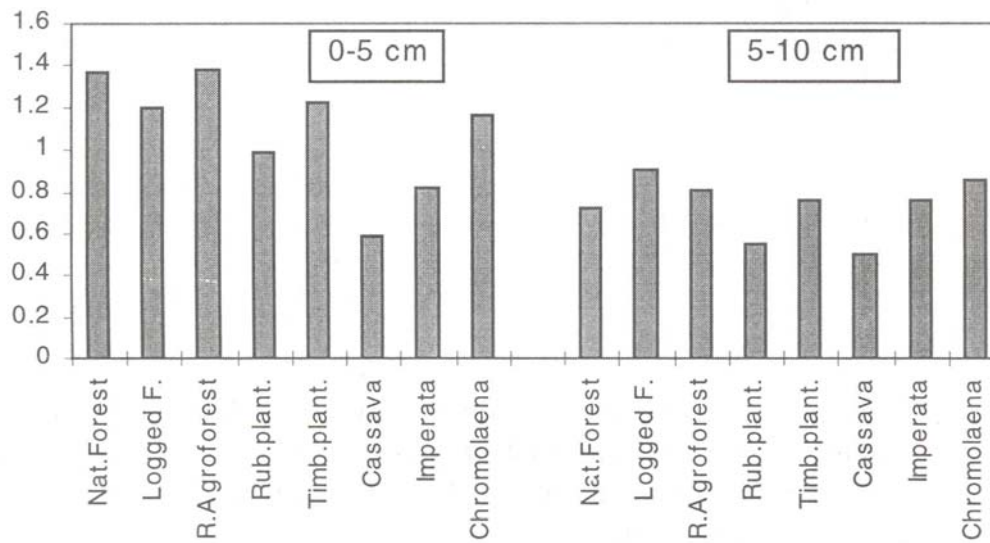
Table 10.3.
Soil organic matter data compared to the reference value C_{ref}
(based on regression of C_{org} on soil texture fore a large data set of Sumatran soils)
and results of the size/ density fractionation of soil with Ludox

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

Corg



Corg/Cref



Fraction, g/kg

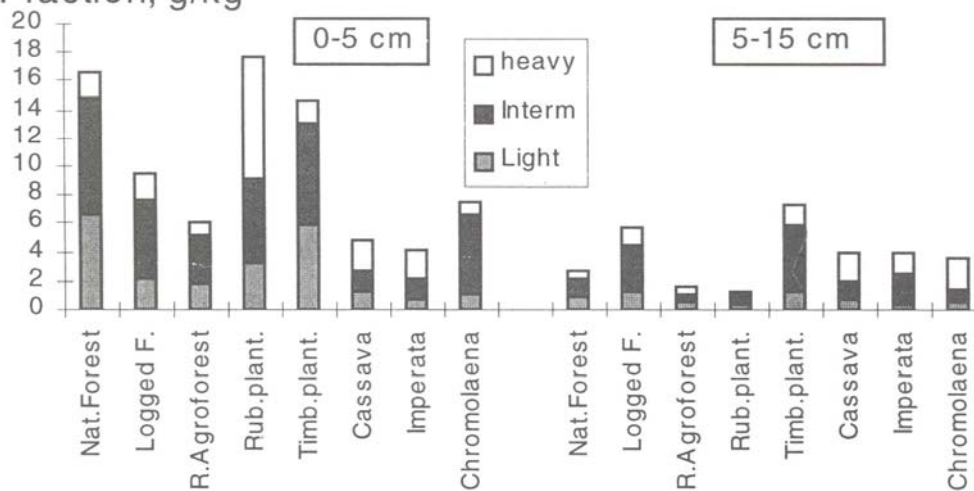


Figure 10.1. Indicators of soil organic matter saturation: A.I; C_{org}, B. C_{org}/C_{ref}, C. Size-density fractions (LUDOX method), grouped by land use.

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

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

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

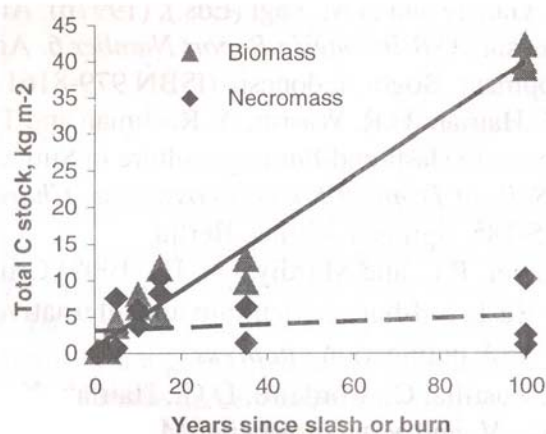


Figure 10.2. Relation between total aboveground C stock (biomass and necromass) and time since last slash, burn or cultivation event; the slope indicates an average annual C stock increment of 2.5 Mg C ha⁻¹ year⁻¹

10.5. References

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SECTION 11: PRELIMINARY SYNTHESIS: SUMMARY OF PLANT-BASED INDICATORS OF BIODIVERSITY AND SOIL NUTRIENT AVAILABILITY

By A.N. Gillison

11.1 Introduction

At the time of writing newly acquired insect taxonomic and beetle trophic data have just come to hand. These will be added to the present data pool and the whole re-analysed to seek new and informative relationships between plant and animal taxa, functional types, and site physical variables. All the data sets thus far have been subjected to correlative analysis to identify those plant-based variables with highest predictive values along the land use intensity gradient. Because biodiversity is made up of interacting complexes of taxa, functional types, individuals and populations, correlation analysis is an appropriate first point of entry in seeking efficient predictors. High correlations do not necessarily indicate causal relationships although in some cases this can be reasonably inferred, especially where correlates between different sets of variables vary consistently with soil nutrient availability.

11.2 Methods

Standard methods of regression (Pearson product-moment, using the MINITAB statistical package) were applied to help identify potentially useful plant-based surrogates of biodiversity. The sets of variables with highest linear correlates were also examined for non-linear pattern (second order polynomial regression as described in Part B, Annex II.) Because some of the highest correlates were associated with richness in plant species, *modi* and a ratio of species:*modi*, these variables were also examined for their potential value in predicting the occurrence of other taxa and functional groups as well as site physical variables. Table 11.1 below outlines the results.

11.3 Results

Plant species and PFTs or *modi* used alone and as a ratio tend to account for more variance in richness in animal taxa than animal taxa themselves. Overall there is a tendency for the species/*modi* ratio to greatly improve prediction for certain taxa and for above-ground carbon. This is evident in Table 11.1 a,b,c,d and is further illustrated in Annex II Figs 1a,b,c,d. for above-ground carbon, collembola, birds and termites. Table 11.2 lists correlations between plant-based variables and soil physico-chemical attributes.

11.4 Discussion

When the pattern of plant and animal taxonomic distribution along the LUTs is examined overall it is clear that the highest values tend to occur in certain pristine forest types and jungle rubber. This may be partly explained by the nature of the available niches in both intact forest and jungle rubber. Whereas the former has allowed the development of a series of cryptic terrestrial and arboreal habitats through a longer timespan, the relatively recent and more dynamic jungle rubber displays a much wider variety of niches due to the micro-fragmentary nature of the stand that is maintained by frequent disturbance by humans and animals. The cumulative graphs shown in Part B, Figure 1.1 show considerable similarity between the area curves for BS05, the richest intact rain forest, and those for jungle rubber (BS10). The nature

of the curves for the ratio values also reflects closely the general dynamic status of the LUT and whether it is degraded or not. The integration of the curves may provide a useful means for developing an index that reflects the overall indicator value of the species, *modi* and ratio combinations and this is the focus of a continuing study.

Of particular significance are the non-linear relationships of certain plant and vegetation structural variables with a sub-set of insect and bird taxa where the correlation is dramatically improved with ratios of species to PFT richness as distinct from correlations with either species or PFTs alone (Part B, Annex II, Fig. 1a,b,c,d). There is no immediate explanation for this improvement although there is some suggestion of covariant patterns in soil nutrient availability. Table 11.2 outlines correlations between plant-based variables and a range of soil physico-chemical attributes. There are clear correlations between certain physical variables such as soil bulk density, soil pH, organic carbon and total N and Aluminium and species and PFT richness and increasing complexity in vegetation structure. The vegetation "V" index (ref: Part B) is also highly correlated with a range of soil variables. While diversity indices are rarely attributed much significance as biodiversity indicators, in the present study each of the Shannon-Wiener, Simpson's and Fisher's Alpha values are significantly correlated with a variety of key soil nutrients (Table 11.2).

11.5 Conclusions and recommendations

Before an appropriate synthesis can be made further investigation of more recently acquired data must be undertaken. However it is safe to say that the study so far clearly indicates that assessments of biodiversity should be designed to sample as much as possible of the spatial ranges of the taxa of concern to management. In general this translates to seeking out representative gradients of land use intensity and soil nutrient availability at landscape level and including climate at ecoregional level. Once these system boundaries have been located they offer a useful spatial and environmental context for identifying, calibrating and testing by spatial extrapolation, the best sets of biodiversity indicators. It is clear that there will be many situations where isolated samples taken for example from rain forest alone, are likely to give a misleading picture of regional patterns of biodiversity. The present study has revealed a new set of indicators that show promise for much wider application and testing. The study has shown that the plant-based attributes with taxonomic + functional complements possess potentially useful predictive value when coupled with certain taxa, soil nutrients and above-ground carbon. Taken together with readily measureable elements of vegetation structure such as mean canopy height and basal area, these offer an exciting prospect for examining the dynamics of biodiversity and associated land use at landscape scale.

Based on present findings, the message for managers of forested and agroforested lands is to maintain a mosaic of land cover types to maximise the availability of ecological niches. Not only is this likely to enhance biodiversity, recent experience suggests this may have a beneficial effect by facilitating biological pest management as well as providing increased flexibility for varying management options under conditions of environmental and socioeconomic change.

Table 11.1a Linear correlations between beetle trophic groups[#], plant species and PFTs*

Troph.Grp	PFT	Species	Spp/PFT
Pchew1sp	0.498	0.663	0.564
Pchew2sp	0.581	0.585	0.369
Pchewspt	0.539	0.650	0.508
Pchew1fm	0.349	0.663	0.713
Pchew2fm	0.764	0.590	0.190
Pchewfmt	0.431	0.713	0.711
Pred1sp	0.336	0.438	0.366
Pred2sp	0.322	0.491	0.443
Predsptt	0.354	0.467	0.394
Pred1fm	0.608	0.449	0.115
Pred2fm	0.044	0.324	0.448
Predfmtt	0.542	0.521	0.286
Scav1sp	0.411	0.404	0.245
Scav2sp	0.407	0.755	0.781
Scavsptt	0.437	0.503	0.372
Scav1fm	0.165	0.362	0.395
Scav2fm	0.338	0.794	0.928
Scavfmtt	0.210	0.471	0.525
Tot1sp	0.447	0.527	0.400
Tot2sp	0.583	0.744	0.608
Utotalsp	0.482	0.580	0.451
Totalsp	0.401	0.337	0.156
Tot1fm	0.335	0.577	0.572
Tot2fm	0.450	0.854	0.899
Totfam	0.339	0.573	0.562

Pchew1sp = Phytophagous chewers – primary species;
Pchew2sp= secondary species;
Pchewt = total; -fm = family;
Pred = predators;
Scav = scavenger;
Utotalsp = total unique species.

*PFTs = Plant Functional Types;
Shaded areas with $r = >0.500$.
Bold type = high indicator value.

Table 11.1b Linear correlations between beetle trophic groups and vegetation structure*

Troph.Grp#	Can. Ht	Cr. Cov%	W. Plts	Ba. Area
Pchew1sp	0.313	0.172	0.734	0.388
Pchew2sp	0.248	0.232	0.529	0.329
Pchewspt	0.298	0.197	0.679	0.376
Pchew1fm	0.343	0.330	0.748	0.552
Pchew2fm	0.600	0.572	0.222	0.530
Pchewfmt	0.405	0.390	0.749	0.599
Pred1sp	0.104	0.126	0.631	0.248
Pred2sp	0.061	0.074	0.559	0.352
Predspt	0.106	0.128	0.661	0.272
Pred1fm	0.203	0.041	0.516	0.182
Pred2fm	-0.090	-0.069	0.520	0.281
Predfmt	0.138	0.007	0.660	0.273
Scav1sp	-0.005	0.142	0.461	0.203
Scav2sp	0.440	0.564	0.742	0.687
Scavspt	0.088	0.239	0.550	0.317
Scav1fm	-0.044	0.117	0.538	0.281
Scav2fm	0.537	0.490	0.731	0.784
Scavfmt	0.063	0.196	0.614	0.397
Tot1sp	0.143	0.167	0.609	0.299
Tot2sp	0.359	0.402	0.705	0.536
Utots1sp	0.192	0.221	0.636	0.355
Totalsp	-0.065	-0.008	0.478	0.103
Total1fm	0.232	0.276	0.680	0.473
Total2fm	0.572	0.549	0.712	0.846
Totalfm	0.223	0.264	0.682	0.465

* Can.Ht = Mean canopy height (m)

Cr.Cov.% = Crown cover percent of dominant stratum

W.Plts = Domin cover-abundance estimate of woody plants <2m tall

B.Area = Basal area of all woody plants m²ha⁻¹ (Bitterlich)

Shaded areas with r = >0.500.

Bold type = high indicator value.

Table 11.1c Linear correlations between richness of plant species, plant functional types and their ratios, and various animal taxa and above-ground plant carbon #

Attribute	Species	Modi	Spp/Modi
Ground-dwelling			
Termite abundance	0.872	0.766	0.946
Termite species	0.849	0.698	0.976
Lep/ground	0.834	0.790	0.920
Canopy:			
Unident. insects	0.771	0.418	0.839
Collembola	0.643	0.089	0.882
Ant-total	0.633	0.729	0.393
Total insects	0.593	0.487	0.526
Orthoptera	0.545	0.378	0.528
Thysanoptera	0.470	0.756	0.138
Isoptera (canopy)	0.417	0.140	0.496
Psocoptera	0.398	0.148	0.457
Coleoptera	0.312	0.458	0.127
Hymenoptera	0.302	0.446	0.129
Formicidae	0.274	0.370	0.142
Acari	0.190	-0.232	0.443
Spiders	0.186	0.307	0.050
Blattodea	0.124	-0.014	0.204
Hemiptera	0.098	0.229	-0.026
Diptera	0.038	0.404	-0.197
Bird total spp.	0.599	0.347	0.704
Above-ground carbon	0.796	0.558	0.909

Shaded areas with $r = >0.500$. Bold type = high indicator value.

Table 11.2 Plant-based linear correlates with soil physico-chemical attributes

	pH _{H₂O}	pH_KCl	C _{org} , %	N _{tot} , %	K	Na	Mg	Al	ECEC	Al _{sat}	Bulk D.
Mean Ht	-0.719	-0.828	0.486	0.386	0.005	-0.205	-0.370	0.632	0.441	0.558	-0.770
Basal A.	0.002	0.000	0.056	0.140	0.984	0.446	0.159	0.009	0.087	0.025	0.000
	-0.684	-0.780	0.503	0.395	0.048	-0.198	-0.347	0.684	0.491	0.595	-0.784
	0.004	0.000	0.047	0.130	0.859	0.462	0.188	0.003	0.053	0.015	0.000
CC%	0.215	0.125	0.092	0.095	-0.063	0.076	0.278	-0.057	-0.107	-0.089	-0.120
	0.424	0.644	0.737	0.728	0.818	0.779	0.298	0.833	0.694	0.743	0.659
WpLts	-0.285	-0.206	0.502	0.376	0.475	0.381	0.300	0.296	0.512	0.137	-0.627
	0.284	0.445	0.048	0.151	0.063	0.146	0.259	0.265	0.043	0.614	0.009
Bryo	-0.593	-0.777	0.459	0.526	0.097	-0.164	-0.300	0.697	0.584	0.527	-0.743
	0.016	0.000	0.074	0.037	0.720	0.545	0.260	0.003	0.018	0.036	0.001
Mean FI	0.172	0.293	-0.144	-0.026	0.093	0.175	0.180	-0.123	-0.094	-0.074	0.291
	0.525	0.270	0.594	0.925	0.732	0.516	0.504	0.651	0.728	0.786	0.274
Modi	-0.402	-0.471	0.878	0.742	0.609	0.393	0.097	0.643	0.880	0.279	-0.890
	0.123	0.066	0.000	0.001	0.012	0.132	0.720	0.007	0.000	0.295	0.000
Species	-0.550	-0.653	0.716	0.550	0.329	0.104	-0.225	0.687	0.650	0.484	-0.868
	0.027	0.006	0.002	0.027	0.214	0.700	0.403	0.003	0.006	0.058	0.000
Spp/modi	-0.683	-0.745	0.405	0.278	-0.012	-0.196	-0.463	0.616	0.353	0.602	-0.742
	0.004	0.001	0.120	0.298	0.966	0.466	0.071	0.011	0.180	0.014	0.001
Vindex	0.664	0.755	-0.611	-0.477	-0.174	0.056	0.291	-0.688	-0.575	-0.544	0.852
	0.005	0.001	0.012	0.061	0.520	0.838	0.274	0.003	0.020	0.029	0.000
Shannon	0.352	0.231	-0.507	-0.496	-0.545	-0.327	-0.348	-0.366	-0.732	-0.049	0.615
	0.181	0.390	0.045	0.051	0.029	0.217	0.186	0.163	0.001	0.858	0.011
Simpson	-0.367	-0.309	0.722	0.661	0.647	0.445	0.327	0.479	0.866	0.100	-0.767
	0.162	0.244	0.002	0.005	0.007	0.084	0.216	0.060	0.000	0.712	0.001
F_Alpha	0.488	0.542	0.240	0.174	0.585	0.633	0.876	-0.348	0.290	-0.651	-0.018
	0.055	0.030	0.370	0.519	0.017	0.009	0.000	0.187	0.276	0.006	0.946

Refer Section 10 and Annex III Table 2 for soil symbols; Mean Ht = mean canopy height, Basal A = basal area m² ha⁻¹, CC% = crown cover percent, WpLts = Cover abundance of woody plants <1.5m tall, Bryo = cover abundance of bryophytes, Mean FI = Mean Furcation Index canopy trees, Modi = total functional *modi* or Plant Functional Types, Species = total plant species, Vindex = Vegetation Index, Shannon = Shannon-Wiener Diversity Index for PFTs, Simpson = Simpson's diversity index for PFTs, F_Alpha = Fisher's Alpha diversity index for PFTs. Correlation 'r' value on each first line, probability value on each second line; shaded cells with p < 0.020. Clay not listed due to poor correlation.



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