BIODIVERSITY Assessment

IN THE NORTH BANK LANDSCAPE, NORTH EAST INDIA

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Citation :
Gillision, A.N. 2004. Biodiversity assessment in the north bank landscape, N.E. India : A preliminary survey. Unpubl. Report for the World Wildlife Fund for Nature - India. 48 pp
http://www.cbmglobe.com

WWF

Published by WWF India, Endangered Species Programme
WWW India 172 B Lodhi Estate, New Delhi - 110 003
Tel : +91-11-51504815/16
Website : www.wwfindia.org

Cover credits : front cover - Nanak Dhingra, back cover - Christy Williams
Designed and printed by Printworks, New Delhi

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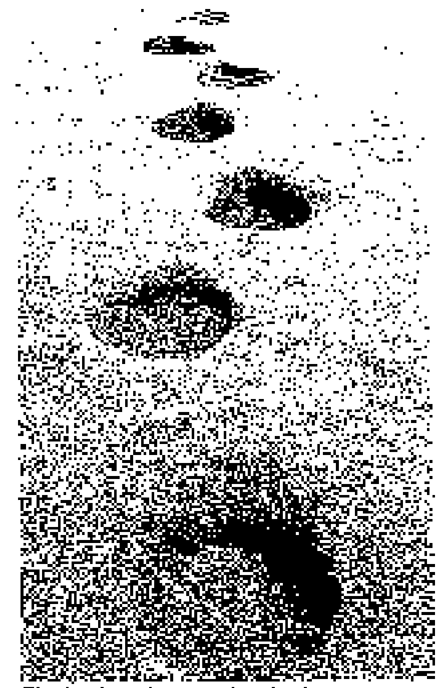
1 Executive Summary

The North Bank Landscape (NBL) covers approximately 14,000 km² of the Himalayan foothill region north of the Brahmaputra river that includes parts of Assam, Arunachal Pradesh, North Bengal and Bhutan. It is a strategic conservation zone that contains an estimated 40% of the Indian population of Asian elephants as well as key populations of Indian rhinoceros, tiger and leopard. The area is included within the Indo-Burma global biodiversity 'hotspot'. Planning for an Eastern Himalayas Conservation Alliance (EHCA) that includes the NBL requires an understanding of the range distributions of key taxa and their environmental determinants. Two teams from four Indian conservation institutions, predominantly WWF, undertook an initial survey of vegetation and large mammal habitat within a representative series of landscape and land use types as a precursor to establishing a broader regional conservation management framework within the eastern Himalayas including the proposed KaSoPaNa reserve (comprising the Kameng-Sonitpur, Pakke and Nameri Reserves in Assam-Arunachal). Team members received intensive training in methods of aboveground biodiversity assessment and survey design beforehand. The study was coordinated by WWF-India and the WWF Asian Rhino and Elephant Action Strategy (AREAS) project in association with the Center for Biodiversity Management, the Smithsonian Institution National Zoological Park and Conservation Research Center with additional funding support from the MacArthur Foundation. Fourteen sample locations were subjectively located along gradsects derived from gradients of elevation (thermal), primary and secondary drainage systems, land use types and land use intensity. The land use types sampled ranged from intensive, padi rice monocropping, degraded pasture, slash and burn (Jhum), Sal (Shorea assamica) timber plantations and humid closed forest, each with varying levels of impact mainly from elephants and humans. The survey data were compared with data collected using the same recording protocol for tropical and subtropical lowland forests in 20 other countries. Preliminary results indicate the NBL may be surpassed in plant diversity only by Sumatran forests in Sundaland thus making it the second richest centre of plant diversity on the planet so far sampled using the same procedures. Within NBL, uncontrolled exploitation of forests and destruction of large mammal habitat are increasingly restricting large mammals to smaller areas of forest. This is clearly impacting both plant and animal habitat and will have significant implications for forest biodiversity short term - a situation that is unlikely to improve with increasing elephant-human competition for common resources. Appropriate policy intervention at national and international level is urgently needed to establish a regional framework for ensuring sustainable human livelihood and balanced conservation management. Policy planning will rely increasingly on high quality baseline information that will come mainly from carefully designed, cost-effective surveys. While further surveys are needed within NBL and KaSoPaNa, these should be designed within the broader context of an EHCA to ensure connectivity along key environmental gradients and habitat corridors. Preliminary results suggest further biodiversity assessment within the proposed EHCA should consider elegibility of the eastern Himalaya region as a global biodiversity hotspot in its own right. A procedure for locating a series of representative sites for comparative biodiversity assessment within the eastern Himalayas is proposed.


Elephant tracks on a river bed

2 Introduction

The study focussed on an area of about 3000 km^2 within the Himalayan foothills known as the North Bank Landscape (NBL) (Fig.1). The NBL lies between the northern bank of the Brahmaputra river in the south to the foothills of the eastern Himalayas in the north and the Manas river in the west to the Dibang river in the east[1]. Within the eastern Himalayas the NBL forms part of the much broader 'Indo-Burma' global biodiversity 'hotspot' (Myers et al. 2000). It contains elements of several terrestrial ecoregions identified by Olson et al. (2001) namely the Eastern Himalayan broadleaf forests (IM0401), the Himalayan subtropical broadleaf forests, the Brahmaputra Valley semi-evergreen forests (IM0105) and minor fragments of the Terai and Duar grasslands (IM0701). The NBL also falls within the Tropical and Subtropical Moist Broadleaf Forest biome identified as vulnerable within the Global 200 set of terrestrial ecoregions by Olson and Dinerstein (1998, 2002). High regional biodiversity is due in part to the evolutionary history of the Himalayas that formed as a result of the upward movement of the Deccan Plateau into the Eurasian continent during the early Tertiary period. This has left a rich legacy of floristic and faunal elements from both Indian and Malesian sources (Rodgers and Panwar 1988). The eastern Himalayas contain elements of the Indo-Malayan, Indo-Chinese, Sino-Malayan and East Asiatic floras as well as several Gondwanan relicts (Rawat and Wikramanayake 2001). Apart from the overlapping ecoregions of Olson et al. (1998, 2002), this complexity is mirrored in a variety of biogeographic classifications that tend to overlap in the NBL, for example the Himalayan highlands and Burma monsoon forest Provinces of Udvardy (1975), the biounits of MacKinnon (1997) and Birdlife International's EBA, Eastern Himalayas (130) (Stattersfield et al.1998).

Under a seasonal monsoon climate with a high annual rainfall (1,500-3,000mm), deep alluvial deposits have accumulated from rivers draining the southern slopes of the eastern Himalayas (Rawat et al. 2001). These deposits once supported extensive, species-rich forests that have been progressively converted to agriculture over the millennia. Relatively recent and largely uncontrolled human migration into forested areas on the alluvial plains and lower foothills to the north of the Brahmaputra river has further impacted remaining forests. Since 1972 approximately 14% of natural forest within NBL has been lost together with 65% of semi-evergreen forest in the lowland Brahmaputra valley[2]. Many important faunal and floristic habitats are under increasing threat. The NBL is a strategic conservation zone containing an estimated 40% of the entire Indian population of Asian elephants (*Elephas maximus*) as well as significant populations of one-horned Indian rhinoceros (*Rhinoceros unicornis*), tiger (*Panthera tigris*) and clouded leopard (*Pardofelis nebulosa*) among others. The zone is an important part of a proposed wider conservation strategy - the Eastern Himalayas Conservation Alliance (EHCA)[3] that includes the upper Chindwin watershed, Hukaung Valley, Naga Hills and northern Kachin region of Burma. This includes a subsidiary reserve system (KaSoPaNa) of 6,440 km^2 comprising the Kameng-Sonitpur, Pakke and Nameri Reserves in Assam-Arunachal. The proposed EHCA is consistent with other regional conservation interests that aim to link reserves for example between India and Bhutan (Sherpa and Norbu 1999). According to Rawat and Wikramanayke (2001), plans to use ecoregions as basic units for conserving biodiversity are supported by similar proposals to establish linkages through conservation landscapes in other areas of the eastern Himalayas (WWF and ICIMOD 2001).

1 http://www.wwfindia.org/programs/tigers-role/areas.jsp?prm=66
2. A.C. Williams pers. com.
3. Eastern Himalayas Conservation Alliance—setting the stage for on-the-ground conservation networks. WWF AREAS proposal (Williams, A.C. 30 May 2002).

3 Aims and objectives

The principle aims of the EHCA are to address current threats to biodiversity and long term livelihood of local populations and to focus on conservation problems caused by rapid, uncontrolled industrial and agricultural development in the region and the impact of the Chinese wildlife and medicine market on biodiversity. An initial objective of the EHCA project is to prepare the groundwork for developing an integrated approach to the conservation of an inaccessible and politically difficult region through a combination of on-the-ground surveys and rapid assessments based on satellite imagery and threat mapping. Specific longer-term goals of EHCA are to:

- Identify conservation targets by mapping remaining intact forest habitats from satellite imagery.
- Assess current and future threats to these conservation targets.
- Perform on-the-ground assessments where possible (or provide remote assessments where necessary).
- Assess the relative conservation value of the remaining intact forest habitats to create a prioritized list of conservation targets
- Build a conservation alliance to focus on these priorities. Partners would include State Forest Departments (Assam and Arunachal), National Agencies (e.g., USFWS, Ministry of Environment and Forests, India), local NGOs (e.g., Wildlife Areas and Welfare Trust of Assam), international organizations (e.g. WWF, Smithsonian, etc.) and research institutes (Wildlife Institute of India, Universities in NE India).
- Drive these processes by using the Asian elephant as a charismatic flagship and umbrella species.

Within Northern India collaboration is planned with the Forest Departments of Arunachal Pradesh and Assam and Government of India's PROJECT ELEPHANT office. Assistance in biodiversity assessment will come from the State Forest Research Institute (Arunachal Pradesh, Guwahati University, Assam), members of local NGOs, and members of the Wildlife Institute of India. The aim of the present investigation was to undertake a preliminary survey of KaSoPaNa as part of the ground preparation for the above. As outlined in the TOR (Annex 1), the main objectives were to:

- Prepare a survey design for the rapid biodiversity assessment of the proposed KaSoPaNa reserve.
- Identify forest areas with highest biodiversity values, past and present human impact, and sites with significant elephant feeding signs and sites under potential threat.
- Identify preliminary plant-based indicators that may be linked with satellite imagery for conservation planning purposes.
- Compare biodiversity values of KaSoPaNa with those done elsewhere in the world using similar techniques.
- Suggest additional survey sites throughout India's Eastern Himalayas to be able to compare values throughout the range.

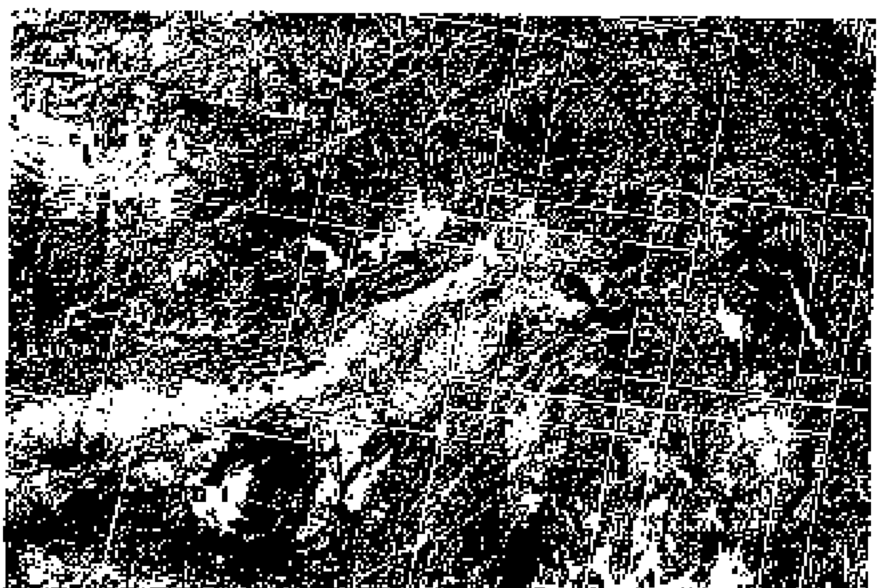
As indicated in Annex 1 the present study was preceded by an intensive training course in survey design and rapid biodiversity assessment[4] involving twelve participants who later took part in a six-day preliminary, plant-based, biodiversity survey of KaSoPaNa.

4. Center for Biodiversity Management (2004). Training workshop in aboveground biodiversity assessment: N.E. India. Report No. 01/04 for WWF – India.

4 Methods

Survey design and sample plot location

Sustainable conservation management requires a basic understanding of the spatial and temporal ranges of key taxa and the principal environmental factors that govern their distribution and survival. Overly restrictive sampling within the known environmental range of a species can seriously distort information about the way in which species respond to change and the way in which response-based biodiversity indicators are selected for conservation management. Many forest birds and mammals for example, range well beyond forest boundaries into other vegetation types such as grassland and woodland savannas and farming systems. If the sampling of such fauna is restricted to forests alone then important ecological information concerning breeding behaviour and food sources can be missed. In selecting an appropriate survey design for biodiversity assessment and monitoring, consideration must be given first, to the purpose and scale of the project, and second to cost-effective methods of sampling those environmental gradients that are considered to be the main drivers of species distribution and performance. If the purpose is to record data that are to be used solely to estimate the number of taxa per unit area then random sampling must be included to satisfy model parameters based on probability theory. While theoretically desirable, from a practical viewpoint, purely systematic or random-based sampling tends to be extremely costly and difficult to implement, especially in heterogeneous landscapes with complex vegetation. Furthermore, the outcomes from such sampling may not satisfy the desired endpoint. If, on the other hand, the purpose is to gather as much information as possible about the distribution of species and related functional types within an area, then purposive selection of transects within a hierarchy of environmental gradients (gradsects) is likely to be far more cost-efficient (Gillison and Brewer, 1985).



Satellite imagery data of NE region of India

More efficient sampling of key environmental gradients using georeferenced sites can also improve the chances of locating rarities among biota as well as increasing the efficiency of extrapolating distribution patterns of specific plant and animal groups throughout the study area. Evidence for improved efficiency of the gradsect approach over other, more traditional, statistical survey designs of plants and animals is supported by independent field evaluations at different management scales (Austin and Heyligers, 1991; Wessels et al. 1998). These include mountainous regions similar to the eastern Himalayas (Sandmann and Lertzmann, 2003). Increasing numbers of international agencies concerned with natural resource management now either recommend or implement this sampling strategy

(WCMC 1996; USGS-NPS 2003; UNEP-CBD 1996, 2001; FAO 2003). Set against this gradient-based background is a backdrop of more traditional survey designs that incorporate pre-classified boundaries such as those from existing forest typologies (*cf.* Champion and Seth 1968). Depending on classification criteria (e.g. dominant tree species, canopy height, deciduousness etc.) vegetation classifiers are forced to impose imprecise boundaries, frequently along highly complex gradients of forest structure and leaf longevity where for example, the line between evergreen and semi-evergreen becomes blurred. Most classifications and their mapped boundaries are also fixed in time and are thus inflexible to changing environmental circumstance and other disturbance drivers. This problem is generic but, becomes most evident where environmental gradients are steepest (as in the NBL foothills). Although, under such conditions, biodiversity assessments cannot rely sensibly on such typologies, they contain nonetheless potentially useful information and the underlying classification rationale should be carefully considered when designing surveys.

In the past, the purpose of most vegetation classifications has been to reduce complexity to manageable proportions. Unfortunately in the process of simplification, much critical information can be lost. The advent of high-resolution satellite imagery and the computer now make it possible to target the disposition of individual species and functional types both as individuals and assemblages, along environmental gradients. This has created a revolution in the way we record and interpret data for conservation purposes. Fine-scale data recorded in this way can be aggregated to whichever classification procedure suits management and mapping scale and purpose or else applied directly in modelling the response of biota to changing environments.

As with overall survey design, criteria for the selection of sample plot size and plot location should be purpose and scale-driven. For most biodiversity assessments the sampling of taxa and functional types a unit plot (transect) size of 40 x 5m (200m^2) tends to be adequate. Evidence for this is largely empirical as experimental evidence is exceedingly difficult to obtain in complex tropical and subtropical forested landscapes. Data collected from more than 1600 (40 x 5m) transects worldwide indicate that for most survey purposes, a 200m^2 sample is significantly less fatiguing for observers in a complex, humid tropical forest compared with 250m^2 especially where all vascular plants species (as distinct from just trees) are to be recorded (Gillison, pers. obs.). Plot location and plot size can be critical when seeking habitat indicators for animals with locally restricted environmental ranges such as stream sides, forest margins or local drainage lines. A 40 x 5m transect can be placed to accommodate such variation with greater sensitivity than a much larger 1ha or 10ha plot. For sampling range distributions of highly mobile, large mammals such as elephant and rhinoceros, multiple 40 x 5m transects can be positioned along broader environmental gradients with minimal cost and maximum return whereas the use of 1ha plots would be both inefficient and impractical. Intensive documentation of vegetation for assessing biodiversity within larger plots such as the 1 ha plot currently recommended by Kuebler (2003) for global biodiversity hotspots in complex tropical environments is difficult to implement in practice or justify on scientific grounds. This is especially the case in heterogeneous landscapes that are characterized for example, by razor-back ridges as in the NBL foothills or where there is a need to document species change along steep local or regional environmental gradients. For situations where a greater degree of environmental representativeness is desired, 200m^2 plots can be added as indicated from a progressive inspection of species:area curves derived from cumulative counts along eight (5x5m) contiguous quadrats within a 40 x 5m transect (Kotto Same et al., 2000; Gillison 2001, 2002). Plots that fail to asymptote indicate a need for further sampling.

In this study preliminary gradsects were located following discussion with local park rangers and WWF personnel familiar with the region. This information was augmented by an examination of recent satellite imagery (Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+)) and field reconnaissance. A Landsat FCC (false color composite) with a 4,3,2,1 band sequence was used as a primary image for subjectively assessing regional gradients. The primary environmental gradient was assumed to be thermal as indicated by elevation, with secondary and tertiary gradients associated mainly with drainage systems and a geomorphology that appear to be dominated by long-term accretion and partial uplift of eroded sediments from the eastern Himalayas. In the majority of cases in the area visited, the underlying substrate was composed of loosely consolidated, alluvial boulder layers, fine sands and silts (Picture 1). Published information on soil type, geomorphology and geology was unavailable at the time of the survey with the team relying mainly on anecdotal information and local observation. For this preliminary survey, soils were characterized according to field estimates of soil texture. Within the study area terrain varied from lowland plains at about 80m a.s.l. to valley systems with sharply rising slopes and narrow ridgelines at about 2,000m. The relatively high dynamism of the landscape is reflected in highly dissected foothills with numerous landslips and landslides (Picture 2).

The physical gradients described above were then subjectively stratified according to a land use 'intensity' gradient as indicated by varying degrees of forest removal, slash and burn (Jhum), forest plantations and intensive, sedentary agriculture. A series of 14 (40 x 5m) transects was then subjectively positioned to represent as far as possible the key characteristics of these overlapping gradients (Fig. 2). Sample sites (Table 1) ranged from relatively intact to highly disturbed, upland and lowland forest, Sal (*Shorea assamica* Dyer) timber plantation, annually fired shrub savanna, degraded cow pasture and rice fields including fields under active cultivation and others abandoned due to repeated elephant damage (Pictures 3,4,5,6,7; Table 1). The presence or absence of any perceived damage that could be attributed to elephants was recorded in each transect. Highly dissected terrain (Pictures 1,2), frequently with slopes in excess of 60%, unstable soil surfaces and razor-back ridgelines restricted the placement of sample transects in the time available. The few slopes of up to 50% inclination that could be accessed by the survey team were also prone to damage by elephants.

Data collection

Data were collected over a six-day period (4.12.04 to 10.12.04) by two separate survey teams (Annexes 2,3). At each 40 x 5m transect biophysical data were recorded according to an established protocol using the VegClass system (Gillison, 2002)[5]. Apart from site physical variables this included vegetation structure, all vascular plant species including epiphytes, and plant functional types (PFTs) (Table 2). The use of functional groups or functional types or 'guilds' to complement species in describing biodiversity is becoming increasingly accepted (Duckworth et al. 2000). However, because the definition of functional types varies with scale, purpose and user and because the use of PFTs in biodiversity assessment is relatively new, some explanation is necessary.


Survey team collecting data

Generic definitions of functional types such as "...*sets of organisms showing similar responses to environmental conditions and having similar effects on the dominant ecosystem processes* " (Diaz 1998) are conceptually useful, but are inapplicable in the absence of known effects on ecosystem processes. Other authors (e.g. Shugart, 1996) characterize plant functional types (PFTs) simply as "*species or groups of species that respond similarly to a suite of environmental conditions*". Duckworth et al. (2000) similarly characterize PFTs as groupings of species that show close similarities in their response to environmental and biotic controls irrespective of their taxonomic

5. Gillison, A.N. (2002). A generic, computer-assisted method for rapid vegetation classification and survey: tropical and temperate case studies. Conservation Ecology 6: 3. [online] URL: http://www.consecol.org/vol6/iss2/art3

classifications. For the present study and as described by Gillison and Carpenter (1997) Plant Functional Types or PFTs or functional *modi* are regarded as combinations of essentially adaptive morphological or functional attributes such as leaf size class, leaf inclination class, leaf form and type (distribution of chlorophyll tissue) coupled with a modified life form classification and type of above-ground rooting system. A more formal definition for PFTs used in VegClass could be: "*Individuals or groups of individuals with similar adaptations to a set of environmental conditions*" (in the sense of Gillison 2002; Gillison and Carpenter 1997). This definition avoids any formal connection with species or any other Linnean taxonomic rank and makes no direct assumptions about PFT influence on ecosystem processes. In this study and as used in the VegClass system, PFTs are constructed according to a specific grammar or rule set from a minimum set of 35 functional attributes (Gillison and Carpenter, 1997). Under this approach, an individual of the species *Shorea assamica* Dyer with mesophyll-sized, composite inclination, dorsiventral and deciduous leaves supported by a phanerophytic life form would be a PFT expressed as the combination me-co-do-de-ph. A rule set that provides for the estimation of a functional 'distance' within and between PFTs can be used to readily quantify similarities and differences between PFTs within and between transects. An algorithm for generating distance matrices based on these measures is available in VegClass.

Given most plants and animals can be measured in terms of species and their genetically determined functional complements an operational definition of biodiversity could be "*The number and composition of all recordable species and functional types in any given area*". With the latter definition, both species and functional types represent complementary units of biodiversity with a potential to provide greater information than just the sum of their parts. This is a significant departure from the conventional, solely restrictive use of the Linnean species as *the* quantum unit of biodiversity. Although richness in PFTs and species tend to be closely correlated, PFTs are independent of species as more than one species can occur in one PFT and more than one PFT in a species. PFTs allow the recording of adaptive responses of plant individuals that can reveal infra- as well as interspecific response to environment (e.g. land use type) in a way that is rarely indicated by a species name. Because the classification system is finite and generic, PFTs possess a major advantage over species as 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. A multi-disciplinary, biodiversity baseline survey in Sumatra, Indonesia revealed strong statistical support for the use of PFTs in combination with vascular plant species as biodiversity indicators and physical environmental conditions along a lowland, tropical, forested land use intensity gradient. In that study PFT richness and plant species richness were closely correlated with soil physico-chemical properties and corresponded with an assumed gradient of land use intensity (Gillison, 2000; Hairiah and van Noordwijk, 2000). The same study showed PFTs in combination with vascular plant species were highly correlated with specific groups of insects, notably termites and birds (Bignell et al. 2000; Gillison 2000; Jepson and Djarwadi 2000; Watt and Zborowsky 2000; Jones et al. 2000, 2002; Gillison et al. 2003)

For the NBL survey, transect georeferences and elevations were recorded with a Garmin Etrex Vista GPS and several Magellan GPS units with an assumed accuracy in most cases of better than 15m. Digital photographs of vegetation and other biodiversity-relevant features such as animal sign, were recorded at each site[6]. Other than field estimates of soil texture, no soil samples were collected for analysis in this preliminary study. Satellite data using raw Landsat imagery (Bands 2,3,4)and available digital elevation models were selected for analysis using DOMAIN potential mapping software (Carpenter et al. 1993). Unlike other potential mapping software 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. In order to gain some idea of the level of regional representativeness

6 A CD-ROM containing a catalogue of photographs recorded by Center for Biodiversity Management has been made available to WWF-AREAS (A.C. Williams).

of all sites investigated, the distribution points for all plot locations were used to construct an environmental envelope using satellite imagery and elevation. This was achieved in DOMAIN by generating a distance measure via a Gower metric in which all data are standardized thus reducing the influence of very high or very low data values. This measure was then used to compute a grid-based distribution map based on the similarity level of each pixel or grid with the original environmental domain envelope for all sites. DOMAIN is widely used for a variety of mapping purposes worldwide (ICRAF/ASB[7]; Espadas Manrique et al. 2003).

Data storage

Copies of field data from all sites were made available in electronic format to each team member at the conclusion of the survey. Subsequently edited data have been distributed to WWF-India (G. Areendran, T. Aziz in New Delhi and S. Bairagi in Guwahati, Assam) as well as with WWF-Int. (A.C. Williams). Data backup will also be maintained by the Center for Biodiversity Management in Australia. Photocopies of original field sheets have been lodged with WWF-India (T. Aziz, New Delhi and S. Bairagi, Guwahati); originals are held by the Center for Biodiversity Management.

Data analysis

As a check for representativeness of transect data for each vegetation type, species:area and PFT: area curves were extracted from the VegClass data summaries. The curves are constructed from cumulative additions of species and PFTs along a series of eight contiguous (5x5m) quadrats making up a complete 40 x 5m transect. Curves that asymptote by quadrat six or higher are considered sufficiently representative of the vegetation type under study. Ratios of species to PFT richness were also examined as these can be a useful comparative measure of an *alpha* or 'within-plot' diversity of the number of plant species per PFT, as well as a general indicator of the dynamic state of vegetation and surrogates for the diversity (richness) of certain fauna (Gillison, 2000; Gillison et al. 2003). Such ratios tend to asymptote rapidly in relatively stable plant assemblages with evenly distributed taxa and PFTs such as annually fired grassland, woodland savannas, forest plantations or old-growth forests for example, whereas they are less predictable in more dynamic forest successional stages. Transect summary data from VegClass were analysed using the PATN exploratory data analysis package (Belbin, 1992) and standard regression analysis (Minitab Ver.13.3.2). VegClass was used to generate PFT diversity indices based on Shannon-Wiener, Simpson and Fisher's alpha measures (Magurran, 1988; Gillison, 2002). Whereas these indices are usually calculated for species based on number of individuals per species, for PFTs they are calculated according to numbers of species per PFT. This procedure avoids the need for time-consuming abundance counts of individuals but at the same time provides a measure of 'functional' diversity in terms of the above indices.


Data analysis at the base camp

In addition to PFT diversity indices, a measure of plant functional complexity (PFC) was derived directly from VegClass. PFC is estimated as the minimum spanning tree distance between all PFTs in a

7 http://www.asb.cgiar.org/txt_only/Gallery.shtm

sample plot derived from a specific rule set of PFT values (Gillison and Carpenter, 1997). While PFT diversity indices can be useful biodiversity indicators (Gillison, 2000), PFC tends to be more robust as well as serving as a complementary measure of plant species and PFT richness; it can be used, for example, to readily discriminate between two transects with the same number of species and PFTs but where the PFT assemblages differ in composition and complexity. As such it becomes a potentially useful, additional descriptor of biodiversity. A complete linear (Pearson) correlation matrix was generated for all biophysical variables recorded by VegClass including derived PFT diversity indices and PFC. In the absence of faunal data and in order to seek readily observable variables that could be used as biodiversity indicators, best single attributes and combination subsets of vegetation structural variables were examined for their correlation with species and PFT richness. Vegetation structural variables such as mean canopy height, crown cover percent and basal area are also meaningful habitat attributes for many fauna and can be used in spatial extrapolation via space-borne satellite and airborne imagery (e.g. Landsat TM, synthetic aperture radar and sidelooking airborne radar) where these are available. In the present study DOMAIN was used to contruct an environmental domain for the 14 NBL sites using three layers of raw satellite imagery (Landsat bands 2,3,4) and a digital elevation model.


Dr Gillison in a survey plot

The NBL survey data were compared with a variety of similarly collected data from other parts of the world. This was undertaken by a simple tabulation of species and PFT richness and PFC from the highest transect records in a series of global, ecoregional gradsects in 21 countries. Graphs of linear regressions of species richness against PFT richness were also used to illustrate differences between NBL and other gradsects across a range of humid, tropical forested landscapes in Sumatra, Cameroon, Brazil, Thailand, Fiji, the Peruvian Amazon basin and North Eastern Australia.


Crossing the river Bharelli for entry into Pakke Tiger Reserve

5 Results

Values for site physical variables are listed in Table 3. While most transects were located on flat terrain, two (NBL 7,8) were recorded on steeply sloping sites (60% and 50% inclination respectively). Due to the widespread, relatively unconsolidated sediments, soil depth was estimated as >100cm in all cases. Plant diversity, PFC and vegetation structural values are listed in Table 4. We recorded a the total of 601 unique plant species for all transects. These, together with PFTs are listed in Annexes 4 and 5. Highest species and PFT richness and PFC values are found in the forest sites NBL 3,4,6,7,8. When all vegetation types are examined, species and PFT richness and PFC and vegetation structural values are highly correlated with total crown cover percent, crown cover pecent of woody plants, basal area and cover-abundance of bryophytes (Table 5). These correlations improve when forests only are examined (Table 6) however statistical reliability is less due to fewer samples.


Butterflies in Namdapha NP

Plant species richness and PFT richness are highly correlated (Fig. 3) with the highest level of statistical significance so far recorded for any series of transects in any global ecoregion. The relatively high alpha diversity of plant species in forest transects is indicated both by species richness totals and by the species:area and PFT: area curves (Fig. 4). To satisfy one of the aims of this study, namely to "Identify preliminary plant based indicators that may be linked with satellite imagery for conservation planning purposes" a preliminary analysis of correlates between vegetation structural variables and plant species and PFT richness showed that 'best subsets' of two variables were adequate. The best subsets of predictors are listed where all vegetation types and forests are considered separately (Table 7). An analysis of the predictive value of mean canopy height and total crown cover percent was considered separately (Table 8) as these two variables are often considered to be among the most appropriate for detection by satellite imagery and can be readily estimated on ground as well as by certain types of spaceborne and airborne sensors. *A comparative analysis of species and PFT richness and PFC values between NBL and other global data (Table 9, Fig. 5) shows that the NBL region as sampled to date is exceptionally high in all values and, on a regional basis, second only to lowland Sumatra where the highest vales have been recorded to date.*

Similarity values obtained from the preliminary DOMAIN analysis (Fig. 6) indicate that the environmental domain or envelope generated for all sites are broadly representative of physical environments below 1,200m a.s.l.

6 Discussion

Lack of roads and highly dissected landscapes with steep slopes and narrow ridges restrict access to most of the foothill forests. In areas such as the Nameri Tiger Reserve, the reluctance of local guides to move away from established routes increased access time to sample points. Despite the lack of roads, semi-nomadic groups of tribal people from upland Arunachal Pradesh frequently access these reserves on foot, setting up transient camping stations en route in their search for medicinal herbs, illegal animal products and other non-timber forest produce. The team encountered one such group of people in the Mithun Nala tributary near NBL 8 who had walked down river from the mountainous interior to collect resin from *Bursera* sp. in the foothill forests of the Nameri Reserve. Soon after meeting this group, we found many dead and dying fish in isolated pools and in several adjoining streams upriver (Picture 8). This suggested that on their way down the Mithun Nala the same group had poisoned streams, probably with insecticide, killing all fish irrespective of size. According to our accompanying park ranger this is common practice and, as with animal poaching, is difficult to control in the absence of sufficient park management staff and effective punitive measures.

Elephant damage to vegetation was evident at all sites and appears to be increasing as natural forest habitats are reduced as a result of uncontrolled land exploitation and forest removal by immigrants (Pictures 9,10). In the lowlands the team observed intensive impact from elephants on agricultural land in some cases causing farmers to abandon rice fields (Picture 7). This type of impact is intensifying conflict between elephants and humans in the NBL. Elephant movement is by no means restricted to the lowland plains and the team found much evidence to suggest these animals access upland forests often via slopes in excess of 60%. While elephant impact on vegetation is generally observable, potentially significant but less visible impact on vegetation dynamics, is browsing by smaller, more numerous ungulates, in particular Sambar deer. In all forested sites in the Nameri Tiger Reserve we found widespread evidence of browsing in the herbaceous and shrub layer where deer had targeted a wide range of species, among them semi-succulent Commelinaceae (*Forrestia hookeri*) and Piperaceae (*Piper longum*) as well as Chloranthaceae (*Chloranthus elatior*) and Acanthaceae (*Strobilanthes* sp.). In each forest transect, but especially NBL 3 and 4, browsing was associated with increased coppicing and ground cover (Picture 3). While experimental exclosures are needed to determine the level of browsing impact, casual observation suggests that an unusually high density of woody plants < 2m tall represents a browsing response that is likely to influence forest regeneration, species and PFT richness and composition and vegetation structure. Under normal circumstances ungulate-browsing might be regarded as an inte-


The survey team at the Nameri NP Office

gral part of natural forest dynamics. Where forest cover becomes progressively reduced relative to increased ungulate populations, negative impacts on forest health and animal habitat may be expected.

An analysis of species:area and PFT: area curves from all transects indicated that, while all non-forest vegetation was reasonably well sampled, all forests sites require additional sampling (Fig. 4). In addition, due to time constraints, the teams were able to access only those forests within a few hours' walk from Bhalukpong and Potasali. In most cases the forest types sampled showed clear signs of impact from humans and elephants. More representative sampling of forests in the interior and on the larger foothills may reveal more intact forests with significantly different and possibly even richer floras. The extraordinarily tight linear correlation between species and PFTs in the NBL survey (Fig. 3) indicates, among other things, a consistent and uniformly high level of recording expertise by the two survey teams. This is testament to the efficiency of prior training and bodes well for the quality of future surveys. One implication arising from this baseline correlation is that, under circumstances where an experienced field botanist might not be available, plant species richness can be estimated with a high degree of confidence by simply using PFT values in the linear regression equation. The richness patterns observed in the NBL transects are generally consistent with those obtained from surveys along similar land use intensity gradients in other tropical and subtropical ecoregions (Gillison, 2000, 2002).

A comparison of plant species and PFT richness and PFC values across 20 other countries shows the NBL ecoregion clearly deserves its status as a global biodiversity hotspot[8]. In terms of total richness it is second only to Sumatra, which at the time of writing, is by far the highest for any vegetation type recorded using the same sampling protocol. The species:PFT regression slope for NBL (Figs. 3,5) is virtually identical to that of humid, west tropical Africa (Cameroon) and similar to mid-montane South East Asia (northern Thailand) and the Brazilian Western Amazon basin. However the NBL richness and PFC values far exceed those of the richest humid, tropical, old-growth forests so far recorded, for example, in north-eastern Australia that is generally regarded as an important refugium of some of the world's most ancient angiosperm families.

Various ecological explanations are given when explaining the reason for high species diversity. One of these is the '*intermediate disturbance hypothesis*' (Connell 1978; Huston 1979). This states that (tree) diversity will be highest at sites with an intermediate frequency of disturbance that prevents competitive exclusion and lowest at sites with very high or very low disturbance frequencies. In tropical forests this phenomenon is frequently associated with events such as naturally occurring storms or selective logging but there are many exceptions (Gillison 2001, 2002). Contradictory evidence for this hypothesis may be resolved in some situations if subtleties of divergent interpretations and differences in study site characteristics are more closely examined (Sheil and Burslem 2003).

One consequence of gaps induced by canopy disturbance is an increase in the number of light demanding, secondary species or so called 'pioneers' that are typically favoured by browsing animals and insect folivores. While this may not be the case in some partially logged, closed-canopy hyper-rich Sumatran forests of Tesso Nilo in Riau Province, intermediate disturbance may have a role to play in NBL where gap-openings are facilitated by elephant damage and human interference. Further study is needed to elucidate this phenomenon and in NBL should include forests that are, as far as possible, intact. The relatively high number of large mammals occupying the NBL region almost certainly exerts an impact that is not replicated in the large-mammal-poor, dryland forests of the Western Amazon basin. Neither have similar patterns been observed so far in lowland forests of Cameroon, Thailand, Sumatra or in the island of Borneo where elephants occur, but where populations of these and other large mammals are much lower. A comparative study of similar forests in other game reserves with elephants at differing population densities would be useful in determining management thresholds beyond which forests and related biodiversity become unsustainable. This might be accomplished within the Indian subcontinent and possibly by comparing data in Kenyan game reserves such as the Aberdare National park where elephant population density has already exceeded thresholds[9] for

8. http://www.biodiversityhotspots.org/xp/Hotspots/indo_burma/
9. Data from these areas are available from the Center for Biodiversity Management

TABLE 2: List of VegClass variables recorded for each 40 x 5m transect

Site feature	Descriptor	Data type
Site feature	Descriptor	Data type
Location reference	Location	Alpha-numeric
	Date (dd-mm-year)	Alpha-numeric
	Plot number (unique)	Alpha-numeric
	Country	Text
Observer/s	Observer/s by name	Text
Physical	Latitude deg.min.sec. (GPS)	Alpha-numeric
	Longitude deg.min.sec. (GPS)	Alpha-numeric
	Elevation (m.a.s.l.) (aneroid and GPS)	Numeric
	Aspect (compass deg.) (perpendicular to plot)	Numeric
	Slope percent (perpendicular to plot)	Numeric
	Soil depth (cm)	Numeric
	Soil type (US Soil taxonomy; texture etc.)	Text
	Soil pH	Numeric
	Parent rock type	Text
	Litter depth (cm)	Numeric
	Terrain position	Text
Site history	General description and land-use / landscape context	Text
Vegetation structure	Vegetation type	Text
	Mean canopy height (m)	Numeric
	Crown cover percent (total)	Numeric
	Crown cover percent (woody)	Numeric
	Crown cover percent (non-woody)	Numeric
	Cover-abundance (Domin) bryophytes	Numeric
	Cover-abundance (Domin) woody plants < 2m tall	Numeric
	Basal area (mean of 3) (m2ha-1);	Numeric
	Furcation index (mean and cv % of 20)	Numeric
	Profile sketch of 40x5m plot (scannable)	Digital
Plant taxa	Family	Text
	Genus	Text
	Species	Text
	Botanical authority	Text
	If exotic (binary, presence-absence)	Numeric
	Unique 4+4 (genus + species) code	Text
Plant Functional Type	Plant functional elements combined according to published rule set*.	Text
Quadrat listing	Unique taxa and PFTs per quadrat (for each of 8 (5x5m) quadrats)	Numeric
Photograph	Hard copy and/or digital image	JPEG/TIF

* Gillison, A.N. and Carpenter, G. (1997). A generic plant functional attribute set and grammar for dynamic vegetation description and analysis. Functional Ecology 11: 775-78

TABLE 1: Site localities* and vegetation types for all transects

Transect Id	Date	Latitude	Longitude	Vegetation type	Location
NBL01	04/12/203	27-0-48 N	92-38-49 E	Degraded pasture grazed by cattle	Bhalukpong, Sonitpur, Assam
NBL02	05/12/03	26-59-58 N	92-53-7 E	Highly disturbed riverine forest with dominant Dillenia indica and Urticaceae Elephant damage.	Nameri Tiger Reserve, near Bhareli river
NBL03	06/12/03	26-57-28 N	92-51-15 E	Selectively logged forest in Tiger Reserve Elephant, Gaur.	Nameri Tiger Reserve near river Khari
NBL04	06/12/03	26-56-58 N	92-51-17 E	Selectively logged forest in Tiger Reserve Elephant, Gaur, Deer.	Nameri Tiger Reserve near river Khari
NBL05	06/12/03	26-56-33 N	92-51-5 E	Annually fired shrub savanna, dominated by Leea crispa, Saccharum spontaneum Elephant, Gaur, Deer.	Nameri Tiger Reserve, Potasali Camp
NBL06	07/12/03	27-2-3 N	92-36-58 E	Degraded forest with signs of Samba deer.	Tipi - inside Pakke sanctuary,
NBL07	08/12/03	27-2-5 N	92-40-2 E	Disturbed forest, signs of elephant	Mithun Nala, Nameri Tiger Reserve
NBL08	08/12/03	27-2-10 N	92-39-58 E	Rainforest disturbed by humans & animals. Elephant	Nameri NP, on the bank of Mithun Nala along the ridge
NBL09	09/12/03	27-5-59 N	92-31-52 E	Riverine forest moderately disturbed on boulder field	1 km south of Sessa, on the eastern bank of the river Sissa
NBL10	10/12/03	26-56-0 N	92-48-6 E	Four year old rice plot abandoned due to elephant damage.	Gamani Forestry Village, Balipara RF
NBL11	10/12/03	26-55-57 N	92-48-6 E	Annual padi rice, damaged by elephants	Gamani Village (Forestry Village), Balipara RF
NBL12	9/12/03	27-2-0 N	92-6-0 E	Highly disturbed riverine forest, elephant resting place	Nameri Tiger Reserve near Bhareli river
NBL13	10/12/03	27-5-31 N	92-35-8 E	2 years abandoned jhum plot	Elephant Flat Village
NBL14	10/12/03	26-55-24 N	92-48-39 E	Sal (Shorea assamica) plantation 30 years old after clearing natural forest with natural Sal.	Salari, Balipara RF

*Latitude and Longitude in degrees, minutes, seconds.

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and humans with a view to identifying sustainable thresholds for conservation management and local livelihoods.

- Close attention should be given to identifying the most appropriate indicators for subsequent assessment and monitoring of key faunal habitats, taking into account the need for spatial extrapolation via satellite imagery (see Fig. 8).
- Regional environmental heterogeneity and steep environmental gradients indicate survey design should be gradient-based (gradsects) taking into account all available sources of biophysical data.
- Exploratory data analysis and iterative DOMAIN mapping or other spatial analysis of potential site locations should be used to indicate the best representative survey sites.
- Survey design in NBL/KaSoPaNa should be integrated with gradsects derived within the broader environmental domain of the eastern Himalayas. This will be needed to ensure connectivity of habitat corridors and interpretation of biodiversity pattern within a regional hierarchy of environmental and spatial gradients.
- Survey of areas within the EHCA will require training of teams in RBA aimed at co-locating multi-taxon baseline reference points for key fauna and flora. Ideally such training should be complemented by instruction in basic exploratory data analysis, statistical analysis and elementary spatial modelling. Trainees should be selected from representative regional agencies.
- The results of surveys within the EHCA should be examined to determine eligibility of the eastern Himalayas as a global biodiversity hotspot in its own right.

9 Acknowledgements

It is a pleasure to acknowledge the assistance given by the staff of WWF-India, the MacArthur Foundation and WWF-International and WWF-AREAS in the preparation and implementation of this survey and the preceding training workshop. Dr A.C. Williams and Dr M. Stowe provided valuable assistance in the formative planning of the survey. Mr G. Areendran and Mr Tariq Aziz kindly assisted with satellite imagery and maps. I am particularly indebted to Dr A. C. Williams, Mr Tariq Aziz and Mr Sujit Bairagi for their kindness and hospitality and for introducing me to one of the world's most fascinating centres of biodiversity.

8 Recommendations

Most conservation agencies concerned with the conservation management of the eastern Himalayas appear to recognise the need for established trans-national corridors that can help sustain broad-ranging habitats for larger mammals such as elephants. The question of which landscape-based conservation corridors are the most appropriate can only be answered through close cooperation between all stakeholders and by the acceptance of a common *modus operandi* for both biodiversity assessment and management. Efficient, low-cost, GIS-based, design-selection algorithms are available that can facilitate interactive selection of the most appropriate zones for a specific conservation target. (Walker and Faith 1998; Nix et al. 2000) The success of such procedures will be a function of the quality of the baseline data. The value of these data will, in turn, depend on the uniformity of survey design and data collection, storage and analysis.

The results of this study have highlighted some key features of biodiversity within the NBL that indicate significantly more sampling is required. However, further sampling should be considered within the overall frame of the EHCA conservation strategy in order to integrate and maximise the benefits of surveying both areas. For this reason, gradsects identified for the NBL / KaSoPaNa should be selected within a hierarchy of gradients identified from within the broader frame of the eastern Himalayas. Procedures for establishing a network of representative sites for comparative purposes in the eastern Himalayas are outlined in Fig. 7. Site selection criteria will be influenced by timeframe and scale and will need to be addressed via all EHCA stakeholders. Initial information will come from from a variety of sources and this will be used to locate and identify the operational gradsects. DOMAIN modelling can assist in gradsect selection by checking the representativeness of different gradsects and site locations against available data including satellite imagery, climate surface, DEM, soil, vegetation, geology and land use pattern. Once the 'ideal' sites are selected, these will be relocated according to logistic and budgetary constraints. The relocated sites should then undergo reiterative checking for DOMAIN representativeness until a final site selection is agreed. These sites will then form the initial set for comparative assessment within KaSoPaNa and the eastern Himalayas and may be compared where necessary with sites for other global ecoregions where data have been collected in the same way.

The establishment of a KaSoPaNa reserve within the broader context of an EHCA will require careful consultation with all stakeholders in order to define operational concerns and budgets. Among these will be a requirement for training survey teams at a higher level than before. Because both fauna and flora sampling needs to be integrated, training should incorporate state-of-the-art rapid biodiversity assessement (RBA) methods designed for multi-taxon baseline surveys. To the extent possible, training in RBA should include basic instruction in statistical analysis and spatial modelling. In this way trainees should become self-reliant in designing and implementing surveys, data analysis and interpretation of results for conservation needs. These and other recommendations are summarised as follows:

- Additional survey is required for both NBL and KaSoPaNa in order to develop an operational database for conservation planning and management. Sampling should integrate flora and fauna taking into account known movements of larger mammals, in particular elephants.
- Uniformity in multi-taxon sampling methods must be ensured to facilitate database development, comparative data analysis and interpretation and communication of results.
- Survey data should be examined for trends in impacts on large mammal habitat from both elephants

7 Conclusion

Hulma kokla crosses Bhareli River

The preliminary survey has identified forest types with highest (plant-based) biodiversity values and a series of vegetation types that have been subject to a range of impacts from both elephants and humans. Not surprisingly, forest areas that appear to be under greatest threat from elephants are those contained in agricultural and forested mosaics closest to human habitat. Conflict between humans and elephants will increase as forest continues to be removed by illegal immigrants and squatters (Pictures 9,10) and as elephants increasingly invade farmed areas. Although the teams recorded no quantitative data for faunal richness, results indicate certain vegetation structural variables are highly correlated with plant biodiversity. Some obvious conclusions are:

- Best indicators of plant diversity (species and PFT richness and PFC) are total crown cover, crown cover of woody plants and basal area of all woody plants.
- For use via satellite imagery, readily measureable canopy-based variables that are significantly correlated with plant diversity are mean canopy height and total crown cover percent. These variables can be used for subsequent rapid assessment and monitoring once the taxonomic and statistical reference baselines have been established for the region under study.
- A comparative analysis of plant diversity values from other tropical and subtropical forested regions of the world clearly indicates the NBL forests are among the richest sites so far recorded using the VegClass sampling protocol and second only to Sumatra (Tesso Nilo) that is currently the highest.
- Plant functional complexity (PFC) values for NBL are very high compared with any other ecoregion. The reason may be associated with intermediate levels of disturbance caused by humans and elephants. Further study is clearly needed to elucidate this finding.
- Despite some obvious trends, more intensive surveys are needed to identify plant-based indicators of preferred elephant habitat and of different levels of elephant-induced impact on vegetation and land use.
- Species:area and PFT:area curves indicate further sampling is required for all forest sites but that sampling frequency for other vegetation types is adequate.
- The biophysical heterogeneity of the NBL and the steepness of key environmental gradients indicate gradient-based surveys or gradsects using small (e.g. 200m^2) plots are likely to more cost-efficient in assessing and monitoring biodiversity than more traditional techniques involving randomly positioned, large plots.
- A highly significant, linear correlation between species and PFT richness across all plots indicates an exceptional level of efficiency for both survey teams.

sustaining forest biodiversity. Experience suggests that to wait until such thresholds have been exceeded can seriously undermine prospects for sustainable management.

Findings from this preliminary survey indicate some general trends in species richness and levels of large mammal impact on forest habitat. They are insufficient to generate robust indicators of large mammal habitat or for monitoring change in such habitat for which considerably more faunal distribution data need to be acquired. The present study identified nonetheless, several readily observable vegetation structural indicators of plant species richness, PFT richness and PFC. Where all vegetation types are considered (Table 7) a combination of total crown cover percent and basal area of all woody plants are 'best' predictors. When only forest types are examined, the best predictors are total crown cover percent and crown cover percent of woody plants. Whereas certain types of remotely sensed imagery such as side-looking radar can detect basal area and below-canopy plant densities, such imagery is not always available. For most conservation planning purposes, canopy surface features tend to be the most favoured when interpreting readily available satellite imagery such as Landsat TM. Two common canopy variables that can be readily estimated on ground and which are compatible with surface image analysis are mean canopy height and total crown cover percent (Table 8). Based on present data, these variables appear to be relatively practical, user-friendly predictors although the levels of significance are somewhat below those based on total crown cover, crown cover of woody plants and basal area. Further field sampling in combination with satellite image analysis will test the robustness of these indicators.

When compared with the outcome of a similar survey in Tesso Nilo, Sumatra, our preliminary results suggest that, at the very minimum, plant species richness in the NBL can be considered among the highest in the world. While there are evident overlaps between Sundanese and lowland Himalayan for plant families and genera, the regions are clearly demarcated at species level. The inclusion of the Eastern Himalayas within the broader context of an "Indo-Burma" hotspot may need revision given that the Eastern Himalayan region could possess many unique characteristics that may well identify it as a global hotspot in its own right. In this respect additional data and further examination of the status of biodiversity within the "Indo-Burma–Sundaland" megazone are needed to better differentiate regional conservation priorities. Within the 'Indo-Burma' hotspot, for example, best management guidelines developed for lowland, seasonal Cambodia and Laos may not necessarily apply to the EHCA. As technologies improve, current perceptions that acquisition of such data at this regional scale is beyond the capacity of national and international agencies are likely to change rapidly. Generic, cost-efficient tools for rapid assessment and monitoring of biodiversity within and between regions are now available as shown in the present study and elsewhere (Gillison 2002, Gillison et al. 2003). Once regional taxonomic and statistical baselines have been established for species, then PFT composition and vegetation structure may ultimately provide the most practical units for assessing and monitoring change in biodiversity.

Based on satellite imagery and elevation, the DOMAIN surface generated for all sites suggests that, with some clear exceptions at higher elevations, points sampled along the initial gradsect account for most physical environmental variability within the study area. Further sampling of vegetation and fauna will establish a basis for improved mapping of species and their habitats. Whereas many predictive modelling procedures require both presence and absence data, DOMAIN produces similarity values based on presence alone and can operate with relatively few georeference points. This is a distinct advantage where species distributional data are few and where the cost of intensive surveys is prohibitive. As such, DOMAIN has the capacity to generate low cost, readily testable, distribution maps of species, functional types and habitat. In this way preliminary surveys can provide an entry point into assessing species distribution and for modelling species performance under different environmental scenarios where, for example, values for current satellite imagery can be varied. Similarly, satellite-based imaging of chronosequences of forest retreat can be examined in turn for their impact on rates of habitat loss for specific fauna. In the current study, areas with low DOMAIN similarity values (e.g. < 80%) suggest obvious priority areas for additional surveys. Spatial modelling of this kind can thus provide a useful tool in initial and progressive survey design.

TABLE 3: Site physical features for all transects

Plot Id.	Elev'n (m)	Slope (%)	Aspect (Deg.)	Soil depth (cm)	Parent rock	Terrain position	Soil texture
NBL01	151	0	0	>100	Alluvium	Old riverine plain	Sandy loam
NBL02	126	0	0	>100	Alluvium	Riverine plain	Loamy sand
NBL03	92	0	0	>100	Alluvium	Old riverine Plain	Sandy Loam
NBL04	109	0	0	>100	Alluvium	Old riverine Plain	Sandy Loam
NBL05	86	0	0	>100	Alluvium	Secondary river flat	Sand
NBL06	88	2	0	>100	Sedimentary	Plain	Sandy loam
NBL07	165	60	30	>100	Sedimentary	Upper slope, hilly	Sandy clay loam
NBL08	165	52	30	>100	Conglom. sed.	Mid slope, hilly	Sandy Loam
NBL09	1040	40	55	~25	Conglom. sed.	Upper slope, hilly	Sandy Loam
NBL10	93	0	0	>100	Sedimentary	Plain	Clay loam
NBL11	90	0	0	>100	Sedimentary	Plain	Sandy clay loam
NBL12	156	0	0	>100	Alluvium	Old riverine plain	Sandy loam
NBL13	470	25	95	>100	Sedimentary	Undulating hilly	Sandy loam
NBL14	85	0	0	> 100	Sedimentary	Plain	Sandy loam

Table 4: Site localities* and vegetation types for all transects

Plot Id	Spp	PFTs	Spp: PFT	Shan	Simp	Fisher	PFC	Ht	CcTot	Cc Wdy	Cc Nwdy	Wdy Plt	Bryo	Litt	BA	MFI	Ficv
NBL01	46	25	1.84	2.99	0.06	22.39	158	0.3	95	0	95	1	1	4	0.01	100.00	0.00
NBL02	72	47	1.53	3.68	0.03	35.41	434	12	95	70	25	8	4	2	13.33	44.75	78.88
NBL03	94	59	1.59	3.85	0.03	66.48	555	15	90	70	20	10	5	1	19.67	45.75	36.03
NBL04	73	46	1.59	3.65	0.03	51.93	427	14	80	70	10	8	4	0	30.00	39.50	42.06
NBL05	34	27	1.26	3.23	0.04	60.73	232	1.8	100	30	70	8	1	1	0.10	54.25	50.86
NBL06	107	74	1.45	4.16	0.02	106.15	763	16	95	85	10	9	4	2.5	22.67	49.25	52.52
NBL07	91	56	1.63	3.81	0.03	61.99	567	10	98	80	18	8	4	1.5	11.33	48.50	78.52
NBL08	107	65	1.65	3.88	0.03	70.20	677	15	95	85	10	6	3	3.5	14.67	57.20	53.55
NBL09	83	60	1.38	3.94	0.02	93.89	704	16	95	80	15	8	6	2.5	22.33	27.25	98.27
NBL10	41	29	1.41	3.21	0.05	44.16	230	0.04	70	0	70	1	1	0.3	0.01	0.00	0.00
NBL11	18	14	1.29	2.55	0.09	28.97	130	0.1	60	5	55	1	1	0.3	0.01	0.00	0.00
NBL12	59	38	1.56	3.43	0.04	46.14	365	18	60	70	10	9	4	3	22.67	34.25	80.97
NBL13	84	59	1.42	3.86	0.03	82.92	612	1.5	90	2	88	4	1	2	1.00	51.43	74.19
NBL14	30	22	1.36	2.98	0.06	33.81	177	20	60	55	5	9	2	0.3	11.00	14.50	112.93

Spp = species; PFTs = Plant Functional Types; Shan = Shannon-Wiener diversity index; Simp = Simpson's diversity index; Fisher = Fisher's alpha diversity index; PFC = Plant Functional Complexity; Ht = Mean canopy height (m); CcTot = Total crown cover %; CcWdy = crown cover % woody plants; CcNwdy = crown cover% Non-woody plants; Wdy Plt = cover abundance of woody plants <1m tall; Bryo = cover abundance of bryophytes; Litt = litter depth (cm); BA = basal area woody plants (m2 ha-1); MFI = Mean furcation index canopy trees; Ficv = coefficient of variation % of furcation index.

TABLE 5: Linear correlations* between species and PFT richness, PFC and vegetation structure for all vegetation types

Spp & PFTs	Ht	CC%	CCWdy	CCNwdy	Wplt	Bryo	Litt	BA	MFI
Spp	0.469	0.607	0.668	-0.440	0.461	0.653	0.431	0.581	0.379
	0.091	0.021	0.009	0.116	0.097	0.011	0.124	0.029	0.181
PFTs	0.464	0.600	0.652	-0.429	0.487	0.653	0.379	0.574	0.294
	0.095	0.023	0.011	0.126	0.077	0.011	0.181	0.032	0.307
Sp/PFT	0.124	0.316	0.195	-0.042	-0.044	0.215	0.569	0.224	0.697
	0.673	0.271	0.505	0.887	0.881	0.461	0.034	0.442	0.006
PFC	0.471	0.563	0.657	-0.449	0.478	0.670	0.371	0.571	0.213
	0.089	0.036	0.011	0.107	0.084	0.009	0.192	0.033	0.465

* Upper line is Pearson product moment correlation, lower line = P value

TABLE 6: Linear correlations* between species and PFT richness, PFC and vegetation structure for forested sites only

	Ht	CC%	CCWdy	CCNwdy	Wplt	Bryo	Litt	BA	MFI
Spp	-0.524	0.837	0.908	0.313	-0.312	0.423	0.479	0.163	0.864
	0.148	0.005	0.001	0.413	0.413	0.257	0.192	0.675	0.003
PFTs	-0.434	0.839	0.918	0.281	-0.242	0.503	0.496	0.219	0.755
	0.243	0.005	0.000	0.464	0.531	0.168	0.174	0.571	0.019
Sp/PFT	-0.625	0.306	0.345	0.308	-0.356	-0.021	0.134	0.007	0.783
	0.072	0.423	0.364	0.419	0.348	0.957	0.731	0.985	0.013
PFC	-0.368	0.819	0.941	0.224	-0.297	0.558	0.558	0.221	0.642
	0.330	0.007	0.000	0.562	0.438	0.118	0.118	0.568	0.062

* Upper line is Pearson product moment correlation, lower line – P value

TABLE 7: Most significant sets of vegetation structural predictors of species and PFT richness and PFC

Data set	Predicted variable	Regression equation * 'best subset' of predictors
All vegetation types NBL 1 > 14	Species richness	Spp = - 57.7 + 2.03 Ht + 1.24 CC%
		R-Sq (adj.) = 57.2% P < 0.004
	PFT richness	PFTs = - 34.0 + 1.27 Ht + 0.777 CC%
		R-Sq (adj.) = 55.6.5% P < 0.005
	PFC	PFC = - 365 + 7.77 CC% + 11.6 BA
		R-Sq = 55.2% P < 0.005
Forests only NBL 2,3,4,6,7,8,9, 12,14	Species richness	Spp = - 89.8 + 0.559 CC + 1.65 CCwd
		R-Sq (adj.) = 83.3% P < 0.002
	PFT richness	PFTs = - 56.6 + 0.341 CC% + 1.07 CCwd
		R-Sq (adj.) = 85.4% P < 0.001
	PFC	PFC = - 819 + 3.00 CC + 14.6 CCwd
		R-Sq (adj.) = 88% P < 0.001

* Spp = Species richness; PFTs = PFT richness; CC = total crown cover percent;
BA = Basal area (m2ha-1) all woody plants; CCwd = crown cover percent, woody plants.

TABLE 8: Mean canopy height and total crown cover percent as predictors of species and PFT richness and PFC*

Data set	Predicted variable	Regression equation * 'best subset' of predictors
All vegetation types NBL 1 > 14	Species richness	Spp = - 57.7 + 2.03 Ht + 1.24 CC%
		R-Sq (adj.) = 57.2% P < 0.004
	PFT richness	PFTs = - 34.0 + 1.27 Ht + 0.777 CC%
		R-Sq (adj.) = 55.6.5% P < 0.005
Forests only NBL 2,3,4,6,7,8,9,12,14	Species richness	Spp = - 84.8 + 1.80 Ht + 1.61 CC%
		R-Sq (adj.) = 62.8% P < 0.022
	PFT richness	PFTs = - 81.8 + 2.21 Ht + 1.18 CC%
		R-Sq (adj.) = 71.3% P < 0.010
	PFC	PFC = - 1258 + 33.6 Ht + 14.9 CC%
		R-Sq (adj.) = 73.3% P < 0.008

* Canopy height and crown cover % selected as predictors suited to detection by satellite imagery.
Note also possible use of CCwd as in Table 7

Table 9: Comparative richness in plant species, plant functional types and plant functional complexity values in humid lowland tropical and subtropical forests in 21 countries *

No.	Country	Location	Georeference	Plot ID	Forest type	Species richness	PFT richness	PFC value
1	Indonesia (Sumatra)	Tesso Nilo, Riau Province,	0° 14' 51" S 101° 58' 16" E	TN02	Complex primary forest, logged 1997	217	73	842
2	Indonesia (Sumatra)	Pancuran Gading, Jambi Province	1° 10' 12" S 102° 06' 50" E	BS10	Lowland forest interplanted with 'jungle' Rubber (Hevea brasiliensis)	112	47	532
3	India	Arunachal Pradesh Tipi - Pakke Sanctuary.	27° 2' 3" N 92° 36' 58" E	NBL06	Complex lowland forest selectively logged	107	74	763
4	India	Assam, Mithun nala, Nameri NP	27° 2' 10" N 92° 39' 58" E	NBL08	Rain forests disturbed by humans and animals (elephants)	107	65	677
5	Indonesia (Borneo)	Gunung Banalang, Long Pusk, Pujungan, East Kalimantan	2° 43' 32" N 115° 39' 46" E	BUL02	Disturbed complex forest along ridge	104	44	462
6	Cameroon	Awae Village	3° 36' 05' N 11° 36' 15" E	CAM 01	Late secondary forest. Previously logged.	103	43	412
7	Papua New Guinea	Kulodagi / West New Britain Province	5° 38' 46" S 150° 06' 14" E	KIMBE2	Complex, primary lowland forest.	99	52	526
8	Costa Rica	Braulio Carillo Parque Nacional	10° 09' 42" N 83° 56' 18" W	CR001	Partially disturbed forest, palm dominated. Many epiphytes.	94	71	817
9	Brazil	Pedro Peixoto, Acré (West Amazon basin)	10° 01' 13" S 67° 09' 39' W	BRA19	ICRAF ASB Site, Secondary forest (Capoeira) 3-4 years after abandonment	82	43	434
10	Brazil	Alcalinas Canamá N.W. Mato Grosso (West Amazon basin)	10° 04' 06" S 58° 46' 00" W	PN24	Primary lowland forest on shallow granitic soils.	75	54	596
11	Perú	Jenaro Herrera, Ucayali river (West Amazon basin)	4° 58' 00" S 73° 45' 00"W	PE02	'High terrace' lowland forest - selective logging	72	39	335
12	Vietnam	Cuc Phuong National Park Ninh Binh Province	20° 48' 33" N 105 42' 44" E	PSIV02	Lowland forest partly disturbed; on limestone	69	46	461
13	Perú	Von Humboldt forest reserve, Pucallpa, (W. Amazon basin)	8° 48' 01" S 75° 03' 54" W	PUC01	Primary forest selectively logged, 1960	63	31	314
14	Fiji	Bua, Vanua Levu	16° 47' 36" S 178° 36' 45" E	FJ55	Disturbed lowland forest on ridge	60	37	320
15	Thailand	Ban Huay Bong, Mae Chaem watershed	18° 30' 42" N 98° 24' 13" E	MC18	Humid-seasonal, deciduous dipterocarp forest fallow system	58	44	353

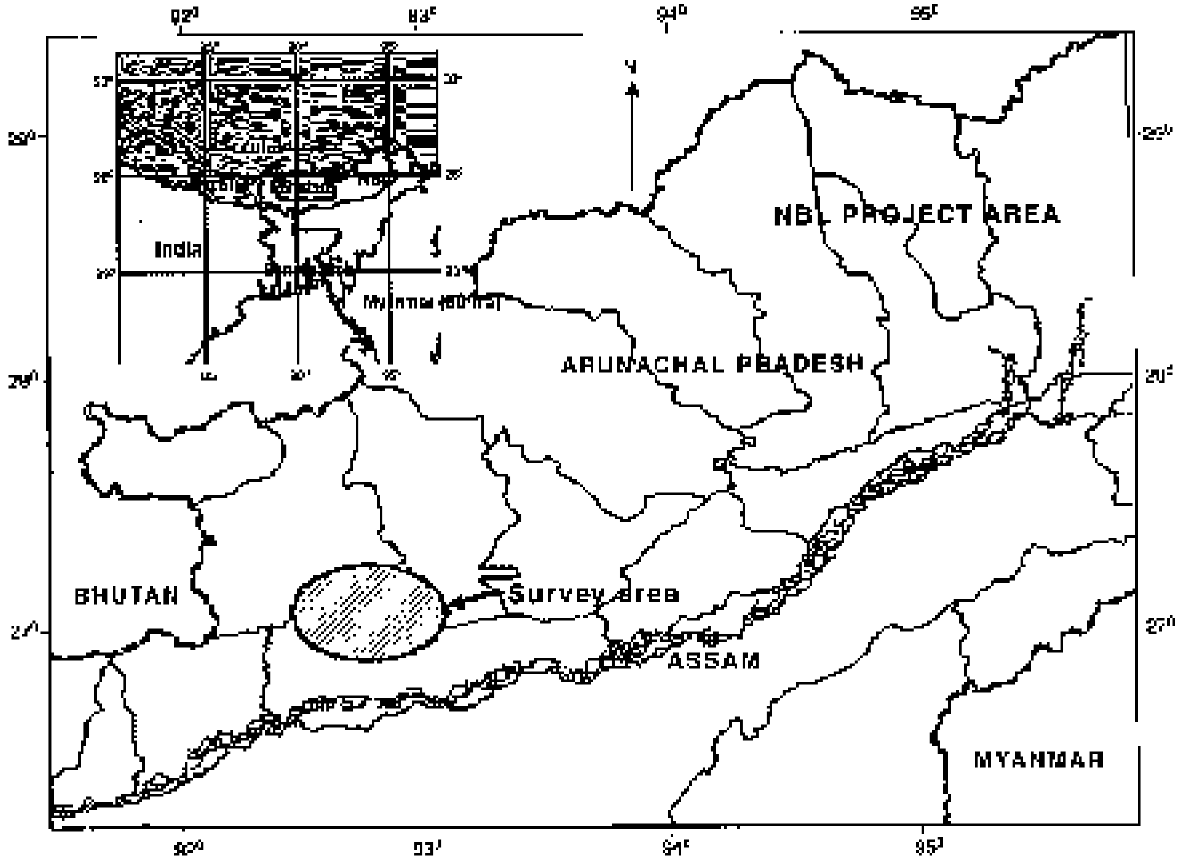
Contd...

...Contd table 9

No.	Country	Location	Georeference	Plot ID	Forest type	Species richness	PFT richness	PFC value
15	Malaysia (Borneo)	Danum Valley, Sabah	4° 53' 03" N 117° 57' 48" E	DANUM3	Primary forest subject to reduced impact logging, Nov 1993.	56	34	331
16	Kenya	Shimba Hills near Mombasa	4° 11' 33" S 39° 25 34" E	K01	Semi-deciduous forest in game park area. Disturbed (logged).	56	33	313
17	Guyana	Iwokrama forest reserve	4° 35' 02" N 58° 44' 51" W	IWOK01	Primary wamp forest in blackwater system.	52	34	270
18	Philippines	Mt Makiling, Luzon	14° 08' 46" N 121° 13' 50" E	PCLASS1	Regenerating forest planted in 1968 with Swietenia macrophylla, Parashorea, and Pterocarpus indicus .	52	26	299
19	Bolivia	Las Trancas, (Santa Cruz)	16° 31' 40" N 61° 50' 48" W	BOL02	Semi-evergreen, lowland vine forest, Logged 1996	46	33	302
20	Australia	Atherton tableland North Queensland	17° 18' 28" S 145° 25' 20" E	DPI012	Upland humid forest managed for sustainable timber extraction	46	25	187
21	Panama	Barro Colorado island	9° 09' 43" N 79° 50' 46" W	BARRO1	Semi-evergreen vine forest, ground layer grazed by native animals	43	30	238
22	Brasil	Reserva Biologica da Campiña Km 50 near Manaus (East Amazon basin)	2° 35' 21" S 60° 01' 55" W	BRA24	Moderately disturbed, microphyll, evergreen vine forest on siliceous sands	42	27	276
23	Vanuatu	Yamet, near Umetch, Ancityum Island	20° 12' 32" S 169° 52' 33" E	VAN11	Coastal primary forest, logged with Agathis macrophylla (Kauri) overstorey	38	22	217
24	Mexico	Zona Maya, Yucatan peninsula	19° 02' 26" N 88° 03' 20" E	YUC02	Logged secondary lowland forest.	37	26	288
25	Indonesia (Borneo)	Batu Ampar, Central Kalimantan	0° 47' 48" N 117° 06' 23" E	BA07	Primary forest, heavily logged 1991/92	35	23	286
26	West Indies (France)	Near Mont Pelée, Martinique	0° 47' 48" N 117° 06' 23" E	MQUE1	Humid, lowland forest on volcanic slopes, heavily disturbed.	32	24	279
27	Argentina	Iguazú Parque Nacional de las Cataratas	25° 39' 00" S 54° 35' 00" W	IGUAZU01	Lowland vine forest, disturbed	28	24	302
28	French Guyana	B.E.C. 16 km from Kourou	14° 49' 23" N 61° 7' 37" W	FRG05	Tierra firme simple evergreen forest on siliceous sand	28	18	146
29	Indonesia (Borneo)	Mandor Nature Reserve, North of Pontianak	0° 17' 12" N 109° 33' 00" E	PA02	Low microphyll evergreen forest in blackwater system on siliceous sand	25	21	228

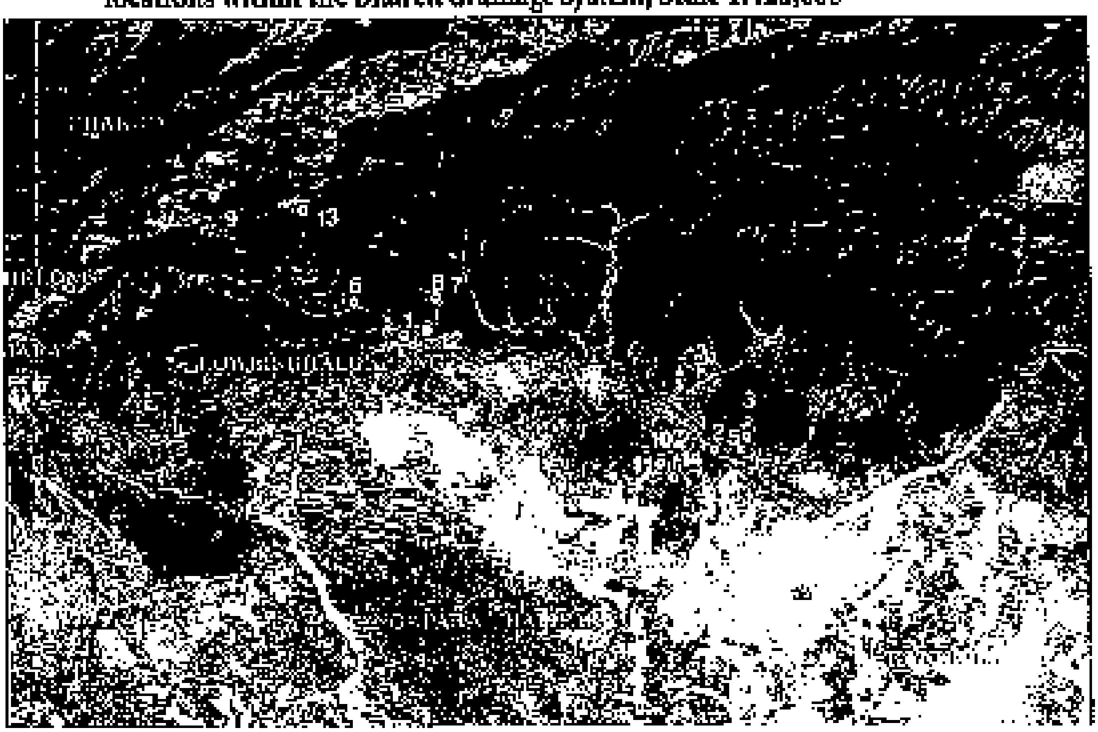
* Data summary from plots with richest vascular plant species and Plant Functional Type (PFT) and Plant Functional Complexity (PFC) values extracted from a series of global, ecoregional surveys and restricted to 'lowland' (0-900m elevation) humid, causal forests. All data collected using a standard 'VegClass' sampling protocol (Gillison, 1988, 2001). Forest conditions range from relatively intact to highly disturbed. Source International Centre for Agroforestry Research, Alternatives to Slash and Burn Programme (ICRAF/ASB); Center for International Forestry Research (CIFOR); WWF AREAS project and CBM (Center for Biodiversity Management).

FIG. 1: Map of NBL project area showing survey locations



source: Tariq Aziz, WWF - AREAS

FIG. 2: Landsat false color composite satellite image within NBL showing sample transect locations within the Bhareli drainage system; Scale 1:420,000



source: G. Areendran, IGCMC, WWF-India

Fig. 3: **Plant species richness regressed against PFT richness for all NBL transects**

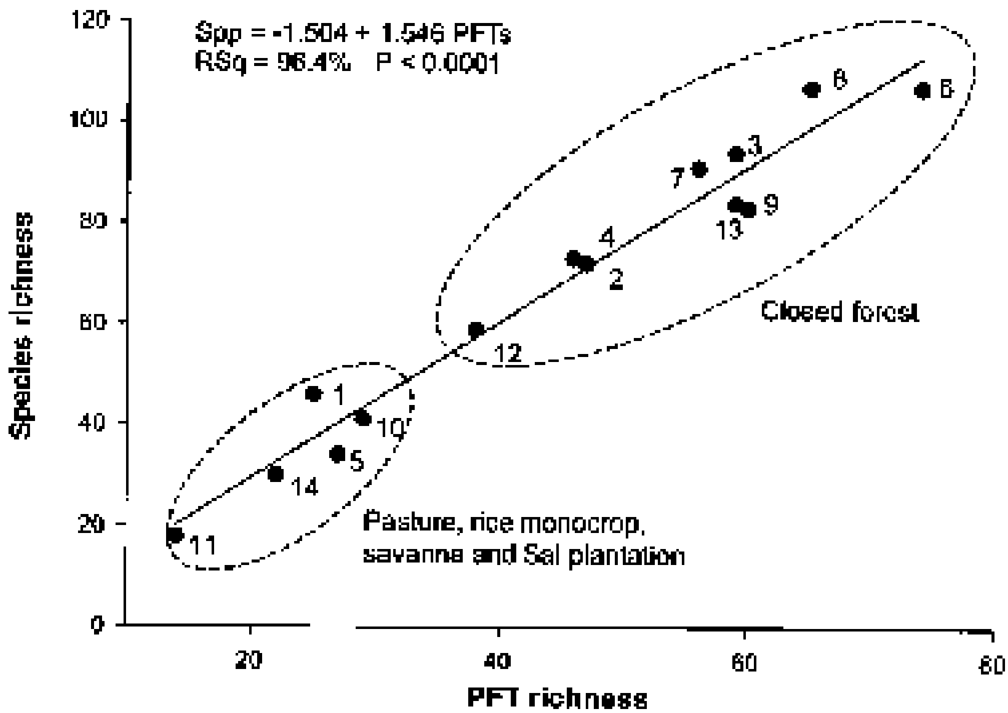


Fig. 4: Species:area, PFT:area and spp/PFT:area curves for six representative vegetation types

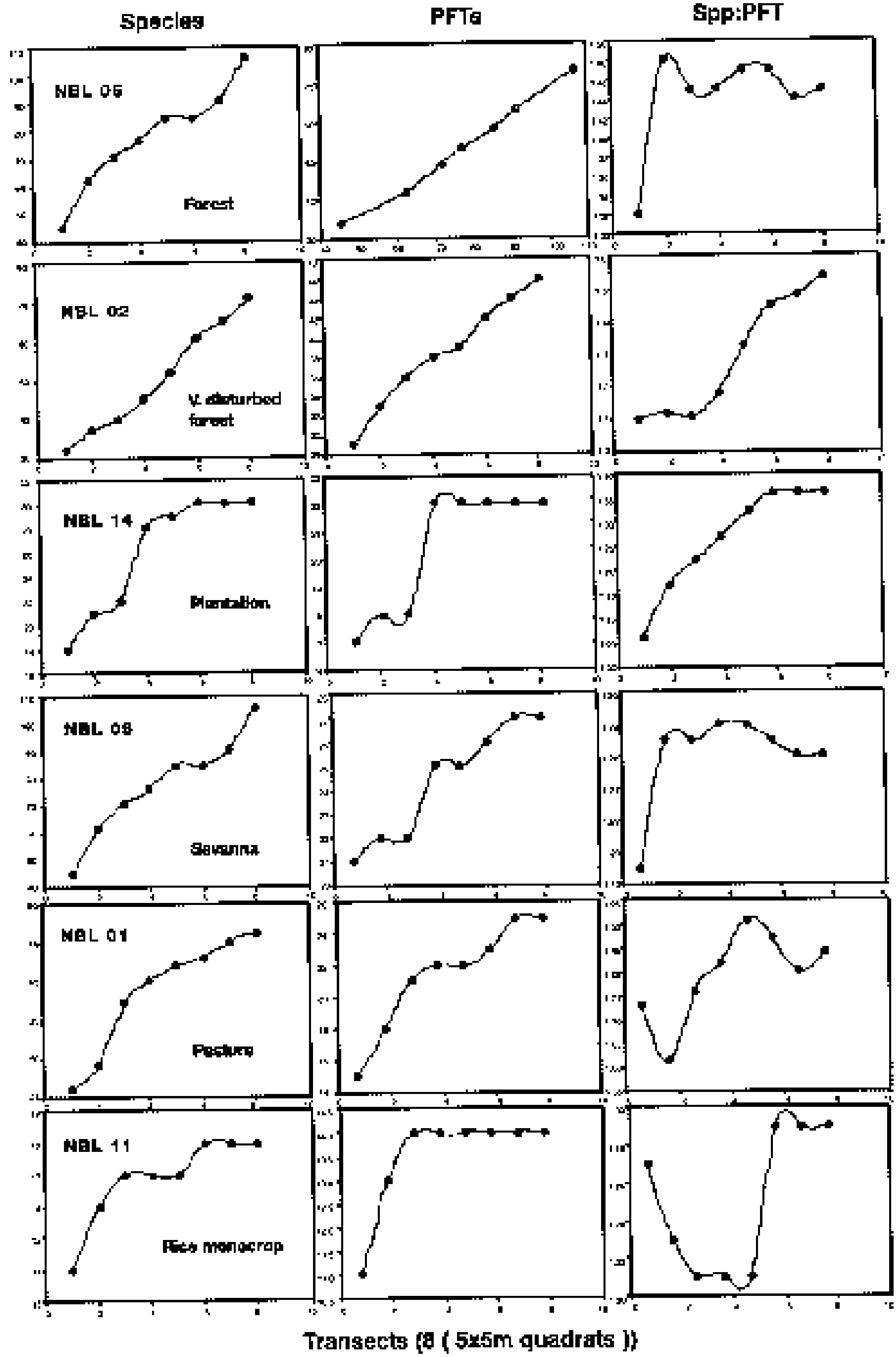


Fig. 5: Examples of linear regression between richness in plant species and PFTs along regional gradsects in different countries and ecoregions (ref. Table 9)

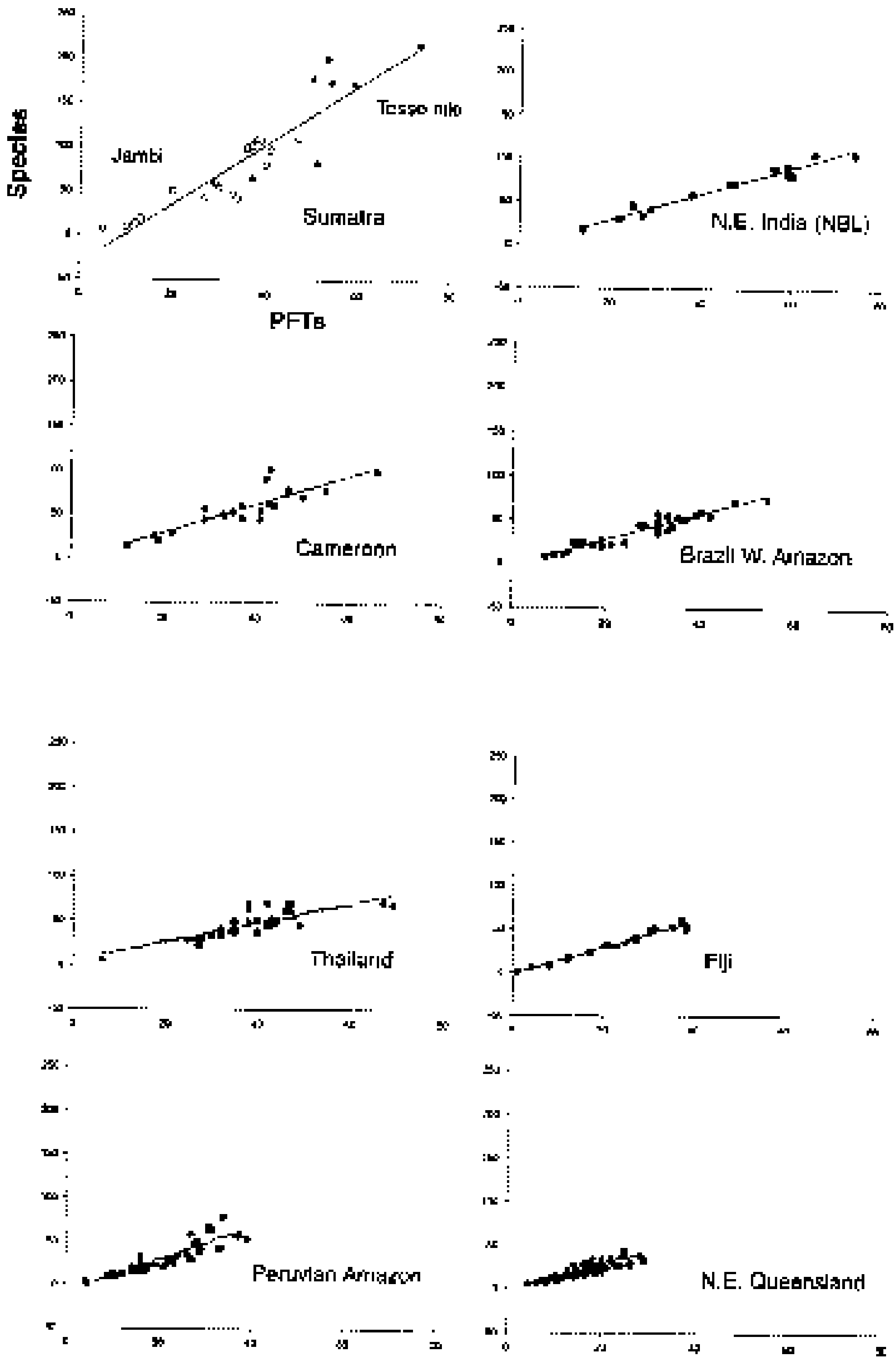


FIG. 6: Domain characteristics for all NBL sites based on Landsat satellite imagery and elevation and compared within the above area. High values (>90%) indicate areas of similar 'habitat'

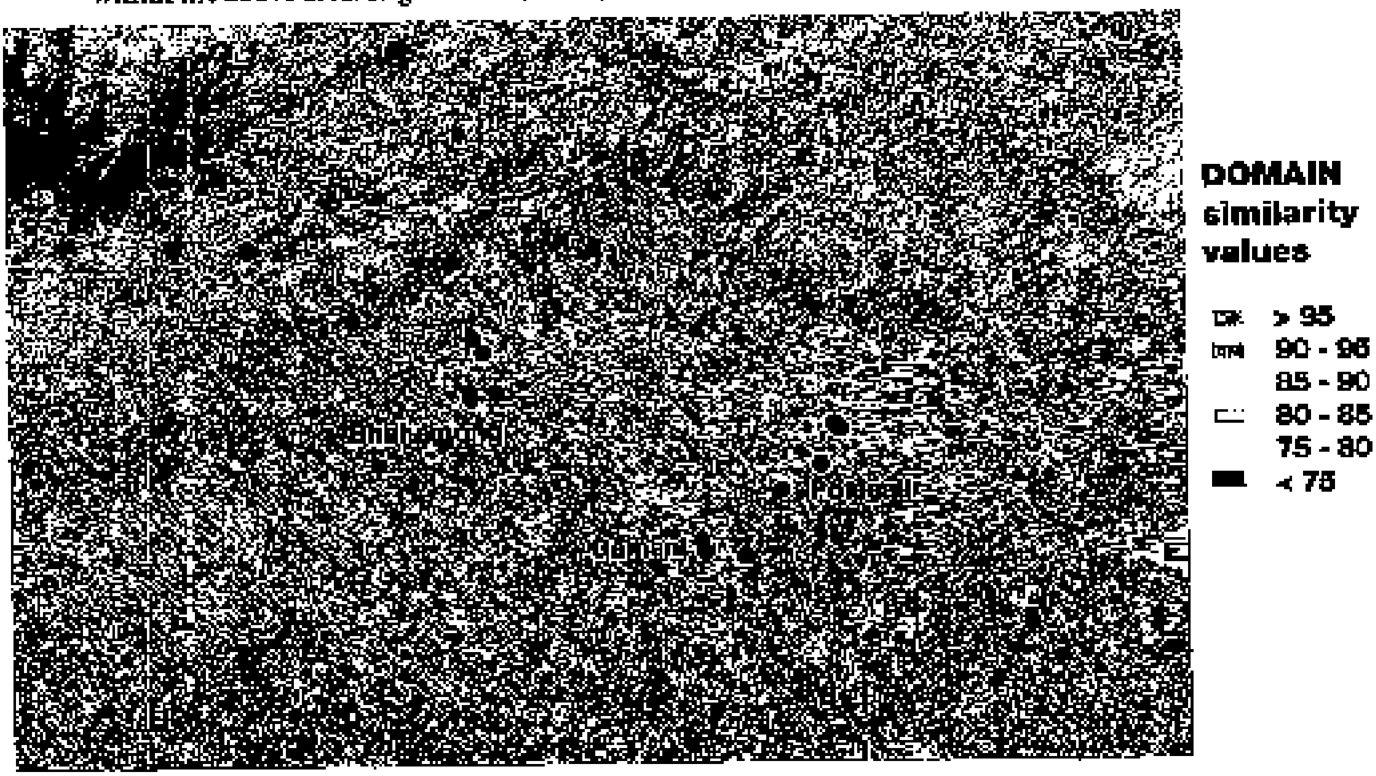


FIG. 7: Flowchart for establishing a representative network of sites within the eastern Himalayas

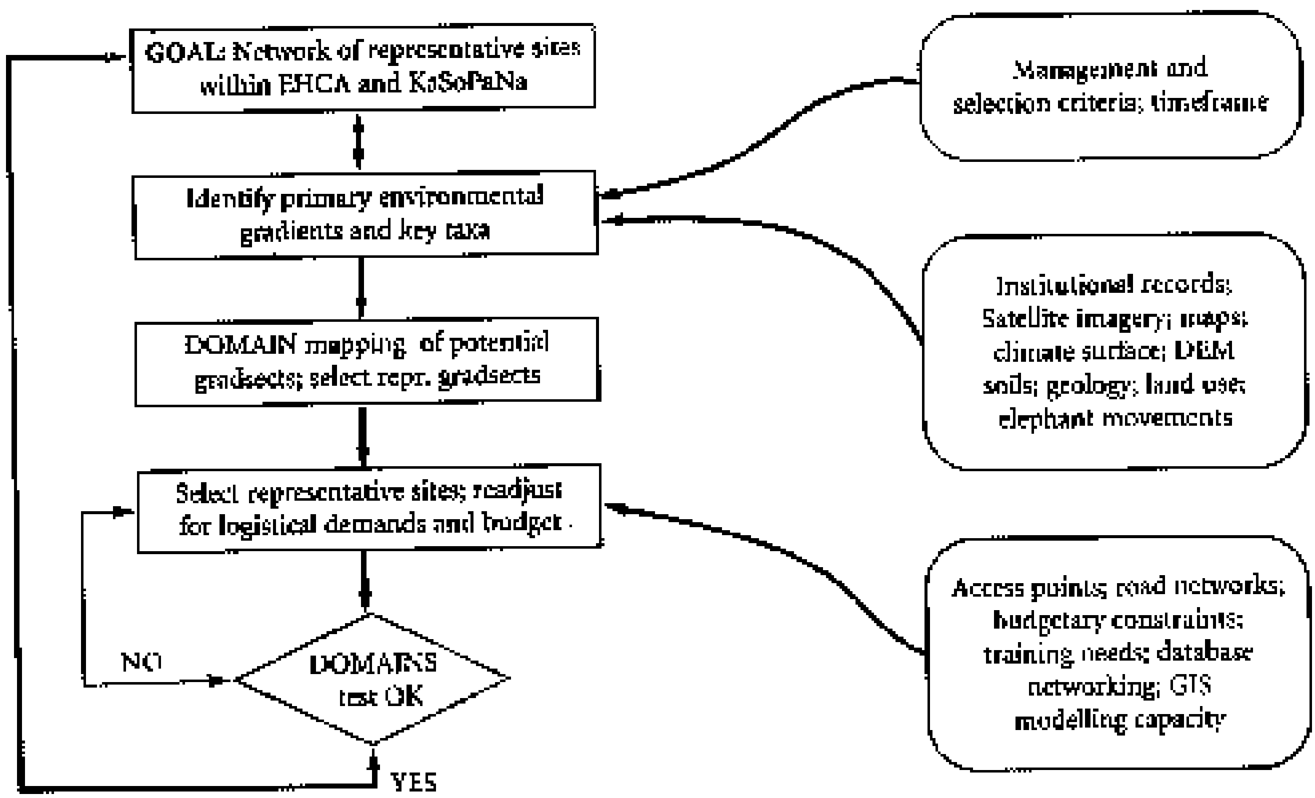
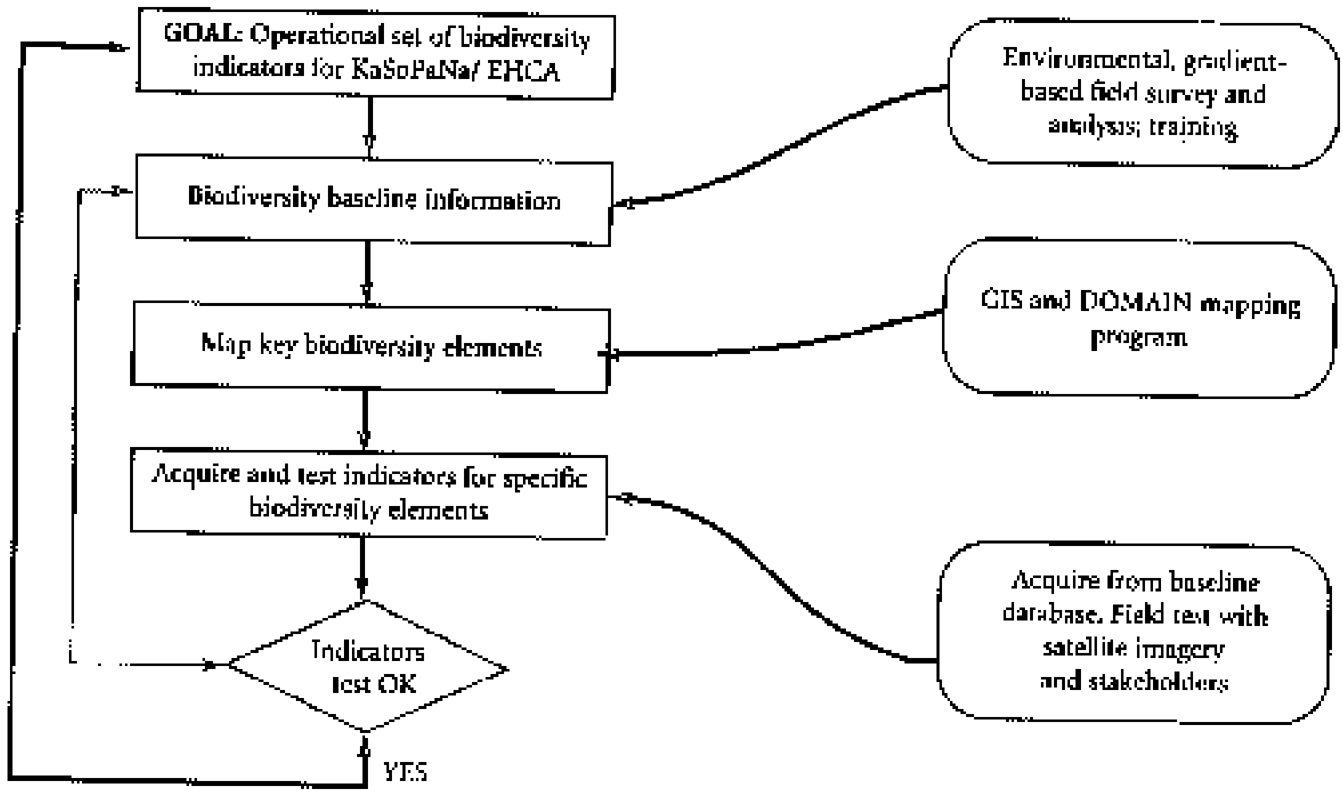
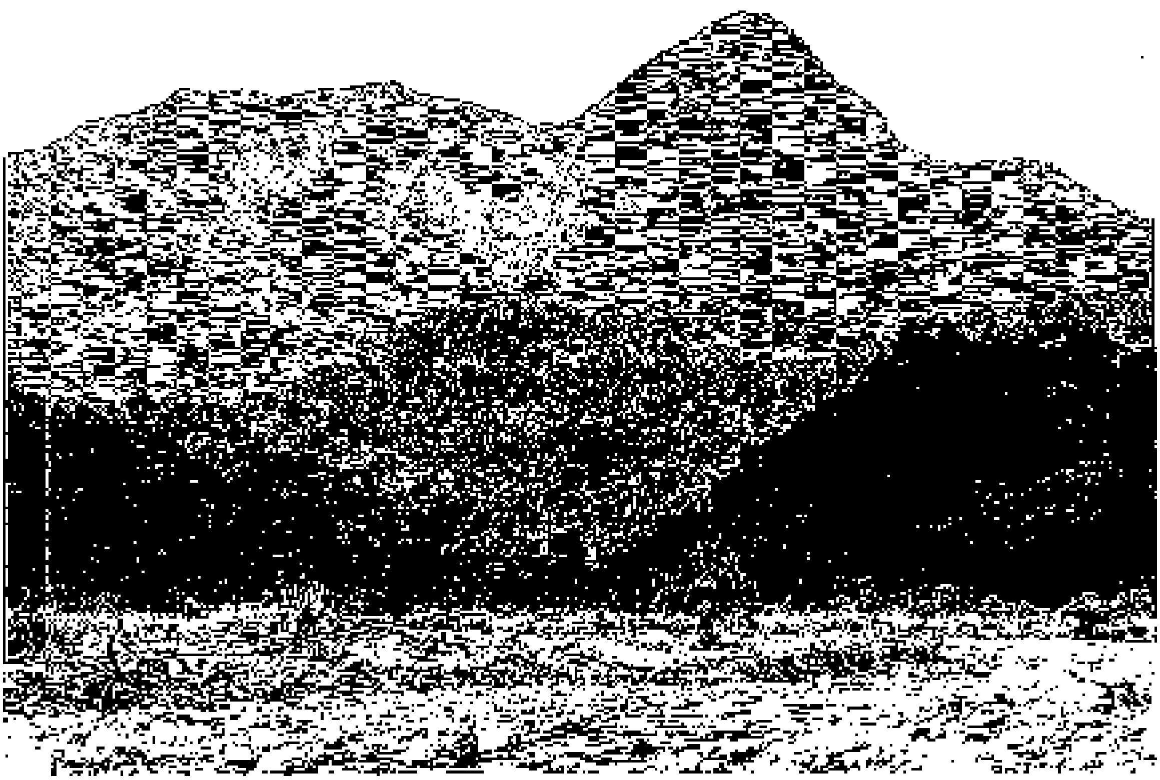


FIG. 8: Flowchart for acquiring an operational set of biodiversity indicators



PICTURE 1: Highly unstable sediments and erodable hills in the Nameri Tiger Reserve (Mithun Nala, near NBL 8)

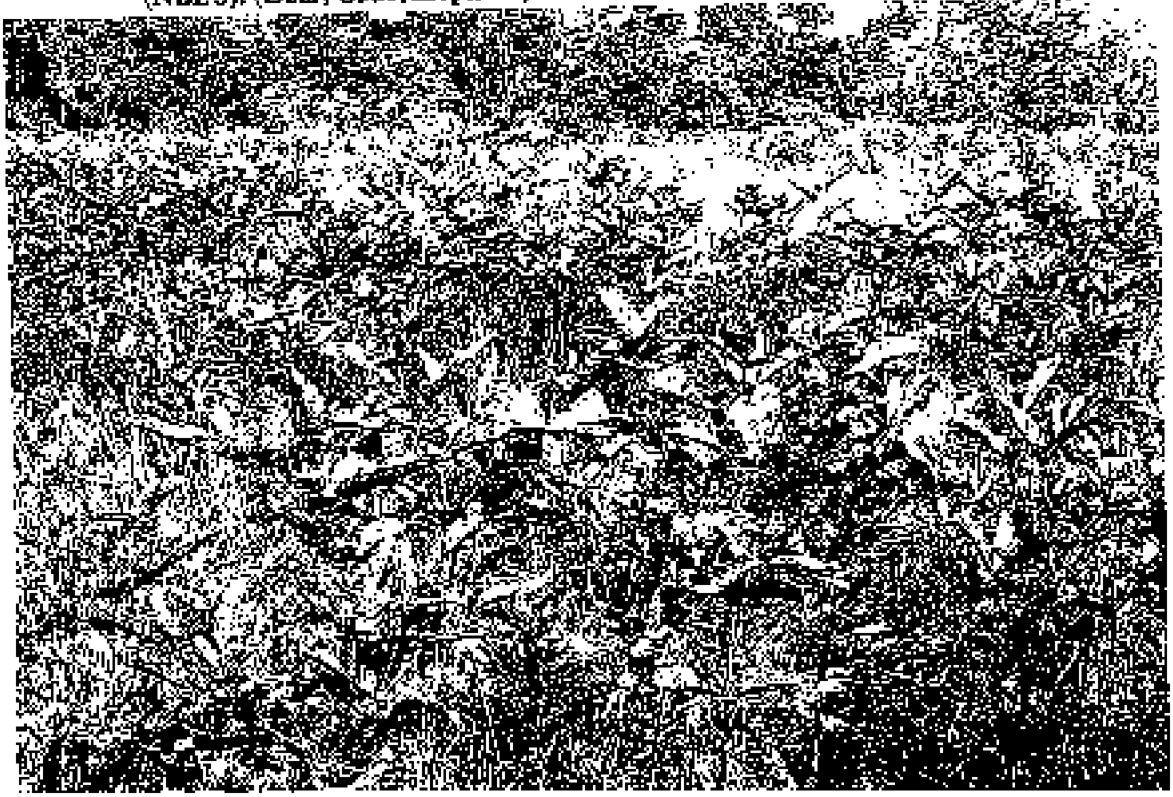
PICTURE 2: Unstable hillslopes in the Arunachal foothills with numerous landslips and landslides. Near NBL 8 Mithun Nala



Picture 3: Lowland forest in the Nameri Tiger Reserve (NBL 4) with dense ground layer heavily browsed by deer

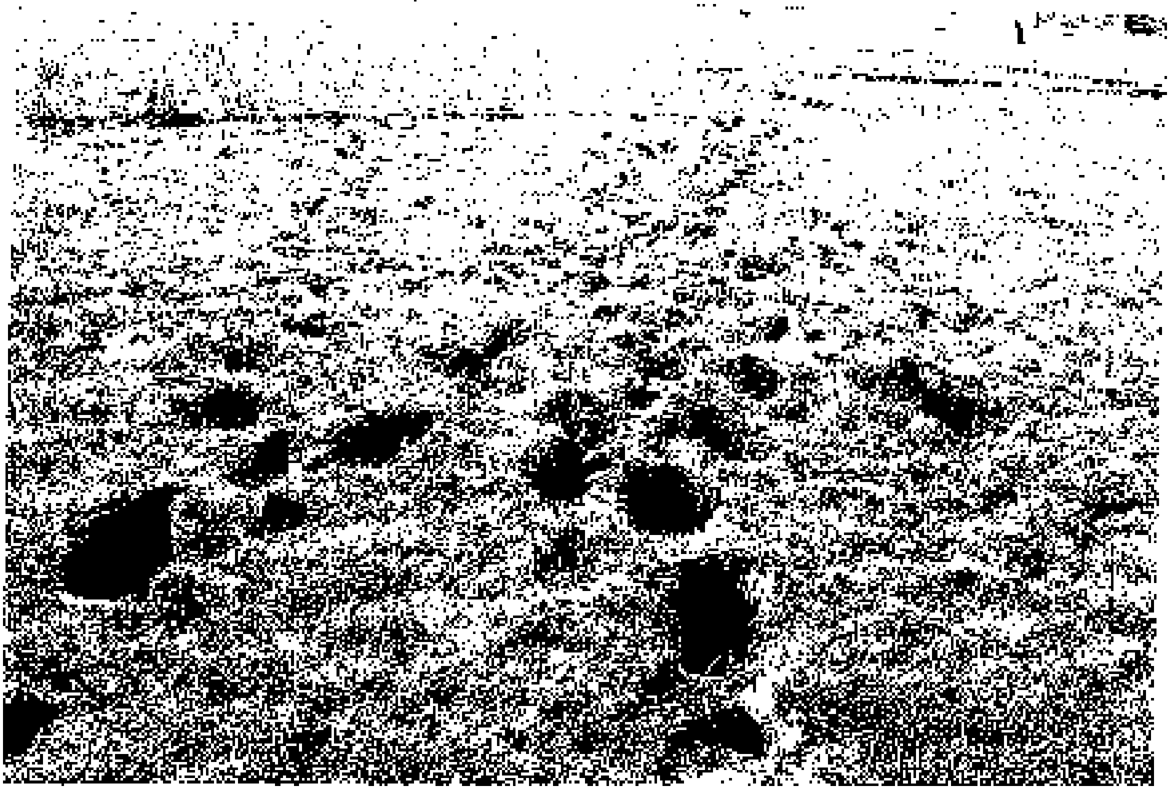
Picture 4: Elephant 'rest' area in highly disturbed lowland forest, Nameri Tiger Reserve near Bhareli river (NBL 12)

Picture 5: Annually fired, shrub *(Leea crispa)* **savanna near Potasali, Nameri Tiger Reserve (NBL 5). (Deer, Gaur, Elephant)**

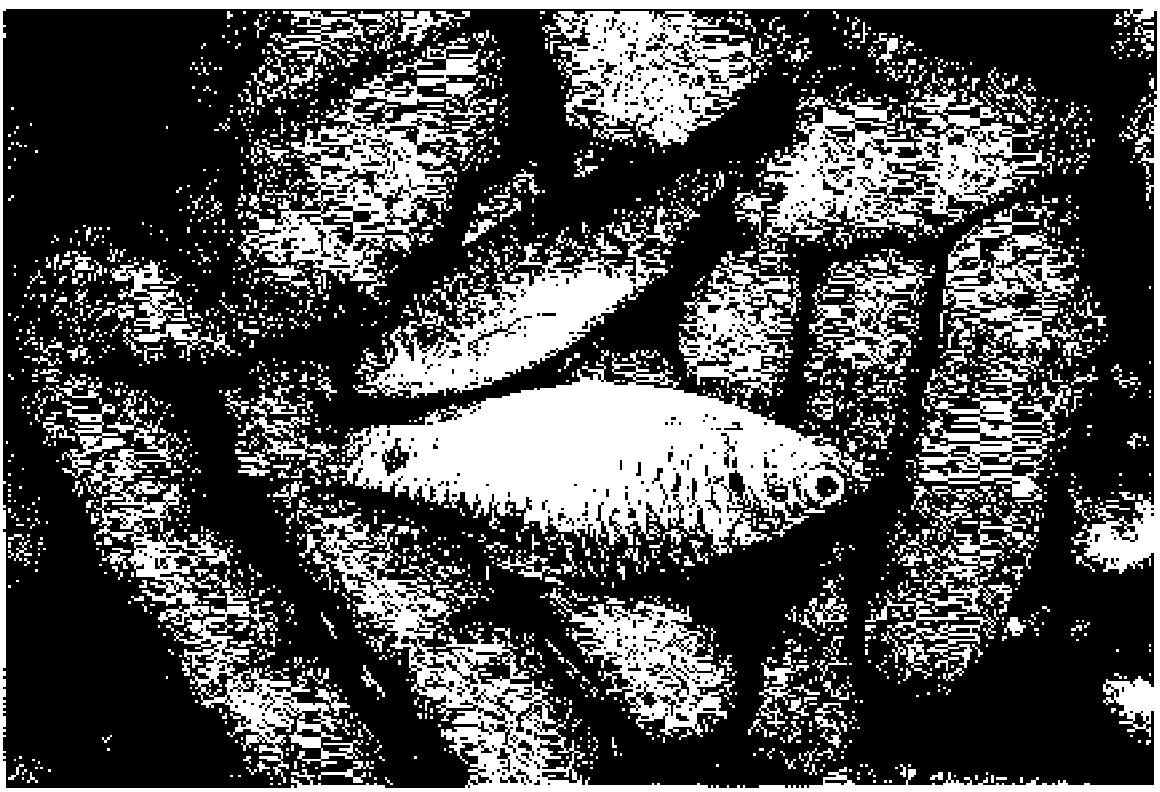


Picture 6: Sal *(Shorea assamica)* **30 year old timber plantation. Frequently fired. Balipara (NBL 14)**

PICTURE 7: Repeated damage by elephants leads to abandoned ricefields. Gamani forestry village, Balipara (NBL 10,11)



PICTURE 8: Fishing with insecticide is common in the Mithun Nala and tributaries. Near NBL 8



PICTURE 9: Recent immigrants to the Sonitpur District have removed existing forest

PICTURE 10: Uncontrolled forest conversion leads to slash and burn and eventually sedentary agriculture such as mustard farming and plantations (*Bombax ceiba*) near Balipara, Sonitpur District, N. Assam

Annex 1

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Annex 2

Unique species from all transects listed aphabetically according to family, genus and species (Example)*

Plot No	PFT	Family	Genus	Species	Code
NBL03	na-la-do-he-ad	Acanthaceae	Ecbolium	linneanum	ECBOLINE
NBL01	na-la-do-he	Acanthaceae	Justicia	procumbens	JUSTPROC
NBL08	pl-la-do-ch	Acanthaceae	Phlogocanthus	sp30	PHLOSP30
NBL06	me-la-do-ch-ad	Acanthaceae	Phlogocanthus	thyrsiflorus	PHLOTHYR
NBL12	me-la-do-he	Acanthaceae	Pseuderanthemum	platyphyllum	PSEUPLAT
NBL06	me-ve-do-ch-ad	Acanthaceae	Strobilanthes	sp13	STROSP13
NBL12	mi-la-do-ch	Acanthaceae	Strobilanthes	sp14	STROSP14
NBL04	ma-la-do-ch	Acanthaceae	Strobilanthes	sp18	STROSP18
NBL02	me-la-do-ct-ph	Acanthaceae	Strobilanthes	sp19	STROSP19
NBL03	me-la-do-he-ad	Acanthaceae	Strobilanthes	sp31	STROSP31
NBL02	pl-la-do-he	Acanthaceae	Strobilanthes	sp35	STROSP35
NBL07	me-la-do-ch-ad	Acanthaceae	Strobilanthes	sp83	STROSP83
NBL09	na-la-do-he-li-ad	Acanthaceae	Thunbergia	coccinea	THUNCOCC
NBL03	na-la-do-he-li-ad	Acanthaceae	Thunbergia	grandiflora	THUNGRAN
NBL08	me-ve-do-he-ad	Acanthaceae	Indet	sp51	INDESP51
NBL09	pl-la-do-ct-ph	Actinidiaceae	Saurauia	macrotricha	SAURMACR
NBL04	ma-la-do-ch	Actinidiaceae	Saurauia	nepalensis	SAURNEPA
NBL07	pl-la-do-ch-ad	Actinidiaceae	Saurauia	roxburghii	SAURROXB
NBL09	me-la-do-ct-ph-ad	Actinidiaceae	Saurauia	sp26	SAURSP26
NBL07	pl-la-do-pv-ph-ad	Agavaceae	Dracaena	sp54	DRACSP54
NBL03	pl-la-do-pv-he-ad	Alismataceae	Indet	sp52	UNIDSP52
NBL13	na-la-do-he-ad	Amaranthaceae	Achyranthes	aspera	ACHYASPE
NBL01	mi-la-do-he-ad	Amaranthaceae	Achyranthes	bidentata	ACHYBIDE
NBL12	na-la-do-he	Amaranthaceae	Cyathula	prostrata	CYATPROS
NBL03	me-la-do-ch	Anacardiaceae	Drimycarpus	racemosus	DRIMRACE
NBL13	mi-la-do-ch-li	Anacardiaceae	Pigea	nitida	PIGENITI
NBL07	pl-la-do-ch	Annonaceae	Goniothalamus	sesquipedalis	GONISESQ
NBL03	me-la-do-ch	Annonaceae	Indet	sp29	UNIDSP29
NBL03	me-la-do-ct-ph	Annonaceae	Indet	sp54	UNIDSP54
NBL06	na-la-do-ph	Annonaceae	Indet	sp56	INDESP56
NBL02	me-co-do-ch	Annonaceae	Indet	sp66	UNIDSP66
NBL09	me-la-do-ct-ph	Annonaceae	Miliusa	roxburghii	MILIROXB
NBL07	me-la-do-ct-ph	Annonaceae	Polyalthia	simiarum	POLYSIMI
NBL10	mi-ve-do-he-ad	Apiaceae	Centella	asiatica	CENTASIA
NBL11	na-la-do-su-he-ad	Apiaceae	Hydrocotyle	sibthorpioides	HYDRSIBT
NBL14	me-la-do-ch	Apocynaceae	Holarrhena	antidysenterica	HOLAANTI
NBL01	me-la-do-he-li	Apocynaceae	Ichnocarpus	frutescens	ICHNFRUT
NBL14	mi-la-do-ch-li	Apocynaceae	Ichnocarpus	sp05	ICHNSP05
NBL01	mi-la-do-ch-li	Apocynaceae	Vallaris	solanacea	VALLSOLA
NBL08	pl-la-do-ph-li	Arecaceae	Calamus	sp08	CALASP08
NBL08	pl-co-do-pv-ch	Arecaceae	Caryota	urens	CARYEURE
NBL06	mi-co-do-ch	Arecaceae	Daemonorops	jenkinsii	DAEMJENK
NBL08	mi-la-do-pv-ch	Arecaceae	Pinanga	gracilis	PINAGRAS
NBL07	ma-la-do-ct-nd	Araceae	Alocasia	indica	ALLOINDI
NBL07	pl-la-do-ct	Araceae	Amorphophallus	bulbifera	AMORBULB
NBL09	me-co-do-ct-ce	Araceae	Amorphophallus	sp35	AMORSP35
NBL09	me-co-do-de-cr	Araceae	Arisaema	sp34	ARISSP34
NBL01	pl-la-do-su-ch-ad	Araceae	Colocasia	esculenta	COLOESCU

* Complete table available from WWF, India

Annex 3

Taxa and PFTs arranged alphabetically according to transect number* (Example)*

Plot No	PFT	Family	Genus	Species	Code
NBL06	me-la-do-ch-ad	Acanthaceae	Phlogocanthus	thyrsiflorus	PHLOTHYR
NBL06	me-ve-do-ch-ad	Acanthaceae	Strobilanthes	sp13	STROSP13
NBL06	me-ve-do-hc-ad	Acanthaceae	Indet	sp51	INDESP51
NBL06	me-la-do-ch-ad	Acanthaceae	Phlogocanthus	thyrsiflorus	PHLOTHYR
NBL06	mi-la-do-ph	Annonaceae	Indet	sp56	INDESP56
NBL06	mi-co-do-ch	Arecaceae	Daemonorops	jenkinsii	DAEMJENK
NBL06	me-co-do-ch-li-ad	Araliaceae	Schefflera	venulosa	SCHEVENU
NBL06	me-la-do-su-ch	Balsaminaceae	Impatiens	sp93	IMPASP93
NBL06	ma-la-do-ct-ph	Caprifoliaceae	Lonicera	micrantha	LONIMICR
NBL06	me-la-do-ct-ph-li	Combretaceae	Combretum	sp86	COMBSP86
NBL06	pl-pe-do-hc-li-ad	Cucurbitaceae	Melothria	heterophylla	MELOHETE
NBL06	me-ve-do-cr-li	Dioscoreaceae	Dioscorea	bulbifera	DIOSBULB
NBL06	me-ve-do-ch	Elaeocarpaceae	Elaeocarpus	glabrus	ELAEGLAB
NBL06	me-la-do-hc-ad	Euphorbiaceae	Baliospermum	montanum	BALIMONT
NBL06	pl-la-do-ct-ph	Euphorbiaceae	Ostodes	paniculata	OSTOPANI
NBL06	me-la-do-ct-ph	Euphorbiaceae	Baccaurea	ramiflora	BACARAMI
NBL06	me-ve-do-ct-ph	Euphorbiaceae	Glochidion	sp99	GLOCSP99
NBL06	pl-la-do-ch-li	Fabaceae	Dalhousea	bracteata	DALHBRAC
NBL06	me-la-do-ch-li	Fabaceae	Millettia	caudata	MILLCAUD
NBL06	no-ve-do-hc	Fabaceae	Desmodium	laxiflorum	DESMLAXI
NBL06	me-la-do-ch-li	Fabaceae	Millettia	pachycarpa	MILLPACH
NBL06	na-pe-do-su-hc-ad-ep	Gesneriaceae	Aeschynanthus	gracilis	AESCGRAC
NBL06	me-ve-do-ct-ph	Lauraceae	Phoebe	angustifolia	PHOEANGU
NBL06	me-la-do-ct-ph	Lauraceae	Actinodaphne	obovata	ACTIOBOV
NBL06	pl-la-do-ct-ph	Lauraceae	Litsea	sp58	LITSSP58
NBL06	pl-la-do-ct-ph	Lauraceae	Indet	sp59	INDESP59
NBL06	pl-co-do-ph	Magnoliaceae	Talauma	hodgsoni	TALAHODG
NBL06	me-la-do-hc-ad	Marantaceae	Phrynium	pubinerve	PHRYPUBI
NBL06	me-la-do-ch	Meliaceae	Dysoxylum	sp79	DYSOSP79
NBL06	me-la-do-ct-ph	Moraceae	Artocarpus	chaplasha	ARTOCHAP
NBL06	pl-co-do-ct-ph	Myrsinaceae	Ardisia	paniculata	ARDIPANI
NBL06	me-ve-do-ch	Myrsinaceae	Ardisia	sp86	ARDISP86
NBL06	me-la-do-ph	Myrtaceae	Syzygium	formosa	SYZYFORM
NBL06	mi-ve-do-ch-ad-ep	Orchidaceae	Dendrobium	sp19	DENDSP19
NBL06	mi-la-do-cr-ad	Orchidaceae	Indet	sp36	INDESP36
NBL06	me-ve-is-hc-ad-ep	Orchidaceae	Coelogyne	sp37	COELSP37
NBL06	no-pe-is-hc-ad-ep	Orchidaceae	Aerides	sp67	AERISP67
NBL06	mi-co-do-de-hc-ad-ep	Orchidaceae	Dendrobium	sp73	DENDSP73
NBL06	me-co-do-fi-hc-ad	Pteridophyte	Indet	sp105	INDESP10
NBL06	no-co-do-fi-hc-ad	Pteridophyte	Indet	sp106	INDESP10
NBL06	me-co-do-fi-hc-ad-ep	Pteridophyte	Indet	sp30	INDESP30
NBL06	pl-ve-do-fi-hc-ad-ep	Pteridophyte	Indet	sp35	INDESP35
NBL06	me-co-do-fi-hc-ad	Pteridophyte	Indet	sp103	INDESP10
NBL06	no-la-do-ch	Rutaceae	Clausena	heptaphylla	CLAUHEPT
NBL06	mi-la-do-ch	Rutaceae	Murraya	paniculata	MURRPANI
NBL06	pl-co-do-ph	Sapindaceae	Sapindus	mucorossi	SAPIMUCO
NBL06	no-la-do-ch	Sapindaceae	Lepisanthes	sp09	LEPISP09
NBL06	me-co-do-ch	Sapindaceae	Indet	sp60	INDESP60

* Complete table available from WWF, India
Total: 601 unique species including unidentified (indet) specimens.

photo: ranak shtyra

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The World Wide Fund for Nature India (WWF-India) has been working to promote harmony between humankind and nature for more than three decades. Today, it is recognized as a premier conservation NGO in the country dealing with conservation and development issues.

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