

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

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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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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

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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 catalogue 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 reconnaissance 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 – Acre 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.
